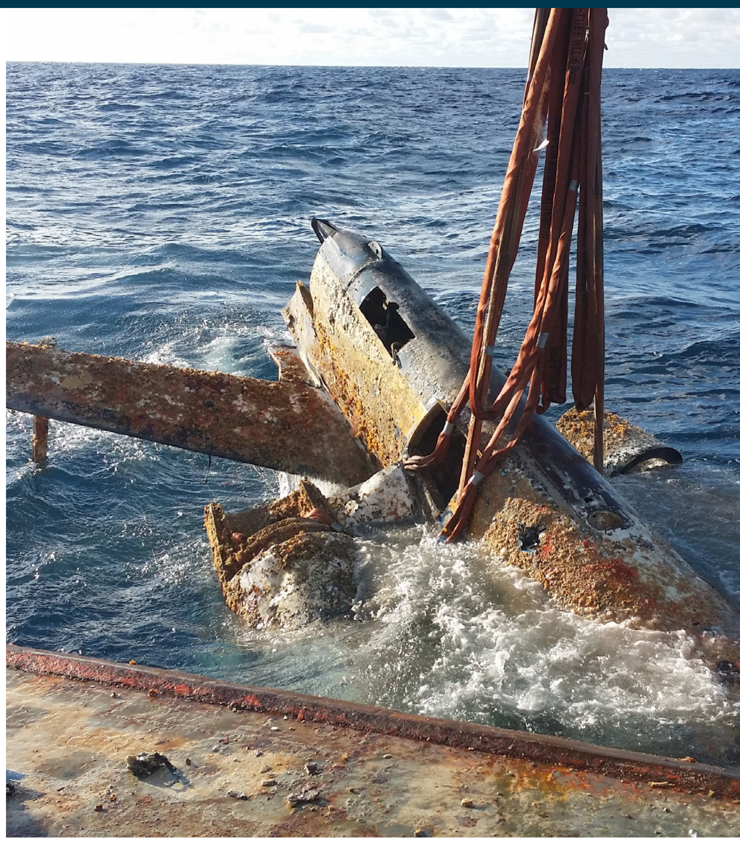
Australian Government
Australian Transport Safety Bureau

Fuel planning event, weather-related event and ditching involving Israel Aircraft Industries Westwind 1124A, VH-NGA

6.4 km WSW of Norfolk Island Airport | 18 November 2009



Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2009-072 (reopened)
Final – 23 November 2017

Cover photos: 1. Aircraft wreckage on the seabed, screen capture from Victoria Police ROV for ATSB
2. Tail section of aircraft wreckage being recovered by Pacific Marine Group for ATSB

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Addendum

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Safety summary

What happened

On 18 November 2009, an Israel Aircraft Industries Westwind 1124A aircraft, registered VH-NGA, was operated on an air ambulance flight from Apia, Samoa to Norfolk Island, Australia. Two flight crew, a doctor, a flight nurse, a patient and a passenger (the patient's husband) were on board.

On arrival at Norfolk Island at night, there was low cloud and the aircraft had insufficient fuel to divert to another airport. After four unsuccessful approaches, the flight crew ditched the aircraft 6.4 km west-south-west of the airport.

During the ditching, the aircraft encountered significant impact forces, and the flight nurse and first officer were seriously injured. The aircraft cabin rapidly flooded, and all six occupants evacuated from the aircraft, but with only three of the six life jackets on board and neither of the aircraft's life rafts. The evacuees were rescued 85 minutes later by personnel on a search vessel launched from Norfolk Island.

What the ATSB found

The flight crew were conducting a long-distance flight to a remote island at night. At the time the flight was planned, the aerodrome forecast for Norfolk Island indicated the weather conditions at the time of arrival would be above the alternate minima.

Contrary to the consistent practice of the operator's Westwind fleet for such flights, the flight departed with full main tanks (or about 7,200 lb of fuel) rather than full main tanks and tip tanks (about 8,700 lb). The reasons why the captain elected to depart without the maximum fuel load on this occasion were not fully determined. However, the ATSB found the captain's pre-flight planning did not include many of the elements needed to reduce the risk of a long-distance flight to a remote island. These included miscalculating the total fuel required for normal operations, not calculating the additional fuel required for aircraft system failures, not obtaining relevant forecasts for upper-level winds, and not obtaining current information about potential alternate aerodromes. Although there was no requirement for the flight to depart with alternate or holding fuel, the fuel on board was insufficient to meet operator and regulatory requirements for the flight to allow for aircraft system failures.

Although the operator's Westwind pilots generally used a conservative approach to fuel planning, the operator's risk controls did not provide assurance there would be sufficient fuel on board flights to remote islands or isolated aerodromes. Limitations included no explicit fuel planning requirements for such flights, no formal training for planning such flights, no formal guidance information about hazards at commonly-used aerodromes, no procedure for a captain's calculation of the total fuel required to be checked by another pilot, and little if any assessment during proficiency checks of a pilot's ability to conduct fuel planning.

There were also limitations with Australian regulatory requirements. Other than requirements for fuel planning of passenger-carrying charter flights to remote islands, there were no explicit fuel planning requirements for other passenger-carrying flights to remote islands, and no explicit requirements for planning flights to isolated aerodromes. In addition, air ambulance flights were classified as 'aerial work' rather than 'charter'. Consequently, they were subject to a lower level of requirements than other passenger-transport operations (including requirements for fuel planning).

During the flight, the weather conditions at Norfolk Island deteriorated below the landing minima. Air traffic services in Nadi and Auckland did not provide the flight crew with all the information that should have been provided. In addition, the flight crew did not request sufficient information prior to passing the point of no return (PNR), and the captain did not use an appropriate method for calculating the PNR. Related to these actions, the operator's risk controls did not provide assurance that its pilots would conduct adequate in-flight fuel management activities during flights to remote islands or isolated aerodromes. The Civil Aviation Safety Authority (CASA) had also published limited guidance material regarding in-flight fuel management.

After the aircraft passed the PNR, there were opportunities to minimise the risk associated with the developing situation. However, the flight crew did not effectively discuss approach options, and they did not effectively review their fuel situation and consider alternate emergency options prior to ditching the aircraft. The flight crew did not refer to the ditching checklist and the final approach was conducted at an airspeed significantly below the reference landing speed (V_{REF}), which increased the descent rate just prior to impact. A range of local conditions influenced the performance of the crew during the latter stages of the flight, including workload, stress, time pressure and dark night conditions.

In addition to the rapid flooding of the aircraft cabin, the occupants' evacuation was hampered by there being no formal, specific procedures and limited training regarding on how to secure life rafts in an appropriate, readily accessible location prior to a ditching, and a designated storage location for the stretchered patient's life jacket. In very difficult circumstances, the nurse and doctor did an excellent job evacuating the patient, and then assisting the injured first officer and the patient in the water, both of whom did not have life jackets.

Due to the inherent limitations of most emergency locator transmitters (ELTs) for a submerged aircraft, and the limited information provided by the flight crew regarding the location of the ditching, search and rescue personnel initially had no reliable information about where to search for the aircraft. It was fortunate that a firefighter made a chance sighting of the captain's torch, resulting in the search effort being redirected to the appropriate area and the successful rescue of the evacuees.

In addition to issues associated with fuel planning and in-flight fuel management, the ATSB identified safety issues with the operator's risk controls for emergency procedures and training, fatigue management, crew resource management training and flight crew training for newly-installed systems on the accident aircraft. The ATSB also identified limitations with the operator's hazard identification processes and the definition of roles and responsibilities of key management personnel, and the processes used for the operator and air ambulance provider for conducting pre-flight risk assessments. Limitations were also identified with the processes used by CASA for planning surveillance, scoping audits and conducting audits.

What's been done as a result

Following the accident, CASA conducted a special audit of the operator, and this audit involved an extensive assessment of the operator's air ambulance operations. The operator voluntarily ceased its Westwind operations and collaborated with CASA during the audit. During this process, the operator reviewed and substantially enhanced its risk controls and management oversight of flight/fuel planning and in-flight fuel management. It also enhanced its risk controls and management oversight of many other areas of its air ambulance operations.

In 2014, CASA modified the requirements for operations to Australian remote islands, so that all passenger-carrying transport flights, including air ambulance flights, were required to depart with alternate fuel. In addition, in 2012 CASA initiated action to change the regulatory classification of air ambulance (or medical transport) flights from aerial work to air transport. However, although CASA released a Notice of Proposed Rule Making about this issue in 2013, no changes have yet occurred. Accordingly, the ATSB issued a safety recommendation to CASA to continue reviewing the requirements for air ambulance operations and address the limitations associated with the current classification of these flights. The ATSB also issued two other recommendations to CASA for it to continue its activities to address the limitations with the requirements and guidance for fuel planning of flights to isolated aerodromes and the requirements and guidance of in-flight fuel planning.

In addition to these actions, since 2009 there have been improvements in a range of other areas. These include improvements to CASA's surveillance processes, weather forecasting processes at Norfolk Island, and the publishing of advisory information about the hazards at remote island aerodromes. In addition, there now exists an enhanced capability for satellites to detect the location of ELT signals from aircraft involved in ditchings and similar impacts where the ELTs are unable to emit signals for extended periods.

Safety message

The investigation report contains 36 safety factors that provide lessons to flight crews, operators, regulators and/or other organisations. Overall, the most fundamental lesson for all flight crew, operators and regulators is to recognise that unforecast weather can occur at any aerodrome. Consequently, there is a need for robust and conservative fuel planning and in-flight fuel management procedures for passenger-transport flights to remote islands and isolated aerodromes.

Additional safety messages include:

- Flight crew should discuss and consider options to manage threats when there is time available to do so.
- Operators should ensure their flight crew proficiency checks assess the performance of all key tasks required of their flight crew.
- Operators should not rely on informal risk controls for managing the performance of safety-critical tasks, particularly when there is significant turnover of pilots in a fleet.
- Operators of air ambulance flights should ensure medical personnel have clearly defined procedures and appropriate practical training for using the emergency equipment on board to ensure they can effectively assist a patient in the event of an emergency.
- All organisations in safety-critical industries should use proactive and predictive processes to identify hazards in their operations.
- Organisations that use a bio-mathematical model of fatigue as part of their fatigue risk management system should ensure they have a detailed understanding of the assumptions and limitations associated with such models.
- Regulators should develop effective methods for obtaining, storing and integrating information about operators and the nature of their operations so that they can develop effective surveillance plans.

Background

On 18 November 2009, an Israel Aircraft Industries Westwind 1124A aircraft, registered VH-NGA and operated by Pel-Air Aviation Pty Limited, was being flown on an air ambulance flight from Apia, Samoa to Norfolk Island, Australia. Two flight crew, a doctor, a flight nurse, a patient and a passenger (the patient's husband) were on board. After the crew were unable to land due to low cloud, they ditched the aircraft 6.4 km west-south-west of the airport. Two of the occupants were seriously injured, and the aircraft cabin rapidly flooded and sank in 48 m of water. All the occupants evacuated from the aircraft and were later rescued by personnel on a search vessel launched from Norfolk Island.

The Australian Transport Safety Bureau (ATSB) conducted a safety investigation, numbered AO-2009-072, into the accident. It released its draft report to directly involved parties in March 2012, and its final report in August 2012. Shortly after the release of the final report, a television program questioned the quality and findings of the investigation.

Soon after, the Australian Senate's Rural and Regional Affairs and Transport References Committee commenced an inquiry to examine the findings of the ATSB's report, the investigation process and related matters. The Committee's report, released in May 2013, made a number of recommendations to the Australian Government, the ATSB and other government agencies. These included recommendations about ATSB's investigation processes, as well as the following specific recommendations regarding the AO-2009-072 investigation:

> The committee recommends that the ATSB retrieve VH-NGA flight data recorders without further delay…
>
> The committee recommends that the investigation be re-opened by the ATSB with a focus on organisational, oversight and broader systemic issues.

Following the Senate inquiry report, the ATSB requested the Transportation Safety Board of Canada (TSB) to conduct an independent peer review of the ATSB's investigation methodologies and processes. The review included an examination of the ATSB's investigation process applied during three investigations, including AO-2009-072.

The TSB finalised its report on 1 December 2014.[1] Although the TSB review provided generally favourable comment on the ATSB's investigation processes and methodologies, it noted significant limitations with the ATSB's application of its processes during the Norfolk Island investigation. A key problem was insufficient collection of factual information in several areas.

On 4 December 2014, the ATSB formally reopened investigation AO-2009-072. The reopened investigation reviewed the evidence obtained during the original ATSB investigation, as well as additional evidence and other relevant points raised in the TSB review, the Senate inquiry and through the Deputy Prime Minister's Aviation Safety Regulation Review. The main focus was on ensuring that the specific findings of the TSB and other reviews were taken fully into account before issuing a final report of the reopened investigation.

The reopened investigation obtained a substantial amount of information that was not obtained or available to the original investigation. This included additional information on:

- pre-flight planning and fuel management procedures and practices
- in-flight fuel management and related decision-making procedures and practices
- fatigue management procedures and practices
- flight crew training and checking
- the operator's oversight of its flight operations activities

[1] Transportation Safety Board of Canada 2014, *Independent review of the Australian Transport Safety Bureau's investigation methodologies and processes*. Available at www.bst-tsb.gc.ca.

- provision of weather and other flight information to flight crews
- cabin safety and survival factors
- regulatory oversight of activities such as those listed above.

The additional data collection activities included:

- recovering and downloading the data from the aircraft's cockpit voice recorder and flight data recorder
- reviewing documentation from investigations into the accident conducted by the Civil Aviation Safety Authority (CASA) and the operator, including interviews conducted with the flight crew
- re-interviewing the flight crew, doctor and flight nurse of the aircraft, and interviewing a significant number of the operator's Westwind pilots, management personnel and safety personnel
- reviewing documentation from the operator, including flight records for several Westwind aircraft, training and checking records for several flight crew, duty times and rosters for other flight crew, occurrence and hazard reports, internal and external audit reports, and safety committee meeting records
- interviewing several personnel from the CASA
- reviewing CASA's files on the operator's flight operations since 2000, including the files associated with the special audit CASA conducted on the operator immediately following the accident
- reviewing documentation from the air traffic services providers in Fiji and New Zealand about their policies and procedures for the provision of flight information, and how these were applied during the accident flight
- recovering and examining the three life jackets used by occupants of the aircraft
- obtaining information from several other organisations, including the aircraft manufacturer, the Bureau of Meteorology, Airservices Australia, the life jacket manufacturer and the air ambulance provider (CareFlight).

The reopened investigation was conducted by ATSB investigators, and oversighted by ATSB managers who were not involved in the original investigation. In addition the Commission review and approval process was led by the ATSB's aviation experienced commissioner, noting that by the time this process commenced, the incumbent Chief Commissioner was a previous senior officer in CASA, including at the time of the accident. The Chief Commissioner formally declared this potential conflict of interest at the time of his appointment and recused himself from any involvement with the reopened investigation. Independent investigators from the Department of Defence Directorate of Defence Aviation and Air Force Safety (DDAAFS) were witness to the download of the cockpit voice recorder and flight data recorder information.

Due to the time elapsed since the accident, the reopened investigation was not able to obtain or had difficulty obtaining some types of information (such as flight recorder data or air traffic control data for other flights). In addition, the recollection of people interviewed regarding some events and conditions in the period prior to the accident was limited. Nevertheless, the ATSB was able to obtain a substantial amount of useful information, and is satisfied that this information was adequate to appropriately examine the lines of inquiry of the reopened investigation and to support the report's findings.

Based on all the available information, the final report of the reopened investigation includes many more findings than the original investigation. In addition, the level of detail in this report on some topics is substantially more than would normally be the case for a safety investigation report. The ATSB adopted this approach to address a wide range of matters raised by various parties regarding the original investigation report.

Contents

The occurrence

Introduction

On 18 November 2009, an Israel Aircraft Industries Westwind 1124A aircraft, registered VH-NGA (Figure 1), was being operated by Pel-Air Aviation Pty Limited on an air ambulance flight from Apia, Samoa to Norfolk Island, Australia. Two flight crew, a doctor, a flight nurse, a patient and a passenger (the patient's husband) were on board.

Figure 1: Westwind 1124A registered VH-NGA

Source: Used by permission.

On arrival at Norfolk Island at night, there was low cloud and the aircraft had insufficient fuel to divert to another airport. At about 1026 Coordinated Universal Time (UTC),[2] after four unsuccessful approaches, the flight crew ditched the aircraft 6.4 km west-south-west of the airport. All the occupants evacuated from the aircraft and were later rescued by personnel on a search vessel launched from Norfolk Island.

This section provides information about the events during the outbound flights from Sydney to Apia on 17 November 2009 and the accident flight from Apia to Norfolk Island on 18 November 2009. All times in this section are in UTC.

The information in this section was obtained from:

- interviews with the flight crew and other relevant personnel
- the aircraft's cockpit voice recorder (CVR) and flight data recorder (FDR)
- recordings of transmissions between the flight crew and air traffic services
- recordings of transmissions between the flight crew and the Norfolk Island Unicom operator
- recorded weather information and various other types of documentation.

Further information about the CVR is provided in appendix A and further information about the FDR is provided in appendix B. Appendix C provides details of the forecasts and weather reports for relevant aerodromes during the outbound flights and the accident flight, and appendix D provides details of the en route winds. Appendix E provides the ATSB's analysis of the aircraft's fuel status during the accident flight.

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[2] Coordinated Universal Time (UTC): the time zone used for aviation. Local time zones around the world can be expressed as positive or negative offsets from UTC. Sydney was UTC + 11 hours, Norfolk Island was UTC + 11.5 hours and Apia was UTC - 11 hours. After 2011, the time zone for Samoa (without daylight saving) changed to UTC + 13 hours.

Task allocation

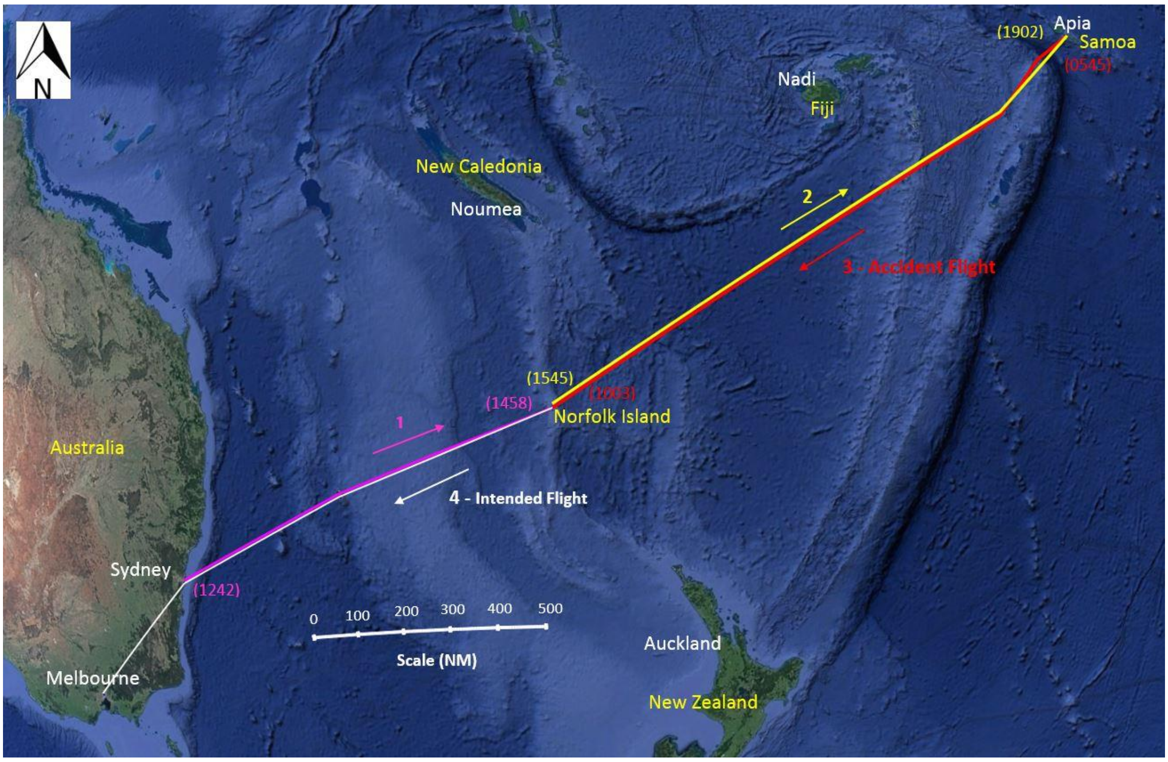
As part of its operations, CareFlight provided an international air ambulance service. It organised for patients in a number of countries to be flown to a hospital, usually in Australia. The air ambulance provider used Pel-Air Aviation Pty Limited as its preferred aviation operator for these air ambulance flights.

At 0651 on 17 November 2009, a medical insurance company requested a quote from the air ambulance provider for the task of transporting an Australian patient from Apia to Melbourne, Australia. After communications with the operator, the air ambulance provider submitted a quote. At 0922 the medical insurance company approved the quote.

During 0933–0935, the operator's Westwind operations manager contacted the captain and first officer and assigned them the task, proposing the crew conduct refuelling stops at Norfolk Island on the way to and from Apia. Figure 2 shows the actual and intended flights for the task.

The air ambulance provider assigned medical personnel (a doctor and a flight nurse) for the task. The medical personnel retrieved equipment from the provider's facilities in western Sydney before travelling to Sydney Airport.

Figure 2: Intended flights for the air ambulance task on 17–18 November 2009



Source: Background image GoogleEarth, annotated/modified by ATSB.

Outbound flights

Flight planning for the outbound flights

The captain conducted the planning for the outbound flights at the operator's base at Sydney Airport and accessed the National Aeronautical Information Processing System (NAIPS) using the NAIPS for Windows client. At 1144, he submitted flight plans for the flight from Sydney to Norfolk Island and the flight from Norfolk Island to Apia. Table 1 provides key details of these flight plans.

Table 1: Selected details of the flight plans for the outbound flights

	Sydney to Norfolk Island	Norfolk Island to Apia
Estimated departure time	1200, 17 Nov 2009	1600, 17 Nov 2009
Estimated flight time	2 hours	3 hours 10 minutes
Cruising speed	Mach 0.72	Mach 0.72
Flight level[3]	FL 350	FL 350
Special handling code	MED 1 (medical priority 1)	MED 1 (medical priority 1)
Alternate aerodrome	Noumea, New Caledonia	Pago Pago, American Samoa
Fuel endurance[4]	6 hours	5 hours

The operator conducted its air ambulance flights under the Instrument Flight Rules (IFR).[5] Consistent with the operator's Air Operator's Certificate, air ambulance flights were classified as aerial work (see *Classification of operations*). The operator's Westwind aircraft were not approved for reduced vertical separation minima (RVSM) operations. However, the flight crew were still permitted to flight plan in RVSM airspace (between FL 290 and 410) on the selected route (see *Reduced vertical separation minima*).

The aerodrome forecast (TAF)[6] for Norfolk Island, issued at 1017, included broken cloud[7] at 500 ft above the aerodrome elevation.[8] These cloud conditions were below the published alternate minima,[9] and the captain was therefore required to nominate an alternate aerodrome. He selected La Tontouta Airport at Noumea, New Caledonia, as the alternate aerodrome. Noumea, 432 NM[10] north of Norfolk Island, was the closest suitable aerodrome to Norfolk Island.

The TAF for Faleolo Airport at Apia, issued at 0955, indicated good weather for the arrival. Although there was no weather-related requirement for the captain to nominate an alternate aerodrome, the captain nominated Pago Pago, American Samoa as the alternate aerodrome on the flight plan. Pago Pago is 81 NM east of Apia.

As part of his flight planning process, the captain requested the following weather information and products for the outbound flights:

- the current TAFs for Sydney, Norfolk Island, Noumea, Apia and Pago Pago

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3 At altitudes above 10,000 ft in Australia, an aircraft's height is measured in hundreds of feet above the standard atmospheric pressure datum of 1013.25 hPa. A height 35,000 ft above that standard pressure datum would be expressed FL 350.

4 This is part of the supplementary information provided during submission of a flight notification, including information relevant for search and rescue purposes.

5 Instrument flight rules (IFR): a set of regulations that permit the pilot to operate an aircraft in instrument meteorological conditions (IMC), which have much lower weather minimums than visual flight rules (VFR). Procedures and training are significantly more complex as a pilot must demonstrate competency in IMC conditions while controlling the aircraft solely by reference to instruments. IFR-capable aircraft have greater equipment and maintenance requirements.

6 Aerodrome Forecast (TAF): a statement of meteorological conditions expected for a specific period of time in the airspace within a radius of 5 NM (9 km) of the aerodrome reference point [BoM website].

7 Cloud cover: in aviation, cloud cover of the sky is reported using words/abbreviations that denote the extent of the cover. 'Sky clear' (SKC) indicates no cloud, 'few' (FEW) indicates 1–2 oktas (or eighths) is covered, 'scattered' (SCT) indicates 3–4 oktas is covered, 'broken' (BKN) indicates 5–7 oktas is covered, and 'overcast' (OVC) indicates that 8 oktas is covered.

8 Cloud heights in TAFs and aerodrome weather reports are provided as the height above the aerodrome elevation, which is the elevation of the highest point of the landing area. The aerodrome elevation at Norfolk Island was an altitude of 371 ft.

9 Alternate minima: specified weather conditions for a particular aerodrome such that, if the forecast conditions are less than the alternate minima, the pilot in command must either provide a suitable alternate aerodrome or holding fuel until 30 minutes after the conditions were forecast to improve.

10 In aviation, the distance between locations is measured in nautical miles (NM). 1 NM equals 1.852 km.

- the relevant NOTAMs[11] for Sydney, Norfolk Island, Noumea, Apia and Pago Pago
- a specific pre-flight information bulletin (SPFIB) containing the forecast winds and temperatures on the route from Sydney to Norfolk Island,[12] valid for the time of the flight
- an SPFIB containing the forecast winds and temperatures on the route from Norfolk Island to Apia, valid for the time of the flight
- a high-level Australian significant weather (SIGWX) forecast chart,[13] valid 1200[14] on 17 November 2009, and covering the first leg from Sydney to Norfolk Island.

The captain did not request any grid point wind and temperature (GPWT) forecast charts or wind and temperature charts.[15,16] He also did not request a SIGWX chart for 1800 or later validity periods (to cover the time period associated with the Norfolk Island to Apia flight), and he did not request a chart for the region east of 180° longitude. The flight from Norfolk Island to Apia passed through 180° longitude at waypoint DUNAK, about halfway between Norfolk Island and Apia (Figure 3).

Outbound flight from Sydney to Norfolk Island

For the flight from Sydney to Norfolk Island, the aircraft was refuelled to its full capacity, with full main tanks and full tip tanks. This equated to a fuel load of about 8,730 lb[17] (appendix E). For the forecast winds and the flight-planned altitude and speed, this fuel load was more than sufficient to fly to Norfolk Island, conduct an approach and divert to Noumea and land with fuel reserves intact. Alternatively, the fuel load was sufficient to divert to other airports such as Nadi, Fiji or Auckland, New Zealand if required.

At 1242, soon after the medical personnel arrived at the aircraft, the flight departed Sydney. The captain was the pilot flying. Air traffic services (ATS) cleared the flight crew to climb direct to FL 370, and the aircraft remained at that flight level for the remainder of the cruise.

At the waypoint TEKEP, 272 NM south-west of Norfolk Island, the aircraft departed the Brisbane Flight Information Region (FIR) and entered the Auckland Oceanic FIR. From this point the flight

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11 Notice to Airmen (NOTAM): A notice distributed by means of telecommunication that contains information about the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel conducting flight operations.

12 An SPFIB included forecast winds and temperatures along the flight-planned route at different flight levels, including FL 340 and FL 385.

13 At the time of the occurrence, SIGWX charts forecast any significant weather that was expected in the airspace FL 100 to FL 250 and FL 185 to FL 445. The significant weather was depicted by symbols on the chart and included the prognosis for moderate or severe turbulence (including clear air turbulence), moderate or severe icing, surface fronts, cumulonimbus cloud associated with thunderstorms, the position and strength of jet streams, tropical cyclones, volcanic eruptions and the height of the tropopause. The Australian high-level SIGWX chart covered the region between the equator and 50° S latitude and 100–180° E longitude.

14 SIGWX charts were available about 16 hours ahead of the fixed validity times 0000, 0600, 1200 and 1800. The charts are valid at those fixed time points, but are used for operations 3 hours either side and any significant variations during that 6-hour period would be included on the chart.

15 A grid point wind and temperature (GPWT) forecast chart provided a text-based tabular display of forecast wind and temperature for multiple flight levels across a wide region. The data was presented in squares of latitude and longitude, overlaid on a geographic background. The wind and temperature chart, provided a pictorial display of forecast wind and temperature for a single flight level, with the data displayed in a grid pattern on a geographic background. These charts provided relevant wind information in the case a diversion from the flight planned route was required and could also be used to augment the data provided in the SPFIB.

16 GPWT forecasts were issued twice each day (at approximately 0800 and 2000 UTC), for three validity times at each issue (0800 issue – valid 1200, 1800 and 0000; 2000 issue – valid 0000, 0600 and 1200). The validity period for GPWT forecasts was ± 3 hours from the validity time. Wind and temperature charts were issued every 6 hours for specified regions and provided a graphical display of forecast wind and temperature data for one flight level. Data was presented in 5° grids on a geographic background. Charts were produced for 6-hourly forecast steps, out to 30 hours. Each forecast was valid ± 3 hours of the validity time.

17 The aircraft's fuel load was measured in pounds (lb). 1 lb equals 0.454 kg.

crew were required to communicate with the Auckland air/ground (A/G) operator via high frequency (HF) radio.

On initial contact with the Auckland A/G operator at 1413, the flight crew were informed there was a SPECI[18] for Norfolk Island (issued at 1400). The first officer requested the details of the SPECI, which included broken cloud at 500 ft. The reported wind was 330° at 11 kt,[19] and the flight crew elected to conduct the VOR[20] approach to runway 29.

At 1437, the crew commenced their descent to Norfolk Island. At 1443, the first officer contacted the Norfolk Island Unicom operator. [21] The Unicom operator provided updated weather information, which was similar to the 1400 SPECI. Table 2 provides more detailed information about the communications between the crew and the Auckland A/G operator and the Unicom operator.

Table 2: Summary of communications between the flight crew and the Auckland A/G operator and Norfolk Island Unicom operator during the flight from Sydney to Norfolk Island

Time (UTC)	Event
1413	Initial contact with Auckland A/G. First officer reported passed TEKEP at 1413, estimated Norfolk Island at 1447. Auckland A/G advised there was a SPECI available, first officer requested details. Auckland A/G provided SPECI issued at 1400. Details included: • AUTO (automatic) SPECI • wind from 330° at 11 kt • visibility at least 10,000 m • broken cloud 500 ft, overcast cloud 800 ft • temperature 20°C, dewpoint 19°C.
1423	Auckland A/G provided a descent clearance. Also advised cloud base was probably better than that reported by the automated weather station ‘according to the observations on the ground’.
1443	Initial contact with Norfolk Island Unicom operator. First officer reported they were 37 NM from Norfolk Island, inbound from the south-west, descending through FL 190. She estimated they would be in the circuit at 1447 to conduct a VOR approach to runway 29.
1443	Unicom operator provided current weather information, which was the same as the 1400 SPECI. Unicom operator advised the cloud observations were from the ‘automatic gear’. He also advised he had parked at the threshold of runway 29 and seen ‘... a fair few stars about...’ on the approach.
1452	First officer informed the Unicom operator they had passed overhead the airport and would be tracking back inbound in about 1 minute. Unicom operator asked if the crew were ‘visual’, first officer replied ‘intermittently’.

The cloud conditions in the 1400 SPECI (broken cloud at 500 ft) were just above the landing minima[22] for the approach (that is, broken or overcast cloud at 484 ft above the aerodrome elevation). However, the Auckland A/G operator and the Unicom operator both advised the crew that the actual conditions were better than those being reported by the automatic weather station (AWS).

[18] SPECI: a special weather observation report that is triggered by a significant change in a set of parameters, including cloud and visibility.

[19] The wind direction in TAFs and aerodrome weather reports are provided in degrees true (°T).

[20] VHF Omni-directional Radio Range: a VHF radio navigational aid which provides a continuous indication of bearing from the selected VOR station.

[21] Unicom: a universal communications service provided by ground personnel at some non-controlled aerodromes to enhance the value of information available to aircraft crews. It was not an air traffic control service.

[22] Landing minima: specified meteorological conditions of cloud ceiling and visibility. In order for an aircraft to land at an aerodrome, the actual weather conditions need to be at or above the landing minima.

The aircraft landed at 1458. The flight crew later reported they encountered some cloud during the approach but had no difficulty acquiring visual reference with runway 29.

The captain advised the ATSB soon after the accident that, while on the ground at Norfolk Island, the duty Unicom operator told him the AWS generally overestimated the severity of the weather (in terms of the height and amount of cloud). The Unicom operator recalled having a general conversation with the captain after the aircraft landed, which included some discussion of the weather. However, he did not state that the AWS generally overestimated the severity of the cloud.

The Unicom operator advised the ATSB that the low cloud that evening was mainly confined to the high terrain north of the aerodrome and the AWS was also located north of the runways. Therefore the AWS was accurately stating the amount of cloud where the AWS was located but there was less cloud present on the approach to runway 29. He stated conditions resulting in low cloud confined to the high terrain were infrequent. Because he had noted the AWS was overstating the amount of cloud when compared to his observation of stars from the runway 29 threshold and along the aircraft's likely approach path, he had mentioned seeing stars from the threshold to the flight crew on the radio while they were on descent. He also recalled that he explained the infrequent nature of the situation to the captain after the aircraft had landed.

The duration of the flight from Sydney to Norfolk Island was 2 hours 16 minutes (2.27 hours), slightly longer than the submitted flight plan time of 2 hours.[23]

The forecast winds for the flight indicated an average tailwind component of about 45 kt at FL 340 and FL 385.[24] Analysis of the flight and available wind information indicated the estimated actual winds[25] were close to the forecast winds (appendix D).

Outbound flight from Norfolk Island to Apia

At Norfolk Island, the aircraft was refuelled so that the main tanks but not the tip tanks were full. This equated to a fuel load of about 7,280 lb (appendix E). For the forecast winds and the flight-planned altitude and speed, this was more than sufficient fuel to fly from Norfolk Island to Apia, conduct an approach and divert to Pago Pago and land with fuel reserves intact.

The flight departed Norfolk Island at 1545, and the first officer was the pilot flying. The flight crew requested and were given approval to climb (in RVSM airspace) to FL 350 (reached at 1606), FL 370 (reached at 1623) and FL 390 (reached at 1758). The crew commenced descent at 1845. The weather conditions at Apia were fine and the crew conducted a visual approach without any delay, landing on runway 08 at 1902 (0802 local time).

The overall flight time from Norfolk Island to Apia was 3 hours 17 minutes (3.28 hours), slightly longer than the submitted flight plan time of 3 hours 10 minutes (3.17 hours). The captain later reported they experienced an average tailwind of about 50 kt during the flight, which was stronger in the early part of the flight and weaker in the latter part of the flight.

The forecast winds for the flight indicated an average tailwind component of about 45 kt at FL 340 and FL 385. The winds in the first half of the flight were stronger and also included a significant crosswind component. Analysis of the flight and available wind information indicated the estimated actual winds were close to the forecast winds (appendix D).

Events at Apia

After the flight crew and medical personnel cleared customs, they boarded a waiting minibus that took them to their hotel. After breakfast, they agreed to meet in the hotel lobby that afternoon at

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[23] The captain stated he normally rounded the flight times he submitted in a flight plan to ATS to the nearest 15 minutes (see also *Calculation of flight time*).

[24] Cruise altitude winds and speeds have been rounded to the nearest 5 kt.

[25] The estimated actual winds were derived from meteorological analysis products used to verify the accuracy of forecasts (see also appendix D).

0400 (1700 local time). The captain and first officer went to their rooms to rest, and the medical personnel went to visit the patient at her home.

Flight from Apia to Norfolk Island (accident flight)

Flight planning

The captain reported he started flight planning about 30 minutes prior to the scheduled meeting time (that is, at about 0330 UTC). He attempted to use the internet to get updated weather information and submit flight plans for the return flights. However, he was unable to get internet access on his laptop or mobile phone. Consequently, he went to the hotel reception desk, where staff advised him that there was an internet problem and no access was available.

The captain reported he called the operator's Westwind standards manager to ask him to obtain weather information and submit a flight plan. The manager did not answer his phone, and the captain did not leave a message.[26]

At 0433, the captain telephoned the Airservices Australia briefing office in Brisbane, Australia. He advised the briefing officer of the internet problem, and asked the officer to help him submit a flight plan for the flight from Apia to Norfolk Island by reversing the plan from his previous flight from Norfolk Island to Apia. During the phone call, the captain provided the details as per Table 3.

Table 3: Selected details of the flight plan for the Apia to Norfolk Island flight

	Apia to Norfolk Island
Estimated departure time	0530, 18 Nov 2009
Estimated flight time	3 hours 30 minutes
Cruising speed	Mach 0.72
Flight level	FL 360
Special handling code	MED 1 (medical priority 1)
Alternate aerodrome	None nominated
Fuel endurance	Supplementary information, not stated during telephone call with the briefing officer

The flight-planned route from Apia to Norfolk Island operated through the Auckland Oceanic FIR, the Nadi FIR and then back into the Auckland Oceanic FIR (see Figure 3). The briefing officer asked the captain for his estimated time intervals for the FIR boundaries. The captain replied that he had not previously provided such times on flight plans and he had not received negative feedback.[27] The briefing officer indicated they were required items for an international flight plan.[28] Together, they estimated approximate time intervals of 1 hour 10 minutes to each FIR boundary. The briefing officer advised the captain he needed to provide revised estimates for these FIR boundary crossings to ATS as soon as he was able to do so.

The briefing officer asked the captain if he needed any briefing material. The captain asked for the latest Norfolk Island TAF, and the briefing officer provided key elements of the TAF. This routine TAF was issued at 0437 on 18 November 2009 and was valid from 0600 to 2400. The provided information included:

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26 Relevant phone records did not show a record of this phone call, which would be consistent with a call being disconnected prior to it being answered or prior to it being diverted to a message service (see also *Assistance with obtaining information and completing flight plans*).

27 The flight plans submitted by the captain for the outbound flight also did not contain the elapsed en route times to FIR boundaries.

28 The Australian Aeronautical Information Publication (AIP) included information relevant for international flight planning. ENR 1.10 Flight Planning, Appendix 2 stated international flights entering or leaving an Australian FIR were required to indicate the estimated elapsed time to the FIR boundary.

- wind from 260° at 8 kt
- visibility at least 10 km
- scattered cloud at 2,000 ft.

The briefing officer also advised the captain there was a ‘trend’ stated on the forecast to commence from about 1500, or in about 10 hours.[29] He noted it probably would not affect the captain’s flight but he asked the captain if he wanted the details. The captain declined. The briefing officer offered the forecast temperatures and QNH[30] and the captain declined.

The captain did not request any other information from the briefing officer, and he did not obtain any updated information from other sources. The captain later reported that he thought the briefing officer was getting frustrated with him.[31] He also noted obtaining a wind forecast would not be practical over the phone due to its detailed nature and the way it was formatted.

The captain ended the phone call with the briefing officer at 0440, and the briefing officer submitted the flight plan at 0445.

At 0446 the captain sent a text message to the Westwind standards manager. He later recalled this message said there was no need for the manager to call him back. At 0447 the captain phoned the Norfolk Island Unicom operator to advise him of the expected arrival time. This Unicom operator was a different person to the operator on duty the previous night.

Fuel planning

During his phone call with the Brisbane briefing officer, the captain estimated the flight time to be 3.5 hours based on his recollection that the outbound flight from Norfolk Island to Apia took about 3 hours and there was a 50-kt tailwind.[32] He assumed the wind would be the same for the return flight, and he estimated a 50-kt headwind rather than a 50-kt tailwind would add about 30 minutes to the flight time.

The captain said the flight time he provided the Brisbane briefing officer was an approximate time for ATS purposes. It was not necessarily the time he used for fuel planning, and he could not recall what time he used for fuel planning purposes.

The captain said he considered full main tanks to be 7,200 lb. For the accident flight, he recalled calculating the total fuel required (including flight fuel and fuel reserves) to be about 200–300 lb less than full main tanks (see also *Application of the captain’s method to calculate total fuel required for normal operations*).

The ATSB interviewed many of the operator’s Westwind pilots and they all reported they departed with full fuel for long-distance air ambulance flights, particularly for flights to remote islands. The captain reported there were no operational limitations on taking full fuel for the flight on 18 November 2009, and he considered taking full fuel (that is, about 8,700 lb). However, based on his estimate of the en route winds, and the aerodrome forecast for Norfolk Island being significantly better than the alternate minima, he was confident that 7,200 lb was sufficient. The captain also noted fuel at ‘remotish’ aerodromes can be expensive, and he thought it was in the operator’s interest to not take unnecessary fuel when departing from such aerodromes (see *Guidance regarding the cost of fuel*). In addition, he noted there was an aircraft performance penalty associated with carrying extra fuel (or weight), and therefore he did not carry weight he did not believe he needed. The captain subsequently reported that another reason he did not take full

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29 The forecast indicated a change within the forecast period, stating that from 1500 there would be showers of rain, scattered cloud at 1,000 ft, broken cloud at 2,000 ft and visibility at least 10 km.

30 QNH: the altimeter barometric pressure subscale setting used to indicate the height above mean sea level.

31 A review of the recording of the telephone conversation indicated the briefing officer made a significant effort to assist the captain.

32 The captain stated he had left the wind information for the outbound flights on the aircraft and therefore could not refer to it during the phone call.

fuel was associated with the aircraft not being approved for RVSM operations (see *Reduced vertical separation minima*).

The published alternate minima at Norfolk Island for a Category C aircraft, such as a Westwind, was a ceiling[33] of 1,269 ft and a visibility of 6,000 m. There were no regulatory or operator-specific requirements for an air ambulance flight to carry sufficient fuel to divert to an alternate aerodrome or hold for an extended period at Norfolk Island. However, there was a requirement to carry sufficient fuel to allow for aircraft system failures, and 7,200 lb was not sufficient fuel to meet that requirement (see *Total fuel required including additional fuel for aircraft system failures*).

The captain did not obtain the forecast en route winds or SIGWX chart for the route from Apia to Norfolk Island for the time period covering the proposed flight. The forecast winds indicated an average headwind component of about 45 kt at FL 340 and 55 kt at FL 385. At FL 385, this was slightly more than the tailwinds experienced on the outbound flight. The forecast winds also included a significant crosswind component, particularly towards the end of the flight. Due to the crosswind influencing the aircraft's drift angle, the expected effective headwind would have been slightly (about 5 kt) more than forecast.[34] As a result, the forecast effective headwind from Apia to Norfolk Island was about 50 kt at FL 340 and 60 kt at FL 385.

The first officer did not participate in the flight planning or fuel planning, nor did the operator's procedures require her to participate. The captain showed her his notes about the Norfolk Island TAF. She recalled this information did not cause her to have any concerns about the flight. She also said that, prior to and during the flight, she was not aware the captain had not obtained any other updated weather or briefing information.

Refuelling and pre-flight preparations

The flight crew, medical personnel, patient and passenger travelled from the hotel to the airport in a minibus. Soon after arriving at the airport, the first officer conducted the aircraft's cockpit and cabin checks and entered the captain's flight-planned route into one of the aircraft's GPS units. The captain conducted the aircraft's exterior inspection and organised the refuelling.

As the first officer had not flown the leg from Apia to Norfolk Island before, the captain asked her if she would like to be the pilot flying. The first officer agreed.[35]

The captain reported that he ensured the aircraft was refuelled so that the main tanks were full. The refuelling records indicated the aircraft was refuelled from 0505 to 0515, and 2,780 L was uploaded. Based on the specific gravity of the added fuel, the fuel added was estimated to be about 4,810 lb and the total fuel on board was estimated to be about 7,190 lb (appendix E).

The captain recalled that after refuelling, the fuel quantity gauges were indicating about 6,800 or 6,900 lb. He also stated that, on the outbound flights on 17 November 2009, he had reviewed the aircraft's flight records for recent flights and estimated the aircraft's fuel quantity gauges were underreading by about 300 lb before fuel was added. The ATSB estimated that, based on previous flight records, the fuel gauges were probably underreading by about 260 lb (appendix F).

The first officer reported that, prior to the refueller departing, she (the first officer) noted the aircraft had not been refuelled to full capacity (that is, full main tanks and full tip tanks). She asked the

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[33] Ceiling: the height above the ground or water of the base of the lowest layer of cloud covering more than one-half of the sky (that is, the lowest level of broken or overcast cloud). When considering the alternate minima, the forecast amounts of cloud below the alternate minima are cumulative.

[34] In such circumstances, the nose of the aircraft is pointed into wind to maintain the desired ground track. With strong winds across the aircraft's track, the drift angle increases and reduces the aircraft's effective true airspeed.

[35] The operator's flight crews normally flew 'leg for leg', alternating their roles as the pilot flying and the pilot non-flying. Because the first officer was the pilot flying from Norfolk Island to Apia, the captain would have been expected to be the pilot flying from Apia to Norfolk Island.

captain whether they should refuel to full fuel. She recalled the captain said he had calculated the amount of fuel they needed and that full main tanks would be sufficient.

The first officer recalled that the flight from Norfolk Island to Apia had taken 3 hours 16 minutes, and the return flight was expected to take 30 minutes longer due to the headwinds. Prior to the aircraft departing, the flight nurse updated the air ambulance provider about the progress of the trip. According to the air ambulance provider's mission log,[36] the flight nurse reported the flight would depart at 0530 and take 3 hours 45 minutes.

The aircraft's occupants recalled that the weather in Apia was hot. During the pre-flight preparations, the medical personnel took the patient to the terminal building. At that stage she was walking without assistance. When they approached the aircraft, the patient collapsed on the tarmac near the aircraft. The medical personnel assisted the patient on to the aircraft, provided her with oxygen and secured her on the stretcher. The captain directed the first officer to start the right engine in order to provide air conditioning to the cabin. Data from the FDR showed that power was supplied to the recorder at 0524, consistent with the right engine being started at this time.

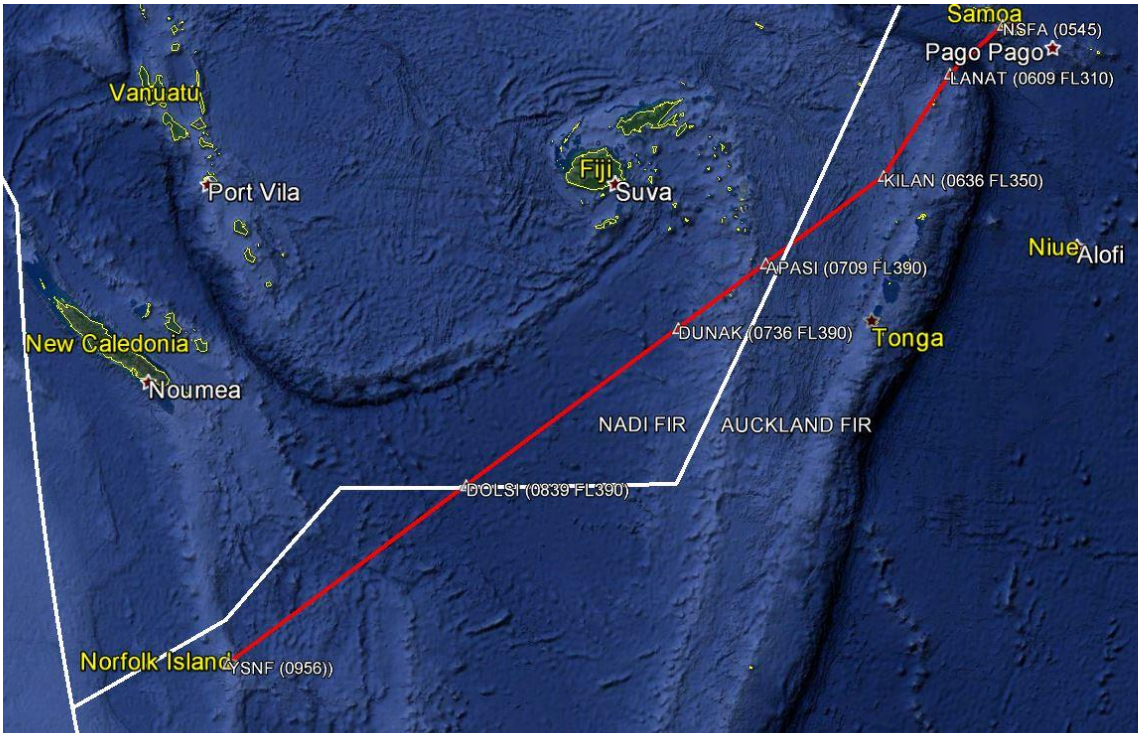
The captain was the last to board the aircraft. Neither of the flight crew could recall conducting a pre-flight safety briefing for the other occupants. The doctor noted the flight crew had not conducted a safety briefing, and he provided a short safety briefing to the passenger.

Departure (0545) and initial cruise

The flight crew started taxiing the aircraft at 0539 and took off from Apia at 0545. Samoan ATS instructed the crew to depart via LANAT before joining the flight-planned route at KILAN. ATS cleared the flight crew to climb to FL 310.

Figure 3 shows the aircraft's flight path and the times the aircraft passed each waypoint. It also shows the FIR boundaries.

Figure 3: Flight path (red) and FIR boundaries (white) for the accident flight from Apia to Norfolk Island



Source: Background image GoogleEarth, annotated/modified by ATSB.

36 The air ambulance provider recorded all significant activities, events and communications associated with an air ambulance task in a 'mission' log.

After passing FL 240 the aircraft entered the Auckland Oceanic FIR and the flight crew were required to communicate with the Auckland A/G operator via HF radio. There was initially a delay obtaining an ATS clearance for a flight level close to the planned level (that is, FL 360). The flight crew were subsequently cleared to FL 390 and reached this level at 0644. Table 4 summarises the communications with the Auckland A/G operator during the initial part of the flight.

Table 4: Summary of communications between the flight crew and Auckland A/G operator prior to reaching APASI

Time (UTC)	Event
0600	Initial contact with the Auckland A/G operator. Captain reported passing through FL 260 on climb to FL 310, estimated LANAT at 0606 and KILAN at 0635.
0608	Auckland A/G operator requested an update time for LANAT. Captain reported maintaining FL 310, estimated LANAT at 0609 and KILAN at 0636.
0620	Auckland A/G operator cleared the crew to climb to FL 350, with a requirement to reach this level by 0630.
0626	Auckland A/G operator instructed the crew to report their current level and stand by for a new clearance.
0628	Auckland A/G operator instructed the crew, due to Nadi traffic, to descend to FL 270, with a requirement to reach this level by 0650.
0629	Captain asked if there was other tracking they could take to avoid descent below FL 310. He advised descending would make it 'difficult for us fuel wise'. Auckland A/G operator asked the crew to stand by.
0630	Captain advised they could climb to FL 390 if that level was available.
0633	Auckland A/G operator instructed the crew to climb to FL 390, with a requirement to reach this level by 0650.
0637	Captain reported passed KILAN at 0636, on climb to FL 390, estimated APASI at 0706.
0644	Captain advised they were maintaining FL 390. Auckland A/G operator requested the crew contact Nadi when they reached APASI.

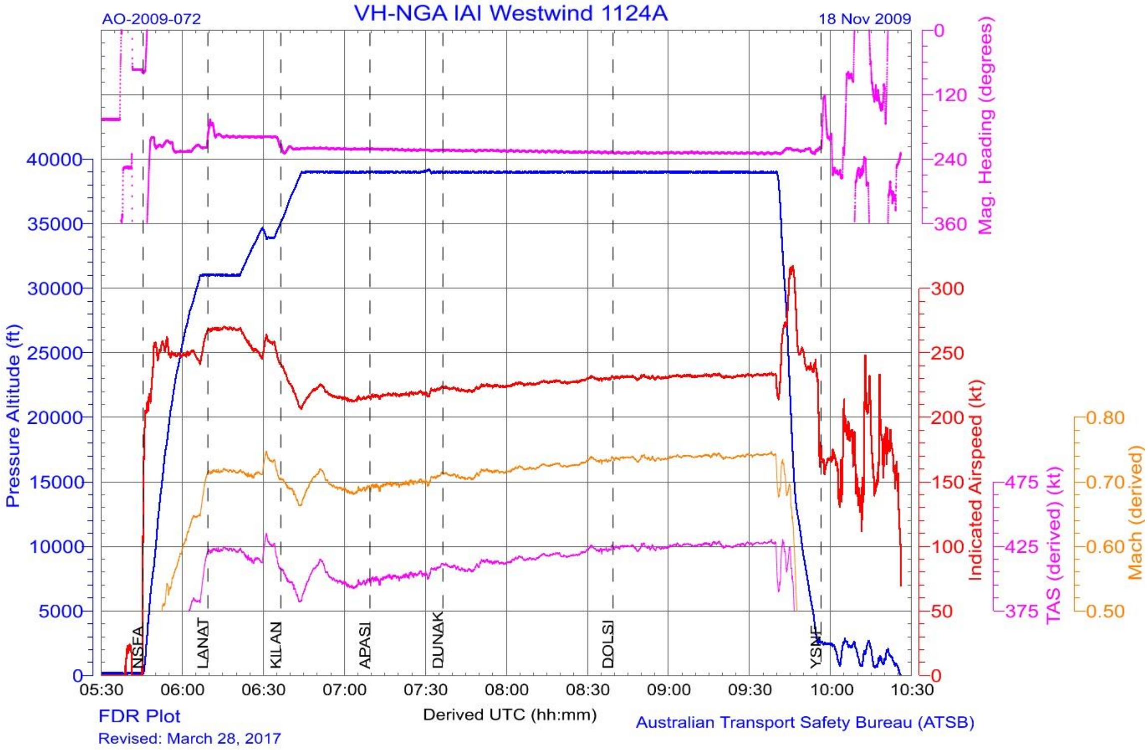
Figure 4 shows downloaded and derived data from the aircraft's FDR for the accident flight, including altitude, indicated airspeed (IAS), true airspeed (TAS) and magnetic heading (see appendix A for more details about the FDR).

As indicated in the figure, the TAS reduced at about 0652 (soon after the aircraft reached FL 390). The TAS then gradually increased from 0703 until the end of the cruise at 0940. The captain reported that, after reaching FL 390, he reduced the thrust so that the engines' inter-turbine temperatures (ITTs) were about 820°C. He said this was his normal practice on long flights to provide a conservative fuel burn without significantly reducing the aircraft's TAS. He did not believe that a long-range cruise (most conservative) thrust setting was required.

Both flight crew recalled that the selected thrust setting resulted in an indicated fuel flow of about 1,100 lb/hour total during the cruise at FL 390. The ATSB analysis of the aircraft's fuel status during the accident flight (appendix E) indicated the thrust remained at about the same setting from 0703 until 0940, and the fuel flow was probably about 1,310 lb/hour during this period.

The captain reported that, soon after reaching FL 390 and setting the thrust, he started doing detailed fuel and performance calculations. At that stage he was confident he had more than sufficient fuel for the flight.

Figure 4: Downloaded and derived data from the FDR for the accident flight



Source: ATSB.

Cruise from APASI reporting point (0709)

The aircraft passed the reporting point APASI at 0709. The ATSB analysis of the wind and aircraft speed during the accident flight (appendix D) indicated that at this time the aircraft's TAS was about 400 kt and the effective headwind component was about 45 kt, resulting in a groundspeed of about 355 kt.

Between APASI and DOLSI, the aircraft was in the Nadi FIR and the flight crew were required to communicate with the Nadi international flight information service officer (IFISO) via HF radio. Table 5 provides further details of the communications between the flight crew and the Nadi IFISO during the accident flight.

Table 5: Summary of communications between the flight crew and Nadi IFISO from APASI to DOLSI

Time (UTC)	Event
0711	Captain attempted to contact Nadi IFISO. Successful communication was established at 0716.
0716	Captain reported passed APASI at 0709, estimated DUNAK at 0736.
0737	Captain reported passed DUNAK at 0736, estimated DOLSI at 0838. Nadi IFISO requested the crew contact Auckland when they reached DOLSI.
0756	Captain requested the latest METAR for Norfolk Island. Nadi IFISO asked the crew to stand by.
0801	Nadi IFISO provided the 0630 METAR. Details included: • wind 300° at 9 kt • visibility at least 10,000 m • few cloud 6,000 ft, broken cloud 2,400 ft • temperature 21°C, dewpoint 19°C. [The 'few' cloud was actually 600 ft, but was incorrectly read out as 6,000 ft.] Captain queried the time of the METAR. Nadi IFISO confirmed that it was issued at 0630 and it was the latest he had.
0802	Nadi IFISO contacted crew to provide 'the latest' weather information, issued at 0800. He stated it was a 'SPECI, I say again special weather'. He correctly read out all the details of the SPECI, which included: • AUTO SPECI • wind 290° at 8 kt • visibility at least 10,000 m • overcast cloud 1,100 ft • temperature 21°C, dewpoint 19°C.
0803	Captain thanked the IFISO for the weather information. He did not ask for any clarifications or for any information to be repeated.

The aircraft passed the reporting point DUNAK at 0736. The ATSB analysis of the wind and aircraft speed indicated the aircraft's TAS was about 410 kt and the effective headwind component was about 65 kt, resulting in a groundspeed of about 345 kt.

The captain recalled that the aircraft's groundspeed stabilised at about 345–350 kt for most of the cruise at FL 390. The first officer also recalled a groundspeed of about 345 kt. The captain stated the winds were stronger than he expected, and his expected arrival time at Norfolk Island had increased by about 30 minutes. He said he was regularly reviewing the fuel remaining and the fuel they would have on arrival. He knew they would arrive with less fuel than he originally planned, but still had sufficient fuel for the flight.

The cloud base at Norfolk Island started deteriorating from about 0700 (appendix C). At 0739, the Australian Bureau of Meteorology (BoM) issued a SPECI, which stated the cloud was overcast at 1,100 ft (above aerodrome elevation). This SPECI was not provided to the flight crew.

At 0756, the captain requested the latest METAR[37] for Norfolk Island from the Nadi IFISO. At 0801, the IFISO provided the 0630 METAR, and at 0802 he provided the 0800 SPECI. Whereas the 0630 METAR was broadly consistent with the current TAF (issued at 0437), the 0800 SPECI indicated the cloud had deteriorated to be overcast at 1,100 ft. These cloud conditions were below the published alternate minima for planning a flight to Norfolk Island, but it was above the landing minima.

37 METAR: a routine aerodrome weather report issued at routine times, hourly or half-hourly.

The captain initially recalled that the weather report he received at 0802 suggested some deterioration but 'nothing major'. He also recalled the difference between the temperature and dewpoint was 2°C. This indicated to him that the lowest level of the cloud base was probably about 1,000 ft above the runway (see information below regarding events at 0916). With some cloud at 1,000 ft, he was content to continue the flight to Norfolk Island. The captain subsequently reported that he did not recall hearing the words 'SPECI' or 'special weather', or that there was overcast cloud at 1,100 ft. Appendix G provides a more detailed transcript of the communications between the captain and the Nadi IFISO between 0756 and 0803 concerning the weather reports.

The first officer did not recall hearing any weather information provided by the Nadi IFISO. Both of the crew stated that at some stage after reaching FL 390, the first officer had a controlled rest (or 'cockpit nap'), which was an approved component of the operator's fatigue risk management system (see *Cockpit strategic napping*). The first officer believed she had this controlled rest at the time the Nadi IFISO provided the weather reports. The extent to which the first officer was subsequently briefed regarding the 0800 weather report could not be determined.

At 0803, the aircraft was about 644 NM from Norfolk Island, 649 NM from Noumea and 317 NM from Nadi. The ATSB fuel analysis (appendix E) indicated there was about 3,480 lb of fuel remaining at this time.[38] This was more than sufficient fuel to divert to Nadi or Noumea and land with the required fuel reserves.

Other weather-related events that occurred when the aircraft was between APASI and DOLSI included:

- At 0803, BoM issued an amended TAF for Norfolk Island. This TAF included showers of rain, broken cloud at 1,000 ft, and visibility at least 10 km. This amended TAF was not provided to the flight crew.
- At 0830, BOM issued another SPECI. It included broken cloud at 300 ft, overcast cloud at 900 ft, and visibility at least 10 km. These cloud conditions were below the landing minima. This SPECI was not provided to the flight crew.

The CVR recording provided information from 0822 until the end of the flight. The first conversation between the crew on the recording was at 0832, when they briefly discussed the route they would take for their next leg from Norfolk Island to Melbourne. The next crew discussion occurred at 0848.

Cruise from DOLSI reporting point (0839)

The aircraft passed DOLSI at 0839. At this time, it was about 435 NM from Norfolk Island, 501 NM from Noumea and 465 NM from Nadi. The ATSB fuel analysis indicated there was about 2,690 lb of fuel remaining. This was more than sufficient fuel to divert to either Nadi or Noumea with the required fuel reserves. The ATSB analysis of the wind and aircraft speed indicated that at DOLSI the TAS was about 425 kt and the effective headwind component was about 90 kt, resulting in a groundspeed of about 335 kt.

At DOLSI the aircraft re-entered the Auckland Oceanic FIR and the crew were again required to communicate with the Auckland A/G operator via HF radio. Control of VH-NGA was transferred from Nadi ATS to Auckland ATS at 0835, just prior to the aircraft's expected arrival time at DOLSI. Table 6 summarises the communications between the crew and the Auckland A/G operator up until the crew contacted the Norfolk Island Unicom operator at 0928.

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[38] The ATSB analysis of the fuel remaining was based on a consideration of all the available information and it necessarily included a number of assumptions. It is possible that there was slightly more or slightly less fuel remaining. Appendix E provides further details.

Table 6: Summary of communications between the flight crew and the Auckland A/G operator from 0835 to 0928

Time (UTC)	Event
0841:22	Auckland A/G operator requested an updated time for DOLSI. Captain reported passed DOLSI at 0839, estimated Norfolk Island at 0956.
0904:27	Captain requested the 0900 METAR. Auckland A/G operator asked crew to stand by.
0905:34	Auckland A/G provided 0902 SPECI. Details included: • AUTO SPECI • wind 270° at 7 kt • visibility 7,000 m • scattered cloud 500 ft, broken cloud 1,100 ft, overcast cloud 1,500 ft • temperature 20°C. Captain requested the dewpoint. Auckland A/G operator stated it had been cut off her printed sheet and asked the crew to stand by. At 0906:30 the Auckland A/G operator provided the 0800 dewpoint (19°C).
0916:54	Auckland A/G operator asked crew for their top of descent time, captain replied 0940. Auckland A/G operator confirmed the 0902 SPECI had temperature 20°C and dewpoint 19°C.

At 0841, the Auckland A/G operator contacted the flight crew to obtain their latest position report. In response, the captain stated the aircraft passed DOLSI at 0839 and he estimated being overhead Norfolk Island at 0956.

From 0848 to 0900, the flight crew discussed the captain’s planned route from Norfolk Island to Melbourne and entered the waypoints for that route into one of the aircraft’s GPS units. At 0900, the crew discussed the fuel they required for that flight (see

Application of the captain’s fuel planning method for the subsequent flight).

The captain recalled that he regularly estimated the point of no return (PNR)[39] during the flight, and he had considered both Nadi and Noumea as potential diversion options as the flight progressed. However, he could not recall the position or time of the PNR. The first officer stated it was the captain’s role to be monitoring the PNR and she could not recall any discussion about the PNR during the flight. There was no discussion on the CVR recording about the PNR for a diversion to either Nadi or Noumea.

The ATSB calculated that, based on using the estimated fuel on board, long-range cruise settings and the forecast winds, the PNR for a diversion to Noumea was about 0844 and the PNR for a diversion to Nadi was about 0900. Using the captain’s reported method, the PNR for Noumea was estimated to be about 0852 and the PNR for Nadi was estimated to be about 0903 (see *Calculation of PNRs for the accident flight*).

At 0904, the first officer said ‘don’t forget to get the winds’ for their arrival at Norfolk Island. The captain then requested the latest METAR from the Auckland A/G operator. The operator provided the 0902 SPECI, which included scattered cloud at 500 ft, broken cloud at 1,100 ft, and visibility of 7,000 m.

At 0906:52, just after the Auckland A/G operator finished providing the latest weather report, the captain told the first officer that they would conduct the VOR approach to runway 29, and the first officer agreed.

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39 Point of no return (PNR): furthest point in the flight from the departure aerodrome to the destination aerodrome that an aircraft can proceed to and still have sufficient fuel to divert to a suitable aerodrome with the required fuel reserves.

At 0907, the aircraft was about 283 NM from Norfolk Island, 428 NM from Noumea and 594 NM from Nadi. The ATSB fuel analysis indicated there was about 2,090 lb of fuel remaining at this time.

The captain recalled that he was aware the weather conditions were deteriorating, but he thought that it would only be a gradual deterioration. Given what had occurred on the previous night's flight to Norfolk Island, he believed the actual conditions would not be as bad as what was being reported by the AWS (in the provided METAR/SPECIs) and he decided to continue the flight to Norfolk Island. There was no discussion on the CVR recording about a possible diversion.

The first officer recalled that she had some concern regarding the 0902 weather report provided by the Auckland A/G operator. However, she knew that, even though the conditions were close to the alternate minima, they were still above the landing minima. She was content to trust the captain's decision to continue, given he had more experience than she did and he was monitoring the fuel situation.

The effective headwind component increased after the aircraft passed DOLSI. The ATSB analysis of the wind and aircraft speed indicated that, at about 0905, the TAS was about 425 kt and the effective headwind component was about 95 kt, resulting in a groundspeed of about 330 kt. The captain recalled that the lowest groundspeed during the cruise was about 330 kt.

Approach briefing

At 0906:57, the crew started discussing the approach chart for the VOR approach to runway 29 (see *Published instrument approach procedures*) and the first officer provided an approach briefing that covered all the relevant details on the approach chart. The briefing included:

- the minimum sector altitude[40] (2,300 ft)[41] and descent point for the approach (at 6.5 NM)
- the minimum descent altitude (MDA)[42] for the approach (850 ft above mean sea level or 484 ft above the runway threshold)
- the final approach track to the VOR was to the left of the runway centreline
- the missed approach track (273°) and altitude (2,300 ft).

At 0909:04, the captain told the first officer he had reviewed previous flight records and refuelling records, and he believed the aircraft had 300 lb more fuel than the gauges were indicating. So instead of the gauges reading 'just south of' 2,000 lb fuel remaining, he believed they should be indicating 'just north of' 2,000 lb. The captain explained why he thought the gauges were underreading (see *Review of flight records to evaluate the accuracy of the fuel quantity gauges*), and the first officer acknowledged the explanation. The ATSB fuel analysis indicated the aircraft had about 2,040 lb remaining at 0909.

During the approach briefing, the crew's discussion of the weather consisted of the following:

- At 0910:19 the first officer restated the cloud (scattered at 500 ft and broken at 1,100 ft). She noted that, according to the approach chart, they should be through the cloud at 'about 3 miles [NM] hopefully' before the runway threshold.
- At 0912:36 the first officer stated the visibility was reported as 7 km and that the approach chart showed the minimum visibility for the approach was 3.3 km.

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40 Minimum sector altitude (MSA): lowest altitude that provides a clearance of at least 1,000 ft above all objects located in an area contained within a sector of a circle of 25 NM radius, centred on the aerodrome reference point.

41 The flight crew were using instrument approach charts that were published on 5 November 2009 and became effective on 19 November 2009. The charts that were effective on 18 November 2009 had the same information, except the minimum sector altitude was 2,200 ft.

42 Minimum descent altitude (MDA): the specified altitude in a non-precision runway or circling approach below which descent may not be made without the required visual reference. The MDA is equal to the ceiling minimum plus the runway elevation.

At 0917:15, the captain explained a 'dewpoint rule' to the first officer. He stated that, for every 1°C difference between the temperature and dewpoint, the lowest level of the cloud base for cumuliform cloud increased by 500 ft. He stated, for example, a 4°C difference would indicate the lowest level of the cloud base was 2,000 ft above the ground. He said he used this rule to check whether the heights of the cloud reported by an AWS in an AUTO weather report were accurate. The crew did not discuss the current 1°C difference between temperature and dewpoint at Norfolk Island.

Between 0918 and 0923, the crew discussed non-operational matters.

At 0925, the flight crew calculated the expected landing weight for the aircraft. The captain noted the fuel quantity gauges were indicating 1,400 lb of fuel remaining, but that they actually had 1,700 lb remaining. He also expected that, with 30 minutes until landing, they would have about 1,200 lb on arrival. Based on the expected landing weight, the crew agreed the reference landing speed (V_{REF})[43] was 120 kt. However, to allow for potential turbulence, the crew agreed that the final approach speed they would use was 125 kt, and these speeds were set on their airspeed indicators.[44]

The ATSB fuel analysis indicated there was about 1,700 lb of fuel remaining at 0925.

As the aircraft progressed towards Norfolk Island, the influence of the jet stream had begun to decrease. The ATSB analysis of the wind and aircraft speed indicated that, at about 0928, the TAS was about 425 kt and the effective headwind component was about 85 kt, resulting in a groundspeed of about 340 kt.

Cruise from first contact with Norfolk Island Unicom operator (0928)

At 0928:23, the captain established contact with the Norfolk Island Unicom operator. He reported the aircraft was 162 NM from Norfolk Island with more than 20 minutes to run. He requested an 'appreciation of the weather'. He noted 'it doesn't sound great, but you guys would know better than the robot weather would'.

In response, the Unicom operator stated the weather was deteriorating. He provided the latest readings from the AWS, which included broken cloud at 300 ft and visibility of 6,000 m. These cloud conditions were below the landing minima. Table 7 provides further details of the communications between the flight crew and the Unicom operator prior to the aircraft's top of descent.

43 The 1124A AFM defined the reference landing speed (V_{REF}) as the minimum speed at 50 ft above the runway during a normal landing. It stated this speed must not be less than 1.3 times the stall speed (V_{SO}).

44 Each of the airspeed indicators had a moveable index mark that could be manually adjusted by the crew. This mark was used to denote particular speeds during flight, including the final approach speed when landing.

Table 7: Summary of communications between the flight crew and the Unicom operator and the Auckland air/ground operator from 0928 to 0940

Time (UTC)	Event
0928:23	First contact with the Norfolk Island Unicom operator. Captain reported they were 162 NM from Norfolk Island and he requested the latest weather details.
0928:44	Unicom operator stated the weather was deteriorating. He provided details from the AWS:[45] • broken cloud 300 ft, broken cloud 800 ft, broken cloud at 1,100 ft • visibility 6,000 m • wind 199° at 7 kt • temperature 20°, dewpoint 18°C.
0929:24	Captain requested the Unicom operator provide an observation from the runway.
0932:21	Auckland A/G operator provided the crew a clearance to descend when ready. She also provided the 0930 SPECI. Details included: • wind 200° at 7 kt • visibility 4,500 m • broken cloud 200 ft, broken cloud 600 ft, overcast cloud 1,100 ft • temperature 20°C, dewpoint 19°C.
0938:36	Unicom operator reported he had just come back from the runway and they had a rain cell over the runway at that time. He stated the AWS was indicating 4 oktas cloud (scattered) 200 ft and broken cloud at 600 ft, and the visibility was 4,000 m. The operator asked the flight crew if they had an alternate airport, and the captain replied 'negative'.

At 0929:24, the captain told the Unicom operator that, on the previous night, the Unicom operator said the 'machine' was reporting weather that was 'far worse' than what he saw from out on the runway.[46] He asked if the operator could go out to the runway and have a look so they could get a 'more human appreciation' of the weather. The Unicom operator agreed.

At 0930, the captain told the first officer that they would not be 'busting' any landing minimas, but if the aircraft started deviating from the required flight path he would assist the first officer in order to prevent an overshoot. The first officer indicated she was comfortable with this suggestion. She also stated if they slowed the aircraft down and flew the correct profile they 'should be fine', and the captain agreed. Other than conduct the missed approach procedure, there was no discussion about what the crew would do if they could not land off the first approach.

On the CVR recording, it was evident that both flight crew were noticeably more anxious about the weather conditions after receiving the initial information from the Unicom operator at 0929. The captain later recalled that he first became concerned about the weather when he received the information from the Unicom operator. However, he was still confident they would be able to land. He was also still expecting the actual cloud conditions would be better than what was being reported by the AWS. He noted that if he had been really concerned he would have elected to conduct the approach as the pilot flying. The first officer recalled that she was much more concerned about their situation after hearing the 0929 and subsequent weather reports.

At 0931:24, the captain said it was a good lesson for him to not assume that the winds from 10–12 hours before would be the same for the return flight.[47] The first officer agreed. As noted earlier, the

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45 There were slight differences in the weather information provided by the Unicom operator at 0929 compared with SPECIs issued at 0925 and 0930 (see appendix E). The Unicom operator was providing data using a display panel indicating output from the aerodrome's AWS.

46 The Unicom operator on 17 November 2009 was different to the operator on the 18 November 2009.

47 The return flight from Apia departed 14 hours after the outbound flight from Norfolk Island, and the aircraft passed over the DOLSI reporting point about 16 hours after the outbound flight.

forecast average effective headwind from Apia to Norfolk Island was about 50 kt at FL 340 and 60 kt at FL 385. The estimated actual winds were close to the forecast winds.

At 0932:21, the Auckland A/G operator provided the crew with a clearance to descend when they were ready. She also provided the 0930 SPECI (see Table 6), which included broken cloud at 200 ft and visibility of 4,500 m. On receipt of this information, the captain expressed dissatisfaction to the first officer with the situation given the original forecast was ‘great’.

From 0937 to 0940, the crew completed the items on the descent checklist.

At 0938:36, the Norfolk Unicom operator reported that he had just come back from the runway and that they had a rain cell over the runway at that time. He also provided updated readings from the AWS, which were similar to the 0930 SPECI (Table 7).

Descent (0940)

At 0940:10, the flight crew initiated the descent from FL 390. The ATSB fuel analysis indicated the aircraft had about 1,360 lb of fuel remaining at this time.

At 0952:27, as the aircraft descended through an altitude of 6,200 ft,[48] the first officer disconnected the autopilot, and it was not re-engaged during the remainder of the flight. At 0955:14, the first officer levelled the aircraft at about 2,500 ft while tracking towards the initial approach fix. She then started slowing the aircraft down for the start of the approach.

During the descent and first approach, the crew received further updates from the Unicom operator (Table 8). Although the first update at 0944:31 indicated conditions were improving, all subsequent updates from the Unicom operator indicated the cloud was below the landing minima.

Table 8: Summary of communications between the flight crew and the Unicom operator and the Auckland air/ground operator after the start of descent

Time (UTC)	Event
0944:31	Unicom operator reported broken cloud 600 ft, visibility 4,300 m, showers ‘sort of abated’.
0945:56	Unicom operator reported broken cloud 300 ft, broken cloud 1,400 ft, visibility 4,300 m. The operator advised he would switch the runway lights to high intensity. He asked if the crew wanted strobe lights on, and the captain replied yes.
0946:48	Captain advised the Auckland A/G operator they had passed FL 240 on descent. [No further communications with the Auckland A/G operator were required until the aircraft landed.]
0948:46	Unicom operator reported broken cloud 200 ft, broken cloud 1,400 ft, visibility 4,700 m. The operator asked which runway the crew were using, and the captain replied runway 29.

During the descent, the flight crew frequently discussed their progress. The first officer regularly announced her intentions and actions, and the aircraft speed, as well as altitude and position relative to the published approach. The captain asked questions and provided suggestions. All relevant items on the descent, transition and pre-landing checklists were completed as required.

The crew reported that, during the descent, they closed the curtain between the cockpit and the cabin to minimise the ambient lighting and maximise their opportunity to acquire visual reference with the ground during the approach.

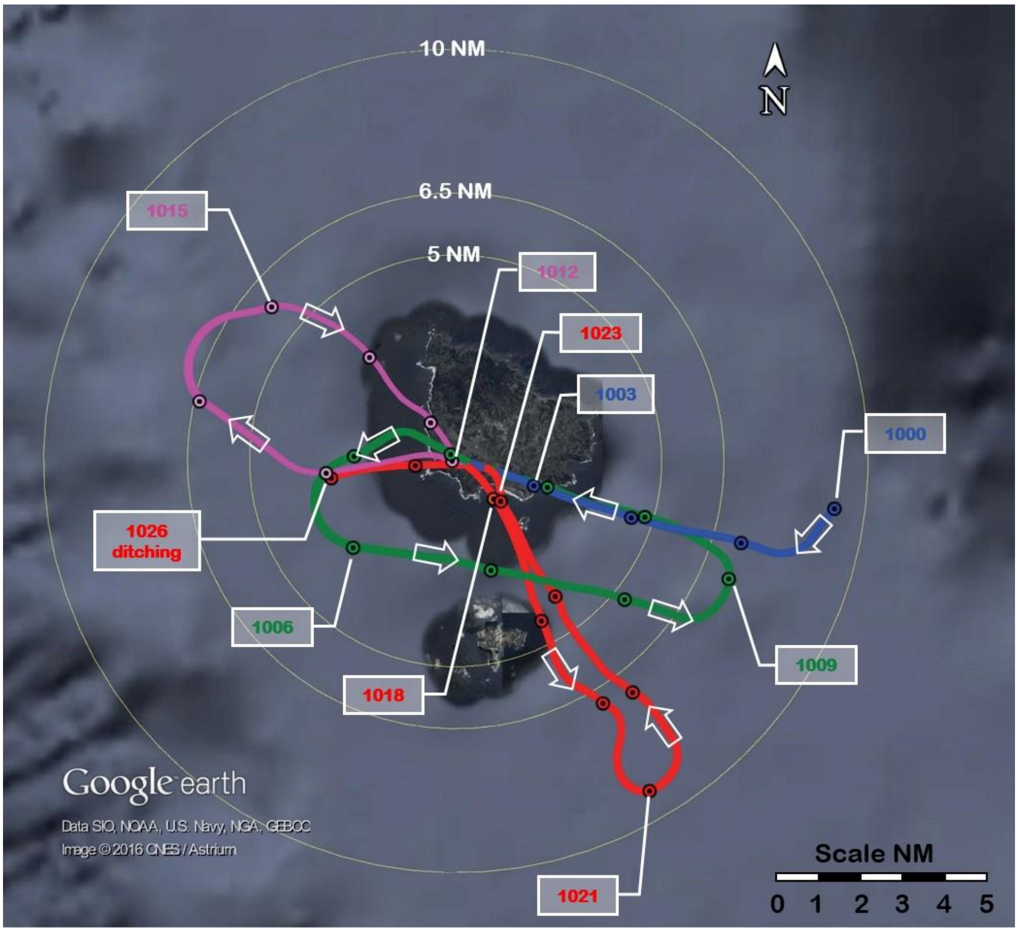
48 Altitudes are stated in ft above mean sea level. Cloud heights in TAFs and aerodrome weather reports are provided as the height above the aerodrome elevation, which is the elevation of the highest point of the landing area. The aerodrome elevation at Norfolk Island was at an altitude of 371 ft.

Instrument approaches

Overview of the approaches

Figure 5 shows the aircraft's track during the four approaches and the ditching. Table 9 summarises the communications between the flight crew and the Unicom operator during this period.

Figure 5: Aircraft's lateral position from 1000 until the ditching showing the first approach (blue), second approach (green), third approach (purple) and fourth approach and ditching (red)



Source: Background image GoogleEarth, annotated/modified by ATSB with the addition of data derived from the FDR.

Table 9: Summary of communications between the flight crew and the Unicom operator during the approaches

Time (UTC)	Event
0958:49	Unicom operator reported broken cloud 300 ft, broken cloud 1,600 ft, visibility 4,400 m.
1004:46	Unicom operator asked if the crew saw the runway on first approach. First officer replied no. Unicom operator reported cloud overcast 300 ft, visibility 4,800 m, fog and rain through in waves but not a heavy shower.
1005:28	First officer asked what conditions were like at the other end of the runway (that is, runway 11). Unicom operator said he thought it was the same at both ends. He noted the visibility had increased to 5,000 m, with broken cloud at 200 ft and broken cloud at 500 ft, and stated he would send someone out to look from the other end of the runway.
1010:06	First officer reported they were on approach to runway 29 again (for second approach).
1012:23	Airport staff at runway 11 advised the Unicom operator it was 'pretty thick up here'.
1013:41	First officer reported they were going to try an approach to runway 11 (for third approach).
1014:03	Airport staff at runway 11 advised the Unicom operator conditions were similar as the other runway, and there was a rain shower coming through.
1019:30	[After third approach.] Captain advised the Unicom operator they had to ditch as they had no fuel.
1019:40	First officer advised the Unicom operator they would 'come around again' (for fourth approach), and requested the latest cloud conditions. Unicom operator reported broken cloud 200 ft, broken cloud 700 ft, visibility 2,700 m.
1023:05	Unicom operator asked the flight crew if they had enough fuel to reach Noumea. First officer replied 'negative'.
1024:37	Unicom operator asked if the flight crew were able to talk yet, first officer replied 'no'.
1025:05	[After fourth approach.] First officer broadcasted 'we're going to proceed with the ditching'. Unicom operator acknowledged the transmission, and stated he would 'put everyone on alert'.

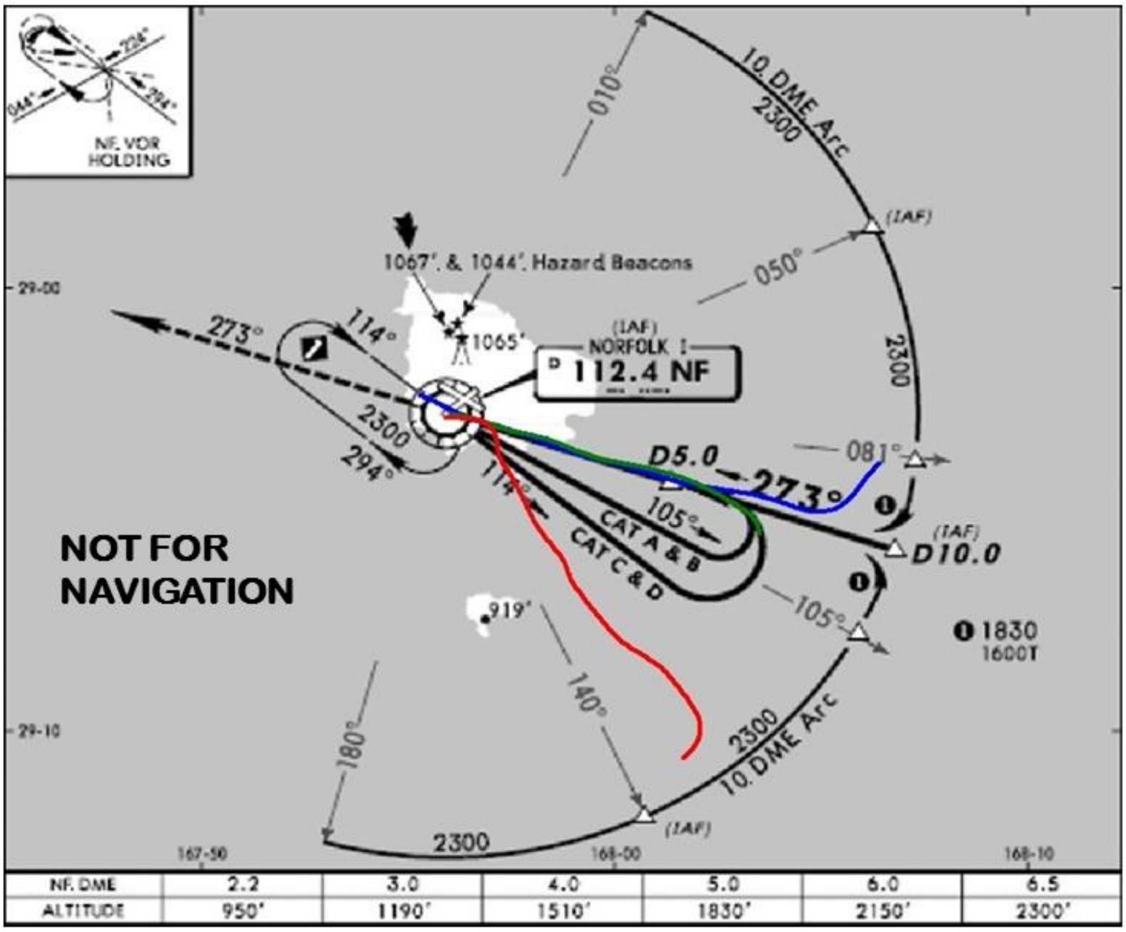
First approach

At 0955:13, the aircraft reached 2,500 ft at about 17 NM[49] from the Norfolk Island VOR and the first officer commenced an intermediate level off. At 0956:38, when the aircraft was about 13 NM from Norfolk Island, the first officer commenced a left turn in order to facilitate joining the 10-NM arc for the start of the runway 29 approach.

Figure 6 shows the approximate ground track of the aircraft during the first approach to runway 29 relative to the instrument approach chart (in blue), and Figure 7 shows the vertical profile relative to the recommended profile (in blue). As shown in the figures, at 1000:21, when the aircraft was about 9 NM from the VOR, the first officer commenced a right turn and intercepted the final approach track.

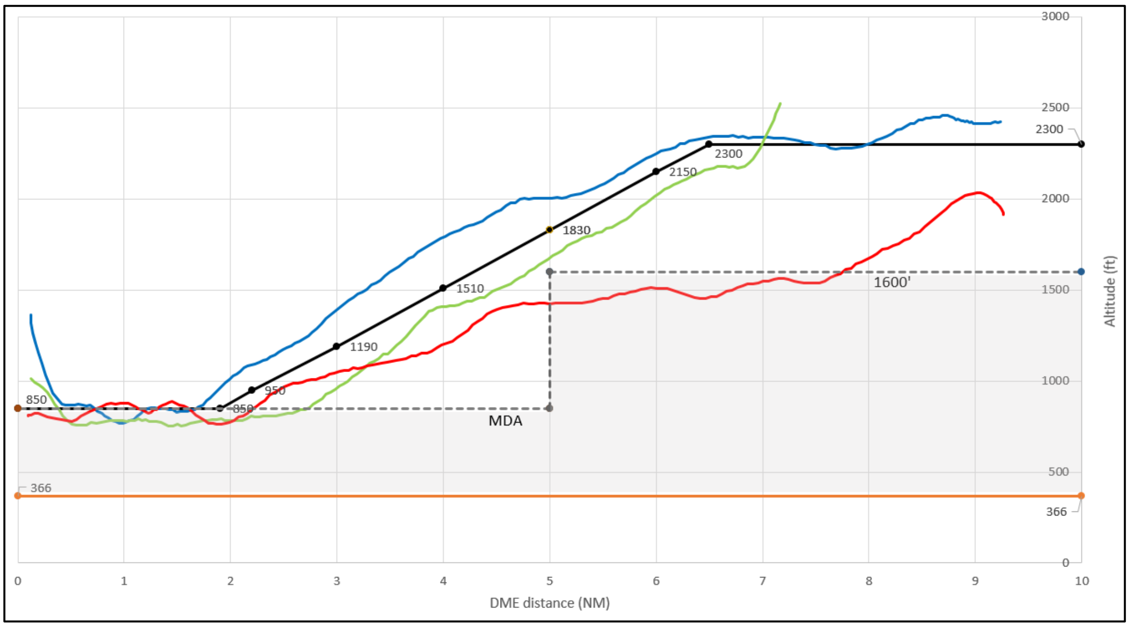
[49] All distances in the rest of this section are referenced to the Norfolk Island DME/VOR navigation aid.

Figure 6: Final approach tracks flown to runway 29 (approaches 1 (blue), 2 (green) and 4 (red)), overlaid on chart extract of procedure used by the crew on the night of the accident



Source: Chart extract reproduced with permission Jeppesen, aircraft track data by ATSB based on analysis of data on the FDR

Figure 7: Vertical profile of final approaches flown to runway 29 (approaches 1 (blue), 2 (green) and 4 (red))



Source: ATSB, based on analysis of data from FDR and instrument approach procedure for runway 29, effective 19 November 2009.

At 6.5 NM, the crew selected the landing gear down and initiated descent for the final approach. The descent profile flown was above the recommended descent profile published on the approach chart. Events during the final approach to runway 29 included:

- 1001:48: The aircraft was on track at the final approach fix (5 NM) at an airspeed of 167 kt and descending through 2,000 ft (recommended descent profile altitude 1,830 ft).
- 1002:40: The captain stated he was starting to notice some ground features (altitude 1,270 ft, airspeed 160 kt, about 2.7 NM). He later recalled that he momentarily saw lights in the water to the south-east of the airport when they were about halfway down the approach.
- 1003:09: The aircraft reached the MDA (altitude 850 ft, airspeed 140 kt, about 1.6 NM). The captain told the first officer to level off. The flight crew later recalled that at the MDA they were in heavy cloud.
- 1003:19: The captain took over control of the aircraft (altitude 850 ft, airspeed 131 kt, about 1.3 NM). The flight crew agreed that they could not see anything, and the captain indicated he would descend a little further.
- 1003:30: The aircraft descended to 770 ft briefly (airspeed 134 kt, about 1.0 NM) before starting to climb.
- 1003:43: After confirming the first officer could not see anything, the captain initiated a go-around (altitude 870 ft, airspeed 159 kt, about 0.6 NM).

Overall, the first approach was flown within lateral tolerances, with the airspeed being within 10 kt of the nominated final approach speed. During the approach, the first officer requested and the captain provided the height required for the different distances on the approach chart. The flight crew completed the relevant checklists and configuration changes as required.

The captain later reported that seeing the lights in the water to the south-east of the airport gave him some comfort that the weather (low cloud) would pass. He also recalled that, after the first approach, he selected the terrain alerting and display (TAD) function of the aircraft’s Enhanced Ground Proximity Warning System (EGPWS). He stated this display provided a very useful picture of the island and the terrain during the subsequent approaches.

The ATSB fuel analysis indicated there was about 1,040 lb of fuel remaining at the end of the first approach prior to commencing the go-around.

Second approach

At 1004:28, the aircraft was about 1.2 NM to the north-west of the VOR, climbing through 2,260 ft and approaching the minimum sector altitude (2,300 ft). The captain commenced a left turn.

At 1004:41, the first officer suggested doing an approach ‘off the other end’ (that is, the VOR approach to runway 11). The captain said ‘yep, that is what I am thinking about’. The first officer contacted the Unicom operator to get advice about the weather conditions at the other end of the runway. The Unicom operator said he thought it was the same at both ends, but would send someone out to have a look. He also provided the latest observations from the AWS (Table 10).

At 1005:09, the captain commenced another left turn in order to track back to conduct another approach to runway 29. The captain did not announce his intentions. The first officer later recalled that, due to their current heading, she was aware at this stage the captain had decided to conduct another VOR approach to runway 29. She then asked the captain questions to determine which way he was intending to track to start the approach.

At 1008:15, the captain stated he wanted to descend to the MDA early and hold it there. He then commenced a left turn to intercept the inbound track, about 6.7 NM and inside the published initial approach fix. The captain later reported he abbreviated the approach slightly in order to save time.

The left turn continued and, at about 1009:09, the aircraft was about 7 NM, descending through 2,300 ft and approaching the final approach track. Figure 6 shows the approximate ground track of the aircraft during the second approach to runway 29 (in green), and Figure 7 shows the vertical profile relative to the recommended profile (in green).

Events during the final approach to runway 29 included:

- 1009:56: The aircraft was on track at the final approach fix (5 NM) at an airspeed of 149 kt and descending through 1,670 ft (recommended descent profile altitude 1,830 ft, segment minimum safe altitude[50] not below 1,600 ft).
- 1010:50: The aircraft descended through the MDA (altitude 850 ft, airspeed 135 kt, about 2.7 NM). The flight crew agreed they would descend below the MDA, but did not nominate a target altitude.
- 1011:22: The aircraft briefly reached 750 ft (airspeed 132 kt, about 1.5 NM) before climbing back to 770–780 ft.
- 1011:46: The flight crew agreed they had no visual reference and the aircraft started climbing (altitude 760 ft, airspeed 149 kt, about 0.5 NM).

Overall, the second approach was flown within lateral tolerances, and at the MDA the airspeed was within 10–15 kt of the nominated final approach speed. During the approach, the first officer provided advice regarding the aircraft's position and advised the captain of exceedances in various parameters, which were acknowledged by the captain. The flight crew completed the relevant checklists and configuration changes as required.

The captain later reported that, at the end of the second approach, the fuel quantity gauges were indicating about 300 lb each side (or 600 lb total). The ATSB fuel analysis indicated there was probably about 820 lb of fuel remaining at the end of the second approach prior to commencing the go-around.

The captain also recalled that the FUEL LEVEL LOW warning light[51] illuminated on the annunciator panel at about the end of the second approach or during the subsequent missed approach. He said both flight crew saw the light and, to avoid the flashing light being a distraction, he selected it off. The first officer recalled that the light came on at some stage but could not recall when. There was no discussion between the crew regarding the warning light, and no indication on the CVR recording the crew assessed the balance of fuel quantity between the left and right tanks or considered opening the fuel tank interconnect valves in response.

The captain reported that, after the second approach, he became significantly concerned about their prospects for landing successfully.

Third approach

At 1012:08, the captain said they should try an approach to runway 11, and the first officer agreed.

At 1013:29, the aircraft reached the minimum sector altitude. The first officer provided a truncated briefing on the required approach path (that is, descend at 6.4 NM from 2,300 ft to an MDA of 750 ft). The first officer recalled that she had the relevant approach chart. However, due to the time constraints the captain was not able to retrieve and review his copy of the chart.

Figure 8 shows the approximate ground track of the aircraft during the approach to runway 11 (in purple), and Figure 9 shows the vertical profile relative to the recommended profile (in purple).

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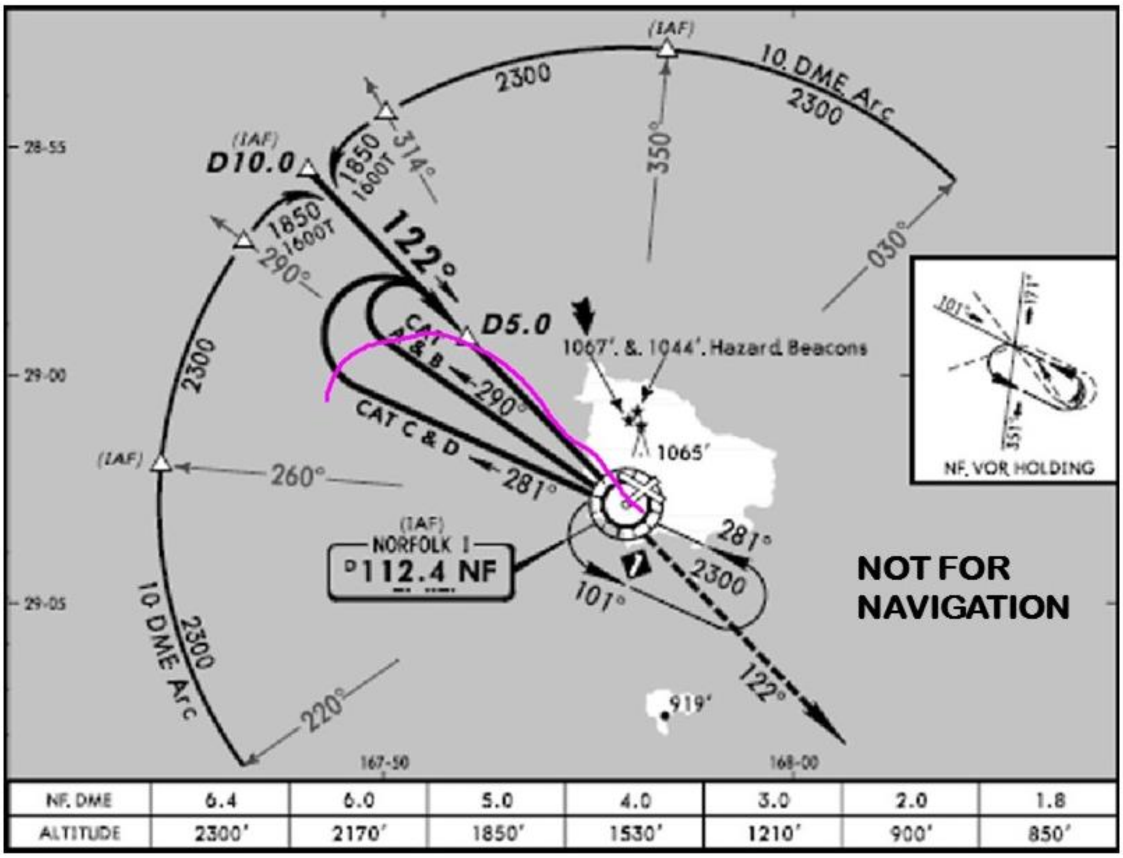
50 Segment minimum safe altitude: the lowest altitude providing the required minimum obstacle clearance for that stage of the approach.

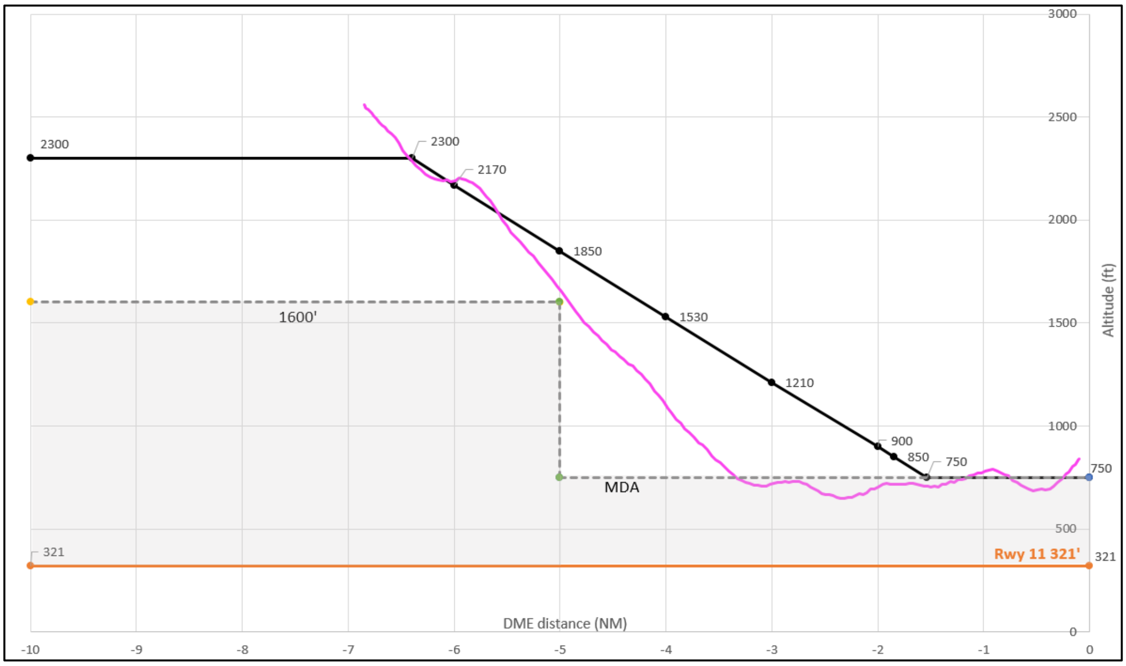
51 The fuel system is designed to illuminate the FUEL LEVEL LOW warning light when the fuel quantity in either the left or the right tank reduced to about 415 lb, and this indication was independent of the fuel quantity gauges.

Figure 8: Final approach track flown to runway 11 (approach 3), overlaid on chart extract of procedure used by the crew on the night of the accident



Source: Chart extract reproduced with permission Jeppesen, aircraft track data by ATSB based on analysis of data on the FDR

Figure 9: Vertical profile of final approach to runway 11 (approach 3)



Source: ATSB, based on analysis of data from FDR and instrument approach procedure for runway 11, effective 19 November 2009.

At 1014:00, and about 6.2 NM, the captain initiated a right turn. The aircraft turned inside the published initial approach fix. The right turn continued and, at about 1015:13, the aircraft was about 5.2 NM, descending through 1,800 ft and approaching the final approach track. The first officer asked the captain if he was going to descend early, and the captain said yes. Analysis of data from the FDR confirmed the aircraft descended below the recommended 3° descent profile, but remained above the segment minimum safe altitude (1,600 ft).

Events during the final approach to runway 11 included:

- 1015:18: the aircraft intercepted the final approach track at about the final approach fix (5 NM) and at 176 kt, descending through 1,650 ft (recommended descent profile 1,850 ft, segment minimum safe altitude 1,600 ft, reducing at 5 NM to 750 ft).
- 1015:36: The first officer suggested they use 700 ft as the MDA, and the captain agreed (altitude 1,250 ft, airspeed 160 kt, about 4.2 NM).
- 1015:58: The aircraft descended through the published MDA (altitude 750 ft, airspeed 156 kt, about 3.3 NM).
- 1016:24: The aircraft briefly reached 650 ft (airspeed 141 kt, about 2.4 NM) before climbing back to 700 ft at 1016:35 (142 kt). Over the next 40 seconds, the aircraft gradually climbed to 790 ft before descending back to about 700 ft.
- 1016:58: The aircraft passed through the extended centreline of runway 11 at about 0.5 NM (920 m) from the runway threshold, while climbing gradually through an altitude of 750 ft (airspeed 147 kt).
- 1017:20: The crew indicated they had no visual reference (altitude 710 ft, airspeed 156 kt, 0.3 NM), and the aircraft started climbing.

Overall, the third approach was generally flown within lateral tolerances, except for a brief period at 1016:43. The airspeed was about 140–150 kt (15–25 kt above the nominated final approach speed) after reaching the published MDA. During the approach, the first officer provided advice regarding the aircraft's position and advised the captain of exceedances in various parameters, which were acknowledged by the captain. Configuration changes were annunciated and completed as required, but some other checklist items were not verbalised.

The captain later recalled that he did not want to descend more than 100 ft below the published MDA during the approaches due to the risk of colliding with terrain.

The ATSB fuel analysis indicated there was probably about 640 lb of fuel remaining at the end of the third approach prior to commencing the go-around.

Preparation for the ditching

At 1017:36, soon after commencing the missed approach from runway 11, the captain stated they had to ditch the aircraft. Between this time and 1020:14, the crew had several discussions about whether to ditch or try another approach before the captain agreed to conduct another approach (Table 10). During this period, the aircraft was heading south-south-east, over the ocean and away from the airport. The captain initially climbed the aircraft to an altitude of about 1,400 ft, before the altitude gradually started decreasing to just under 900 ft. At 1019:07, the aircraft passed within 1.5 NM of the 919 ft spot height at Phillip Island[52] at about the same height as that terrain (Figure 5).

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52 Phillip Island was about 5 NM south of the airport at Norfolk Island.

Table 10: Flight crew discussion about ditching

Time (UTC)	Event
1017:36	Captain stated they had to ditch. First officer suggested they hold for a bit longer, and the captain said he did not want to run out of fuel.
1018:05	First officer suggested coming down a lot lower to the runway, especially to runway 11 where the MDA was lower. Captain said they did not have enough fuel.
1018:28	First officer asked where the captain was going to ditch. Captain instructed first officer to brief the passengers. First officer acknowledged this instruction, and asked captain 'what do you want?'. [She later recalled that she was asking the captain for more information about how and where they were going to conduct the ditching.]
1018:35 – 1018:48	First officer again asked where the captain was going to ditch, captain stated 'just straight out here'. First officer queried the captain's decision, and stated they should go back and attempt another approach below the MDA. Captain stated again he did not want to run out of fuel.
1018:55	Captain stated they needed to ditch, and instructed the first officer again to brief the passengers. First officer commenced briefing the passengers.
1019:15	First officer asked captain if they could ditch closer to the island. Captain agreed.
1019:30	Captain advised the Unicom operator they had to ditch as they had no fuel.
1019:38	First officer reminded the captain that they had 300 lb more fuel than indicated on the gauges, and the captain agreed to conduct another approach.
1019:40	First officer advised the Unicom operator they would 'come around again' (for a fourth approach).
1020:01	Captain stated again that they had to ditch. First officer stated not to do it away from the island, captain agreed and stated they would turn back.
1020:05	First officer recommended doing one more approach. Captain said he did not want to run out of fuel close to the runway. First officer reminded the captain they had 300 lb more fuel than indicated on the gauges, and the captain agreed to do one more approach.

The captain later recalled that, after the third approach, he was very concerned about their fuel. He wanted to avoid a situation where an engine ran out of fuel when they were manoeuvring the aircraft during an approach.

At 1019:04, the first officer told the passengers that they were going to have to ditch. She asked the doctor to come forward to the cockpit. At 1019:17 she instructed the doctor to get the life rafts out and clear the exits. She also stated 'need all the lights on'. She later recalled that she turned the cabin lights ON at this stage. Both the first officer and the doctor recalled that she also instructed him to ensure the passengers had their life jackets on.

The doctor assisted the patient's husband to put his life jacket on and also made sure his seat belt was secure. The flight nurse and doctor put their life jackets on. The patient was lying on a stretcher on the right side of the cabin and was restrained by a number of harness straps. The doctor recalled briefly looking for a life jacket for the patient at the back of the aircraft but could not find one. He ensured that the patient's harness straps were secure and instructed the patient to cross her arms in front of her body for the ditching.

The doctor also cleared baggage and other items from the aisle, and he removed the two life rafts from their storage and placed them in the aisle between the seats to be easily retrieved after they ditched. The life rafts were not secured in position, or able to be secured in position on the floor of the aircraft.

At 1020:03, the doctor advised the flight crew that the passengers had put their life jackets on. The flight crew later reported they did not have time to put their life jackets on.

Fourth approach

At 1020:17, the captain agreed to attempt one more approach and asked the first officer to set the inbound track for another approach to runway 29. The first officer asked if he wanted 273° (the final approach track for the instrument approach), and the captain said yes. He then initiated a left turn and established the aircraft in a climb from 1,300 ft.

Figure 6 shows the approximate ground track of the aircraft during the approach to runway 29 relative to the instrument approach chart (in red), and Figure 7 shows the vertical profile relative to the recommended profile (in red). As indicated in Figure 6, at 1021:19 the aircraft was about 9.2 NM and turning on to an inbound track to the VOR that was about 30° left of the published inbound track (altitude 2,040 ft and commencing a descent).

At 1022:49, the flight crew selected the landing gear down, and the first officer stated all the checklist items up to that point had been completed.

Events during the final approach included:

- 1022:40: The aircraft was about 5 NM, descending through 1,430 ft. The aircraft was not established on the final approach track for the runway 29 VOR procedure.
- 1023:42: The aircraft descended through the MDA (altitude 850 ft, airspeed 160 kt, about 2.2 NM). The first officer stated they were not on the inbound track, and the captain acknowledged. The captain later reported he used this inbound track to overfly the area where he had seen the surface lights on a previous approach.
- 1023:55: The first officer stated she could see some buildings (altitude 820 ft, airspeed 145 kt, about 1.8 NM).
- 1024:13: The aircraft was within 5° of the final approach track at an intercept angle of 30° and the captain commenced a left turn and maintained this track to the VOR (altitude 860 ft, airspeed 155 kt, about 1.1 NM DME from the VOR).
- 1024:42: The captain stated ‘let’s go, we’re going to have to ditch straight ahead’ (altitude 760 ft and gradually decreasing, airspeed 152 kt, close to the VOR and heading west away from the airport).
- 1024:56: The crew agreed they had gone past the runway (altitude 670 ft, airspeed 146 kt).

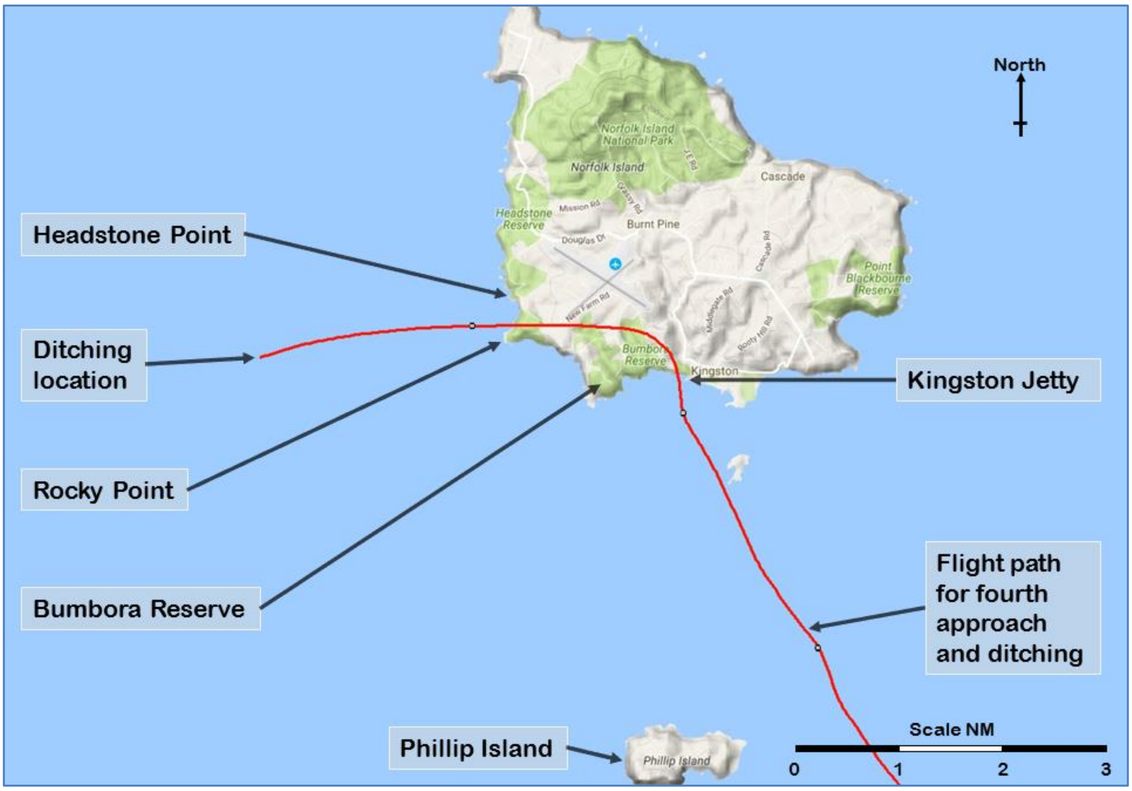
During the fourth approach, the airspeed briefly slowed to 144 kt but was generally over 150 kt. There was no indication on the CVR recording that full flap was requested or selected during the approach. As far as could be determined, other checklist items were conducted but some were not verbalised.

The first officer later recalled the fuel gauges indicated a total of about 200 lb remaining at the start of the fourth approach. The ATSB fuel analysis indicated there was probably about 520 lb of fuel remaining at the start of the fourth approach. The captain recalled there was between 0 and 100 lb indicated on each fuel quantity gauge at the end of the fourth approach.

Ditching

Figure 10 shows the flight path of the aircraft during the final stage of the fourth approach and the ditching. The captain recalled there was low terrain to the south and west of the airport. He said turning left (to the west) was the quickest way to reach the water and he knew there were no islands in that area.

Figure 10: Map showing Norfolk Island and flight path of aircraft in period prior to ditching



Source: Google terrain, annotated by ATSB.

Events during the approach to the ditching included:

- 1024:59: The captain requested 'full flap', which was selected (altitude 590 ft, airspeed 153 kt).
- 1025:05: The first officer broadcasted on the Unicom frequency 'we're going to proceed with the ditching'.
- 1025:06: The EGPWS annunciated 'too low terrain' (altitude 415 ft, airspeed 151 kt). The aircraft briefly levelled off at about 420 ft and the airspeed started decreasing.
- 1025:13: The first officer instructed the passengers to brace (altitude 440 ft, airspeed 134 kt). The seated occupants in the cabin recalled they adopted the brace position prior to impact.
- 1025:17: The captain recommenced the descent (altitude 417 ft, airspeed 128 kt).
- 1025:20: The EGPWS commenced annunciating 'too low terrain' until 1025:39 (altitude 390 ft, airspeed 125 kt).
- 1025:33: The aircraft was established in a stable descent with a descent rate[53] about 950 ft/minute and the airspeed about 114 kt (until 1025:43).
- 1025:37: The first officer called out '200 ft' (airspeed 113 kt).
- 1025:39: The EGPWS commenced annunciating 'terrain ahead pull up' for the remainder of the flight (altitude 160 ft, airspeed 114 kt). Because it was providing these alerts, the EGPWS did not provide any advisory callouts of the aircraft's radio height.[54]
- 1025:42: After checking the aircraft's configuration, the first officer said 'gear up?' (altitude 115 ft, airspeed 114 kt, descent rate decreasing). The captain requested gear up and the gear was

53 Descent rate was not recorded on the FDR. The ATSB estimated descent rates based on recorded parameters and other considerations (see appendix B).

54 Measured by the radio altimeter and annunciated by the EGPWS. These callouts would normally have occurred at 500, 200, 100, 50, 40, 30, 20 and 10 ft above the terrain/water.

selected up (1025:43). The landing gear warning horn activated on gear retraction and remained on for the rest of the flight. The landing gear was fully retracted at about 1025:48.

- 1025:47: The descent rate stabilised at about 360 ft/minute (altitude 80 ft, airspeed 108 kt and decreasing).
- 1025:52: The aircraft descended through about 50 ft above the sea surface (airspeed 103 kt and decreasing). From 1025:53, the first officer called out heights of '40 ft', '30 ft' and '10 ft'.
- 1025:58: The aircraft impacted the sea (airspeed 92 kt). The CVR recording and the FDR data indicated there were three impacts, with the last occurring at 1026:02.

The flight crew later reported they did not have time to refer to the emergency checklist for ditching. The captain said he could not recall what the ditching checklist said about the airspeed for a ditching, so he decided to slow the aircraft down to 100 kt. At about 30 ft, he gently pulled back on the control column to flare the aircraft.

Data from the FDR is consistent with the indicated airspeed steadily decreasing to about 100 kt when the aircraft reached 30 ft. The recorded data indicated there was a slight increase in the vertical acceleration at about this time, consistent with an attempt to flare. However, the descent rate then increased prior to the impact. Based on the available data, the descent rate at impact was likely about 500–600 ft/minute and very likely to be in the range of 400–700 ft/minute (appendix B).

The flight crew reported the aircraft's landing lights were on. However, they did not see anything outside the cockpit prior to impacting the water. Therefore, the crew were unable to ensure the aircraft's approach path was aligned with the sea swell. The captain reported he was looking at the aircraft's attitude indicator and the radio altimeter readout during the final stages of the ditching manoeuvre.

The peak vertical acceleration recorded for the first impact was 3.24 g. The vertical deceleration during the second and third impacts were 2.30 g and 1.98 g. Vertical acceleration was recorded eight times a second. Therefore, the peak values may have been higher than those recorded. The flight nurse, seated at the rear of the aircraft, reported the first impact involved a very significant vertical force. The first officer said the aircraft's nose entered the water on the final impact, resulting in a significant longitudinal deceleration.

The ditching occurred 6.4 km west-south-west of the airport, or 4.6 km west of the nearest land (which was Rocky Point, Figure 10). The ATSB fuel analysis indicated there was probably about 440 lb of fuel remaining at the time of the ditching.

Evacuation

The occupants reported the main entry door partially opened during the last impact, and the aircraft rapidly started flooding with water through the door. The flight nurse also reported water entered the rear of the cabin up through the cabin floor. The occupants evacuated as soon as they could, with the captain opening and departing out of the left emergency exit and the doctor and nurse assisting the patient out of the right emergency exit. The passenger and the first officer subsequently evacuated out of the left emergency exit, and both reported having to swim up to reach the surface of the water. Further details of the flooding and evacuation sequence are provided in *Impact, flooding and evacuation sequence on the accident flight*.

None of the occupants were able to retrieve either of the aircraft's life rafts before leaving the aircraft. The doctor, flight nurse and passenger were the only occupants with a life jacket. They inflated their life jackets after leaving the aircraft. However, only one of the two chambers of the nurse's life jacket was inflated.

The aircraft fuselage separated into two sections soon after coming to a stop, and the tail section remained afloat for a short period of time. Although the occupants initially considered using the wings and tail section for buoyancy support, the jagged metal and the movement of the wreckage with the wave action made that hazardous and impractical. The captain initially considered returning to the aircraft to retrieve a life raft, but he quickly realised this also was hazardous and impractical.

The occupants could see lights on Norfolk Island, and they slowly started making their way towards the lights. The captain organised for all the evacuees to keep close together, and regularly kept them talking. The doctor supported the injured first officer and the flight nurse supported the patient.

Search and rescue

Prior to the aircraft ditching, the Unicom operator contacted the Norfolk Island emergency services coordinator (ESC)[55] to advise him of the situation. The coordinator began to monitor the situation using the aviation-band VHF radio fitted to the emergency service's general utility vehicle (GUV). When the first officer broadcast that the aircraft had insufficient fuel to divert, the ESC called out the other members of the airport rescue and firefighting services, and the airport manager contacted the owners of two fishing charter vessels that could be used for a search.

At 1025:05, the first officer broadcasted on the Unicom frequency 'we're going to proceed with the ditching'. She did not provide any further details. The transmission was relatively rapid and the Unicom operator did not fully perceive or understand it. As a result, he thought the flight crew were still planning another approach and then potentially a ditching. He initiated full emergency procedures, which included contacting the Norfolk Island police and the Auckland Oceanic controller to advise them of the situation. The Auckland Oceanic controller contacted the Rescue Coordination Centre New Zealand (RCCNZ).

During the ditching impact, the aircraft's 406-MHz beacon emergency locator transmitter (ELT) transmitted one alert signal. Although the alert was detected by a geostationary satellite, the single alert was insufficient for the search and rescue services to determine the location of the ELT.

After a period of time in the water, the captain remembered that he had a bright light emitting diode torch in his shirt pocket. He shone the torch into the air and towards the island, in an attempt to alert rescuers as to their position. However, the torch stopped working after a limited period.

After it became clear that the aircraft had ditched, the airport firefighters repositioned to the Kingston Jetty to assist with the search. The ESC and two firefighters used the GUV to travel to the jetty. One of the firefighters elected to travel via the cliffs at Headstone Point, west of the airport. He stopped his vehicle to check the sea to the west of the island, believing that it was possible the aircraft had ditched there. He recalled looking out to sea and seeing what he thought was an occasional and intermittent glow of light (which was from the captain's torch). After looking for a few minutes, he was convinced the light was real and at about 1120 he phoned the observation through to the ESC, who was still travelling towards the jetty. The ESC relayed this information to the Unicom operator.

Soon after 1120, the first search vessel was preparing to depart Kingston Jetty. Given the lack of search coordinates derived from the ELT, and the absence of a position report from the flight crew, the initial plan was to search to the south-east of the island as the airport personnel believed the aircraft had probably ditched after conducting a second approach to runway 11.

About the same time, several local pilots had arrived at the airport and had been discussing possible ditching locations. That group included one pilot who had heard the aircraft fly over his house to the west of the airport, but did not think it was climbing. The consensus of the group was that the most likely ditching location was to the west of the island and this information was passed to the officer in charge of the Norfolk Island police, who was the police incident commander in charge of coordinating the local emergency response and was with the Unicom operator at the airport's emergency response centre.

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55 The ESC was also the officer in charge of the Norfolk Island Fire Service.

At about 1125, personnel on the first search vessel were advised of the sighting of the light to the west of the island and also the opinion expressed by pilots. The search vessel personnel took the view that the new information was better than what they were working with and in consultation with the police incident commander, decided to head to the west of island. The skipper of the vessel plotted a safe passage around rocks offshore Bumbora Reserve and headed towards the light's reported location, west of Headstone Point. A short time later, a series of radar returns were seen on the vessel's marine radar display at a range of about 1.4 NM. Although these returns were intermittent, each time they reappeared they were closer to the vessel. The skipper steered towards that position and, at a range of about 1 NM, a crew member saw lights from the evacuees' life jackets. Those lights were used to steer the final approach to that position and then, at closer range, a hand-held spotlight was used.

At about 1150, after about 1 hour 25 minutes in the water, the aircraft's six evacuees were located and assisted on board the search vessel.

Further details of the search and rescue sequence are provided in *Other search and rescue aspects*.

Injuries and damage

Table 11 summarises the degree of injury sustained by the six occupants.

Table 11: Summary of injury levels

Injuries	Flight crew	Medical personnel	Other occupants
Fatal	0	0	0
Serious	1	1	0
Minor/none	1	1	2

The flight nurse received serious and permanent spinal injuries during the impact sequence, as well as injuries to her right arm, right knee and several cracked teeth during the impact sequence. Her head also hit the wing after she evacuated the aircraft.

The first officer was seriously injured as a result of her chest hitting the control column.[56]

The doctor initially reported that he received minor injuries, but was subsequently diagnosed with a permanent back injury due to the impact sequence. The patient and passenger reported that they received minor injuries, such as bruises and lacerations, during the accident. The captain was uninjured.

The aircraft's fuselage sections sank in 48 m of water. Further details of the aircraft damage are provided in *Wreckage and impact information*.

56 The first officer was shorter in stature than the captain and she had adjusted her seat and rudder positions appropriately to enable full and free access to the flight controls.

Context

Personnel information

Captain

Qualifications and experience

The captain obtained a Commercial Pilot (Aeroplane) Licence (CPL) in August 1996 and an Air Transport Pilot (Aeroplane) Licence (ATPL) in October 2002. Table 12 summarises his aeronautical experience.

Table 12: Summary of captain's aeronautical experience

Total flying[57]	4,347 hours
Total in command	2,418 hours
Total in command (multi-engine)	913 hours
Total flying on the Westwind	889 hours
Total hours in command on the Westwind	294 hours
Total flying last 90 days	45 hours
Total flying last 30 days	8 hours
Total flying last 7 days	6 hours
Last proficiency check	2 September 2009 (base check, line check, CAO 20.11 emergency procedures check)

The captain obtained his initial multi-engine command instrument rating (CIR) in September 1997. His last annual CIR renewal was conducted in February 2009 and he was endorsed to conduct VOR, NDB, ILS and LLZ instrument approaches.[58] He had previously held an RNAV (GNSS) endorsement, but this was not included on instrument rating renewals conducted by the operator for its Westwind pilots.

The captain met all relevant recency requirements. His last instrument approach prior to the accident flight was the runway 29 VOR approach at Norfolk Island the night before (17 November 2009). Prior to that his most recent instrument approaches included an ILS approach at Sydney on 10 November 2009 and VOR approaches at Norfolk Island on 29 and 30 September 2009.

Prior to joining the operator, the captain primarily worked as a flight instructor (1,446 hours). He obtained his initial (grade 3) instructor rating in May 2000 and obtained a grade 1 instructor rating in May 2003.

The captain had worked for the operator since 2005. More specifically:

57 The 4,347 hours total flying time included 1,567 hours as a copilot (or first officer). As copilot time is divided by two for the purpose of calculating total aeronautical experience, his total aeronautical experience was 3,564 hours.

58 These are published procedures that provide guidance with reference to ground-based navigation aids. The VOR, NDB and LLZ (localiser) were non-precision approaches providing lateral flight path guidance that enabled crews to safely descend the aircraft clear of obstacles while operating in IMC, to establish visual reference with the runway or if not visual, to commence a missed approach and climb back to a safe altitude. The ILS was a precision approach that provided lateral and vertical flight path guidance, to descend clear of obstacles and establish visual reference with the runway or if not visual, to climb back to a safe altitude.

- In October 2005 he joined the operator as a first officer on the SA-227 (Metro) turboprop aircraft and obtained a Metro copilot endorsement. He did not pass his first check to line[59] as a first officer after 101 hours line training. Following 30 hours additional line training, he passed the second check to line. No problems were noted on subsequent proficiency checks conducted in February 2006, August 2006 and February 2007.[60] He accrued 1,030 flight hours on the Metro, primarily on night freight operations.
- In July 2007 he joined the operator's Westwind fleet as a first officer. He obtained a Westwind command endorsement after 5 hours flight time, and was checked to line as a first officer in September 2007 after 68 hours line training. No problems were noted on a subsequent proficiency check in April 2008.
- In April 2008, he commenced training to be a Westwind captain. He did not pass his initial check to line in June 2008 after 98 flight hours. The check pilot's comments listed several procedural errors with flight tasks and aircraft handling, and recommended the captain undertake an additional eight sectors under supervision. The captain recommenced command training in October 2008, and he passed a second check to line in November 2008 after an additional 23 hours command line training.[61] No problems were noted in subsequent proficiency checks conducted in February 2009 and September 2009.

Westwind check pilots commented that the captain's abilities and performance were about average for the fleet. A range of comments were noted on his command line training forms, and these comments were not associated with any one particular theme. The comments were generally similar in nature to those provided for other pilots who undertook command training during the same period.

The captain's first officer training and command training on the Westwind were completed in Darwin during freight flights. Outside of this training, he was primarily based in Sydney and mostly conducted air ambulance and charter flights.

The captain completed the operator's training programs in the following areas:

- crew resource management (CRM) computer-based training (CBT) course (initial course soon after joining the operator, March 2008, March 2009)
- fatigue risk management system training CBT course (initial course soon after joining the operator, March 2008, March 2009)
- controlled flight into terrain awareness CBT course (March 2008, March 2009)
- ditching procedures 'wet drill' course (April 2008).

The operator's training and checking activities were conducted in an aircraft rather than a full flight simulator. The pilot had previously had some experience in a full flight simulator during second officer training in 2004 with a major Australian airline. This training was discontinued after he did not meet the required standard on multiple exercises.

Previous flights to Norfolk Island and international aerodromes

Prior to the accident flight, the captain conducted four flights to Norfolk Island:

- three from Sydney (December 2008, September 2009, November 2009)
- one from Apia (September 2009).

All four flights were air ambulance flights conducted at night.

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59 According to the operator's OM, a check to line involved a proficiency line check conducted over two sectors with a check pilot. The operator normally conducted a proficiency base check and proficiency line check before clearing a pilot to commence line operations (see also Proficiency checks).

60 It was normal practice for the operator's check pilots to record no comments on flight crew proficiency check forms.

61 During the period May to October 2008, the captain conducted an additional 63 hours as a first officer. He also had some time off flying duty due to a broken arm.

For the 17 November 2009 flight, the forecast conditions were below the alternate minima and the weather reports on arrival indicated the weather was at or about the alternate minima. For the other three flights, the forecast conditions were better than the alternate minima, and the actual conditions on arrival (as indicated in weather reports) were better than the forecast conditions.

The flight from Apia to Norfolk Island on 30 September 2009 was conducted in VH-NGA. The flight time was 4.57 hours. The flight departed with full fuel (about 8,700 lb) and landed with 1,500 lb.

As well as the four flights to Norfolk Island, the captain conducted five other flights to remote aerodromes, 10 flights to Noumea (seven as captain), two flights to Nadi (both as captain), two flights to Apia (both as captain) and 25 flights to other international aerodromes. Further information about the flights to remote aerodromes are provided in *Review of the operator's previous flights to remote aerodromes*.

Medical information

The captain held a Civil Aviation Safety Authority (CASA) Class 1 Medical Certificate that was valid until January 2010. His recent aviation medical assessments did not indicate any medical problems, and he reported that he was not experiencing any medical problems in the period leading up to the accident.

Recent history

The captain's roster pattern generally consisted of 3 days standby, a grey day[62] and then 2 days off duty. Table 13 summarises his roster and duty periods from 10 to 18 November 2009, with all times listed in Australian Eastern Daylight-saving Time (AEDT), which was the local time for the captain's home base (UTC + 11 hours). He was on leave from 25 October to 9 November 2009.

Table 13: Summary of captain's recent duty periods

Date	Roster day	Duty periods (AEDT)
10 November	Standby	1330–1830 (5 hours). Conducted 3 charter flights.
11 November	Standby	
12 November	Standby	
13 November	Grey day	
14 November	Off duty	
15 November	Off duty	
16 November	Standby	
17 November	Standby	2200–0645 (8.75 hours). Conducted 2 ambulance flights.
18 November	Standby	Commenced 1430. Scheduled 3 ambulance flights (about 13.50 hours).

The captain reported that he normally slept from 2300 to 0700 AEDT each night. He also said that when he was on standby he would normally have a brief nap in the afternoon. The captain stated that in the days prior to commencing duty on the 17 November he had been sleeping normally. He had exercised and performed some work for his family's business, but he reported this work did not involve much time or significant effort.

The captain's mobile phone records indicated he made a telephone call at 0522 AEDT on 17 November to check his voicemail messages. During interviews conducted during the reopened investigation, he indicated he probably made this call for personal reasons, and he could not recall if he went back to sleep afterwards. He also could not recall whether he had his usual standby-afternoon nap on this occasion.

[62] According to the Westwind operations manager, a grey day could be used to assign work duties but a pilot had the right to refuse the duty if the task was expected to finish after 2200 local time. The term 'grey day' was not defined in the operator's OM or other relevant documentation.

The Westwind operations manager advised the captain of the Apia trip at 2033 AEDT on 17 November. It was estimated that the crew arrived at Sydney Airport to commence their duty period at about 2200 AEDT. The captain reported that during the flights from Sydney to Apia, he had a short cockpit nap, as permitted by the operator's fatigue management procedures.

The flight to Apia landed at 0602 AEDT (0802 local time) on 18 November, and the crew reported that they finished their duties at the airport relatively quickly. Based on the recorded flight times and duty periods for similar flights, the flight crew's first duty period was estimated to have ended at about 0645 AEDT (8.75 hours). The captain reported that he started flight planning at about 1430 AEDT. Therefore, he had about 7.75 hours of time off duty in Apia (0645–1430 AEDT).

The flight crew and medical personnel reported that they reached the hotel near the airport in Apia relatively quickly. However, when they arrived at the hotel, staff advised them their rooms were not ready. Consequently, they ate breakfast together while their rooms were prepared. After breakfast, the flight crew and medical personnel agreed to meet in the hotel lobby at 1700 local time (1500 AEDT). The doctor reported that originally they were due to meet earlier, but because of the delay in getting rooms he suggested they push the meeting time and departure time back. The time that the flight crew were able to access their rooms is unknown.

The captain recalled that his sleep at the hotel was disrupted by room service and that the room's curtains did not effectively block out sunlight.[63] He also reported his sleep was disrupted by a phone call. His phone records indicated he received a call at about 1100 AEDT from a family member.[64] From that time to about 1210 AEDT he made multiple calls to the family member (about 25 minutes in total), and sent several text messages to various people. When interviewed during the reinvestigation, the captain thought the number and length of calls to the family member was unusual, but he could not recall the reason for the calls or whether they were associated with an issue that could have affected his sleep.

Based on the captain's recollections and a review of his phone records, the ATSB estimated the captain probably obtained about 3.50–4.00 hours sleep in Apia, with this sleep period broken by the series of phone calls between 1100–1210 AEDT.[65]

The captain did not think that he was fatigued after the rest period. The other aircraft occupants did not report noticing anything unusual about his behaviour prior to or during the accident flight, and there were no overt indications on the CVR recording of tiredness such as yawning or statements about being tired.

The captain reported that as well as breakfast he ate additional food in the afternoon and/or evening.

First officer

Qualifications and experience

The first officer obtained a CPL in September 2004. She completed the theory requirements for an ATPL in May 2008. Table 14 summarises her flying experience.

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[63] Given the time since the accident, the reopened investigation did not evaluate the hotel's rooms or the reasons for any disruption by room service. As noted in *Rostering practices,* the operator was not aware of any previous difficulties at this hotel.

[64] The captain reported he left his phone on because he believed that was what he was required to do. He also noted family members generally did not call him when he was away on a task. The operator stated captains were not required to keep their phones on during periods off duty during a trip. The operator's fatigue management training (see *Fatigue management training*) stated flight crew should minimise distractions when trying to sleep, including turning phones off and letting calls go through to voicemail.

[65] The captain originally reported to the ATSB soon after the accident that he had slept most of the rest period in Apia. He also reported he had slept well and definitely felt refreshed. He subsequently reported to CASA that he had 4 hours sleep and this sleep was disrupted. After the ATSB met with the captain in 2015 and reviewed his mobile phone records, it was agreed that the information he provided CASA was more likely to be correct.

Table 14: Summary of first officer's aeronautical experience

Total flying[66]	1,961 hours
Total in command	951 hours
Total in command (multi-engine)	9 hours
Total flying on the Westwind	656 hours
Total flying last 90 days	84 hours
Total flying last 30 days	18 hours
Total flying last 7 days	7 hours
Last proficiency check	28 September 2009 (line check) 3 October 2009 (command instrument rating renewal, base check, CAO 20.11 emergency procedures check)

The first officer obtained her initial multi-engine CIR in October 2004. Her last annual CIR renewal was conducted in October 2009 and she was endorsed for VOR, NDB, ILS, LLZ and DGA[67] instrument approaches. Her last instrument approach prior to the accident flight was an NDB approach at Nowra on 13 November 2009. She met all relevant recent experience requirements.

Prior to joining the operator, the first officer had worked as a flight instructor. She obtained her initial (grade 3) instructor rating in December 2004 and obtained a grade 2 instructor rating in December 2005. She obtained a Cessna Citation C500 copilot endorsement in July 2007 and a command endorsement in October 2007. She worked as a charter pilot for another operator on the C500, and accumulated 96 hours experience on the aircraft.

The first officer joined the operator in January 2008. She obtained a Westwind command endorsement in January 2008 after 5 hours flight time. She was checked to line as a first officer in March 2008 after 99 hours line training. No problems were noted on a subsequent proficiency check in October 2008.

In February 2009, the first officer commenced training to be a Westwind captain. Her training records noted that, after 95 hours in command under supervision (ICUS), her progress had stopped improving. It was recommended that she conduct flights ICUS where possible and return to command training after a suitable period, and she was checked back to line as a first officer. No problems were noted on a subsequent proficiency check conducted in late September / early October 2009. The availability of further command training was limited after the operator ceased regular freight operations in Westwinds in April 2009.

The first officer's line training was completed in Darwin during freight flights. Outside of this training, she was primarily based in Sydney and mostly conducted air ambulance and charter flights.

The first officer completed the operator's training programs in the following areas:

- CRM CBT course (March 2008, March 2009)
- fatigue risk management system training CBT course (March 2008, March 2009)
- controlled flight into terrain awareness CBT course (March 2008, March 2009)
- ditching procedures 'wet drill' course (April 2008).[68]

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66 The 1,961 hours total flying time included 596 hours as a copilot. Therefore, her total aeronautical experience was 1,663 hours.

67 This non-precision approach procedure was previously referred to as a DME/GNSS arrival.

68 The first officer also completed a similar wet drills course in July 2007 when employed by another operator.

Previous flights to Norfolk Island and international aerodromes

Prior to the accident flight, the first officer conducted three flights to Norfolk Island. All three flights were air ambulance flights that departed from Sydney and landed at night (October 2008, December 2008 and November 2009). Other than the 17 November 2009 flight, the forecast conditions and reported conditions at Norfolk Island were better than the alternate minima. All three flights departed with full fuel, and two of the flights were conducted with the captain of the accident flight.

In addition to the three flights to Norfolk Island, the first officer conducted two other flights to remote aerodromes, five flights to Noumea, one flight to Nadi, one flight to Apia and 18 flights to other international aerodromes.

Medical information

The first officer held a CASA Class 1 Medical Certificate that was valid until April 2010. Her recent aviation medical assessments did not indicate any medical problems, and she reported she was not experiencing any medical problems in the period leading up to the accident.

Recent history

The first officer had the same type of roster pattern as the captain. Table 15 summarises her roster and duty periods from 10 to 18 November 2009. Prior to 13 November, her last duty period was on 3 November 2009.

Table 15: Summary of first officer's recent duty periods

Date	Roster day	Duty periods (AEDT)
10 November	Day off in lieu	
11 November	Standby	
12 November	Standby	
13 November	Standby	0830–1215 (3.8 hours). Conducted 2 ferry flights.
14 November	Grey day	
15 November	Off duty	
16 November	Off duty	
17 November	Standby	2200–0645 (8.75 hours). Conducted 2 ambulance flights.
18 November	Standby	Commenced 1500. Scheduled 3 ambulance flights (about 13.50 hours).

The first officer reported she normally slept about 5–6 hours per night, and could not recall anything unusual about her sleep in the days prior to 17 November 2009. When interviewed during the reopened investigation, she recalled when on standby she would normally have a nap from about 1600–1800 AEDT.

As she was not involved with the flight planning, the first officer had 8.25 hours of time off duty in Apia (0645–1500 AEDT). She reported getting about 5–6 hours sleep at Apia and that the hotel room was good. She then had lunch and felt well rested prior to meeting the captain and medical personnel. According to her phone records, she sent text messages at 0725 and 1212 AEDT, indicating that her sleep period may not have been continuous.[69]

The first officer reported that she did not think she was fatigued after her rest period at Apia. The other aircraft occupants did not report noticing anything unusual about the first officer's behaviour prior to or during the accident flight.

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[69] The first officer reported she kept her phone on 'silent' when trying to sleep during rest periods, and the review of phone records indicated that the text messages did not appear to be a direct response to any incoming call or text message. She also indicated that she did not always have one continuous period of sleep.

The flight crew recalled that, after the aircraft reached FL 390 during the accident flight, the first officer had a controlled rest. However, the exact time and duration could not be determined. The first officer noted that having a controlled rest was normal practice on long flights and it did not mean that she was fatigued or lacking sleep.

On the CVR recording, there were sounds consistent with the first officer yawning three times during the period from 0910 to 0915 UTC. The first officer noted such yawns were not necessarily associated with fatigue, and could be associated with boredom or sitting on long-distance flights and not being able to move around much.

Relationship between the flight crew

The captain and first officer had flown together on many occasions in the previous 12 months, including several international flights and flights to remote aerodromes. They both reported they had a good working relationship and that they had experienced no difficulties when flying with each other.

The captain reported that the first officer provided good support during flight operations, and that if she was concerned about anything she would communicate those concerns to him. The first officer reported that the captain was inclusive and shared information. She also felt that if she had any concerns then she had no difficulty raising them with the captain. Other first officers also reported that they did not recall having any difficulties communicating with the captain.

Medical personnel

Experience

The doctor joined the air ambulance provider in July 2009 and he completed seven tasks on a Westwind aircraft prior to the 17–18 November 2009 task. He also undertook tasks with the air ambulance provider on its helicopters. For that role, he had completed a helicopter underwater escape training (HUET) course.[70]

The flight nurse joined the air ambulance provider in January 2008 and she completed many tasks on Westwind aircraft prior to the 17–18 November 2009 task, including five tasks in 2009. She had also undertaken several tasks with other fixed-wing air ambulance operators. She had undertaken a HUET course as part of a university course.

Both of the medical personnel reported that their HUET training had helped them prepare for the evacuation from the aircraft.

Both of the medical personnel had received familiarisation training from the aircraft operator on the Westwind aircraft, but they had not received emergency procedures training or checking as outlined in Civil Aviation Order (CAO) 20.11 (see *Emergency procedures training and checking*).

Recent history

The medical personnel reported that on the outbound flights on 17 November 2009 they obtained some sleep on the aircraft. However, it was not good quality sleep.

After they had breakfast at the hotel in Apia on 18 November 2009, the medical personnel arranged to visit and assess the patient at her house, before returning to the hotel for a rest. However, it took a significant time to reach the patient at her house. After they met the patient and provided some pain relief and other medical care, it was apparent the original plan of returning later to pick up the patient would not be efficient. Instead, they travelled back to the hotel with the patient and the patient's husband. They set up the patient in a hotel room and took turns monitoring her condition. The doctor and flight nurse each obtained about 30–45 minutes sleep in

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[70] HUET training exposes trainees to simulated helicopter ditching and controlled underwater escape exercises. The training is conducted in simulated dark conditions and with simulated failed or obstructed exits.

another room before it was time to go to the hotel lobby and meet the flight crew. They each had a meal prior to leaving the hotel.

For the return flights, the medical personnel agreed that the flight nurse would rest on the flight from Apia to Norfolk Island and the doctor would rest on the flight from Norfolk Island to Melbourne. The nurse reported getting a limited amount of sleep on the accident flight.

Aircraft information

General information

The Israel Aircraft Industries (IAI) Westwind 1124A (Figure 1) is a medium size twin-engine business jet, certified in the transport category as a two-pilot aircraft. Depending on the installed seating configuration, the aircraft can carry up to 10 passengers. The cabin could also be configured for executive seating and other specialised roles, such as air ambulance and freight flights.

The aircraft was fitted with two Garrett AiResearch TFE-731 turbofan engines. The cabin was pressurised and the aircraft's maximum operating altitude was 45,000 ft.

The Westwind 1124A aircraft was approved (type-certified) by the Israeli Civil Aviation Authority in December 1979 and the US Federal Aviation Administration in April 1980. The 1124A evolved from a previous series of aircraft, including the 1121 (certified in the US in 1964), the 1123 (certified in Israel and the US in 1971) and the 1124 (certified in Israel and the US in 1976). The certification basis for the 1124A included US Civil Aviation Regulation 4b effective 31 December 1953, as well as some amendments and additions. The aircraft type was certified for a ditching (see *Aircraft certification for ditching*).

The 1124 and 1124A are very similar. Although the engines remained the same, a number of aerodynamic modifications enhanced the 1124A's performance, such as a new leading edge profile for the wing and the installation of winglets on the wing tip tanks. When compared to the 1124, the 1124A had an improved specific fuel consumption, higher initial cruise altitude capability and increased range. The modification to the leading edge of the wing also marginally increased the capacity of the aircraft's main fuel tanks.[71]

VH-NGA was a Westwind 1124A, manufactured in 1983 (serial number 387) and placed on the US civil aircraft register. In 1989 the aircraft was imported into Australia and issued with an Australian certificate of airworthiness and certificate of registration. At the time of the accident, it had accumulated 21,528 airframe hours and conducted 11,867 landings.

Aircraft maintenance

The aircraft was maintained as a Class A aircraft in accordance with a CASA-approved system of maintenance (SOM). A review of the aircraft's maintenance records indicated there were no deferred maintenance entries in the aircraft's logbook or technical loose leaf log.

Following the accident, CASA conducted a special audit of the operator. During this audit, the operator's Westwind pilots advised CASA they often reported aircraft defects via informal means rather than entering defects into an aircraft maintenance log (AML). CASA's review of maintenance records, including the records for VH-NGA, confirmed the pilots' reports. It noted defects were often entered into maintenance records by maintenance personnel that had not been entered into the AML. CASA also found general evidence that the aircraft being maintained at Nowra, such as VH-NGA, were being maintained to an acceptable standard.

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71 The modification of the wing that increased the aircraft's fuel capacity applied to 1124A aircraft with a serial number of 355 or higher.

Westwind pilots advised the ATSB that aircraft defects, whether reported formally or informally, were generally attended to and rectified by maintenance personnel. The pilots did not express any concern regarding the general standard of maintenance of the aircraft.

Fuel system

Fuel specification

The aircraft was certified to use commercial aircraft turbine fuels including JET A-1.[72]

Fuel storage

The aircraft's fuel system included:

- four fuselage tanks (upper and lower tank on each side)
- six wing tanks (centre, inboard and outboard tank each side)
- two wing tip tanks.

The fuselage and wing tanks on each side were interconnected, and they were collectively known as the 'main tanks'. The wing tip tanks were commonly known as the 'tip tanks'.

The fuel tanks on the left side provided fuel for the left engine, and the fuel tanks on the right side provided fuel for the right engine.

Table 16 shows the usable fuel capacity of the main tanks and the tip tanks for 1124A aircraft with a serial number of 355 or higher (including VH-NGA). It also shows the equivalent weight of the fuel. The aircraft's fuel quantity gauges indicated the amount of fuel in pounds (lb). The aircraft manufacturer used a specific gravity (SG) value of 6.7 lb/US gallon in the Airplane Flight Manual (AFM), which equated to 0.803 kg/L. The operator reported it normally used an SG value of 0.790 kg/L.[73]

Table 16: Usable fuel capacity of Westwind 1124A fuel tanks (serial number 355 and higher)

	Volume		Weight (SG = 0.803 kg/L)		Weight (SG = 0.790 kg/L)	
	US gal.	Litres (L)	lb	kg	lb	kg
Main tanks	1,098	4,156	7,356	3,337	7,238	3,283
Tip tanks	226	856	1,514	686	1,491	676
Total (full fuel)	1,324	5,012	8,870	4,023	8,729	3,959

Westwind 1124 aircraft, and Westwind 1124A aircraft with a serial number less than 355, had main tanks with a capacity of 24 US gallons (91 L) less than the figures in Table 16. This equated to:

- 7,196 lb for full main tanks and 8,710 lb for full fuel (using an SG of 0.803 kg/L)
- 7,080 lb for full main tanks and 8,569 lb for full fuel (using an SG of 0.790 kg/L).

All the operator's other Westwind aircraft, including another 1124A, had the smaller capacity main tanks.

The aircraft was refuelled using a single-point pressure fuelling system.

The Westwind 1124A AFM stated the maximum permitted imbalance between the left tanks and the right tanks was 300 lb for take-off and landing and 800 lb during cruise. If required, the fuel in each side could be balanced by opening interconnect valves in the lower fuselage tanks. Opening

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[72] The other approved turbine fuels were either not normally available outside of North America, specialised fuel blends for cold weather operations ('wide-cut fuel') and other turbine fuels of a military standard specification. The AFM also indicated that aviation gasoline could be used as an emergency fuel, subject to operational and maintenance limitations.

[73] The operator's OM stated flight crew were required to use an SG of 0.78 kg/L or 1.78 lb/L (which equated to 0.81 kg/L).

the valves would distribute the remaining fuel evenly between the left and right sides while operating in coordinated (balanced) flight. These valves were operated by a control switch located on the fuel system control panel.

Normally the interconnect valves would be closed. The normal pre-flight checklist required the fuel balance to be checked and the interconnect valves set to the CLOSED position. Similarly, the normal descent checklist required the fuel balance to be checked and the interconnect valves set to the CLOSED position.

Information about the tip tanks included:

- There was a tip tank manual fuel fill valve located underneath each wing, close to the wing tip. When the valves were in the UP position, they prevented fuel from moving from the outboard wing tank into the tip tank. To add fuel to the wing tip tanks during refuelling, the manual fuel fill valve needed to be pulled to the DOWN position. If only full main tanks (or less) was required, then the valves were left in the UP position.
- Westwind pilots reported that, except where they commonly refuelled at Sydney and Darwin, refuellers generally did not know that the manual fuel fill valves had to be pulled down to add fuel to the tip tanks. Therefore, in most locations it was the flight crew's responsibility to pull the valves down if more than full main tanks was required.
- During flight, fuel was automatically transferred from the tip tanks to the outboard wing tanks as soon as capacity was available in the wing tanks. The first half of each tip tank drained under the effect of gravity and the remaining fuel was transferred by the tip tank jet pump.[74] The manual fuel fill valves prevented fuel from flowing from the wing tanks back into the tip tanks.
- When there was fuel in the tip tanks, a 'fuel in tip tank' light was illuminated on the centre instrument panel in the cockpit. If there was no fuel in the tip tanks, the light was extinguished.

Fuel quantity indicating system

The fuel quantity indicating system measured the weight of usable fuel on board the aircraft. A fuel capacitance probe was located in each side's lower fuselage tank, inboard wing tank, outboard wing tank and tip tank. A change in the fuel level caused a change in the capacitance of the probes, which sent signals to the fuel quantity indicators. The system also included compensators that automatically adjusted the gauge indications to account for changes in fuel temperature.

There were two fuel quantity indicators (or gauges), one for each side. They were located on the centre instrument panel. Figure 11 shows the gauges installed on VH-NGA. As indicated in the figure, each gauge had markers at 200-lb intervals up to 4,800 lb. When the TIP TANK pushbutton was pressed, the gauges showed the amount of fuel remaining in the tip tanks only.

Figure 11: Fuel quantity gauges on VH-NGA

Source: Pel-Air Aviation. Each reading shows the amount of fuel in lb, with each indication needing to be multiplied by 100. The gauges in this figure are indicating 600–650 lb per side, or a total of about 1,300 lb. This image was taken on 29 August 2009 and provides the best quality image available of the fuel quantity gauges fitted to VH-NGA.

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74 A three-position (OPEN/AUTO/CLOSED) fuel transfer valve controlled the fuel pressure supplied to operate tip tank jet pumps. In the AUTO position, the transfer of the remaining tip tank fuel to the outboard wing tank was automatically controlled.

US certification regulations required that the fuel quantity be calibrated to read 0 lb during level flight when the quantity of fuel remaining in the tank was equal to the amount of unusable fuel. The regulations also required that this requirement be published. Accordingly, the AFM included the following note:

> Fuel remaining in the tanks when fuel quantity indicator reaches zero, is not usable in flight.

Fuel level low warning system

Two low-level float switches were located in the left and right lower fuselage fuel tanks. When the fuel quantity in the left or right fuel tank was below 415 ± 25 lb, the switch closed and illuminated the FUEL LEVEL LOW warning light located on the annunciator panel.[75] The annunciator panel was located on the centre instrument panel.

The low-level warning system was independent of the fuel quantity gauges. A low-level warning did not produce an auditory alert.

The 1124A AFM provided checklists for emergency and abnormal procedures. These procedures were also included in a Quick Reference Handbook, located on the aircraft. The abnormal procedure for a FUEL LEVEL LOW warning light stated:

> Illumination of the FUEL LEVEL LOW light indicates low fuel quantity (425 lb) or less in either left or right fuel tank.
>
> 1. Fuel quantity and balance – CHECK
> 2. Fuel TRANSFER switch – CLOSED
> 3. FUEL INTERCONNECT VALVE switch – AS REQUIRED
> 4. LAND AS SOON AS POSSIBLE.

None of the required actions were immediate action memory items.[76]

Fuel flow indicating system

A fuel flow transmitter was installed on the side of each engine. Each transmitter measured the fuel flow rate downstream of the engine's fuel control system. The transmitters sent signals to the fuel flow indicators (or gauges).

There were two fuel flow gauges, one for each engine. They were located on the centre instrument panel, above the fuel quantity gauges. Figure 12 shows the fuel flow gauges installed on VH-NGA. As indicated in the figure, each gauge had markers at 50 lb/hour intervals.

Figure 12: Fuel flow gauges on VH-NGA

Source: Pel-Air Aviation. Each reading shows the fuel flow in lb/hour, with each indication needing to be multiplied by 100. This image was taken on 29 August 2009 and provides the best quality image available of the fuel quantity gauges fitted to VH-NGA.

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75 The switch closed when the volume in the tank reduced to 62 US gallons, which equated to 415 lb at an SG of 0.803 kg/L. Variations in the SG of the remaining fuel would have a small influence on the fuel's volume and therefore when the switch closed.

76 The manual stated that actions framed with a red border were 'immediate action memory items', which meant that flight crews had to be able to perform them without referring to the checklist. Some other abnormal procedures (such as engine failure during take-off, single engine go-around) contained immediate action memory items.

Based on his experience, the captain believed that the fuel flow gauges were quite accurate.

Fuel status indicating system

The fuel status indicating system received inputs from the fuel quantity gauges and the fuel flow gauges. An indicator panel provided a digital display of the fuel status. Flight crew could select whether the system displayed the fuel remaining or the fuel consumed.

For all 1124 or 1124A aircraft with serial number 309 or later,[77] including VH-NGA, the fuel status indicating system obtained the fuel remaining figure by continually sampling data from the fuel quantity gauges. In other words, it displayed a figure that was the sum of the figures on the two fuel quantity gauges.[78] The fuel consumed figure was based on the sum of inputs from the fuel flow gauges. Pressing a reset button would reset the fuel consumed figure to 0 lb.[79]

The fuel status indicator panel was originally located on the centre instrument panel, to the left of the fuel quantity gauges. On VH-NGA the indicator panel was moved to the lower, far-left of the instrument panel in August 2009 in order to allow for the fitment of other displays.[80] In this location, the fuel status indicator would not have been easy to read from the first officer's position.

The captain reported he would use both the fuel quantity gauges and the fuel status indicator's functions during a flight to gain an appreciation of the fuel on board. He said that on some aircraft the fuel status indicator was accurate and on other aircraft it was inaccurate. He recalled that, during the accident flight, the indicator's fuel remaining function was initially displaying about 200 lb less than the total of the fuel quantity gauges, and this difference decreased as the flight progressed. For the accident flight in VH-NGA, he had more confidence in the fuel quantity gauges than the fuel status indicator.

The Westwind standards manager noted fuel quantity gauges and fuel flow gauges could have errors. For older Westwind aircraft, the fuel remaining function could therefore be subject to errors from either fuel quantity gauge or either fuel flow gauge. For later Westwinds, such as VH-NGA, the fuel remaining function did not have the same potential for error as it was only based on the fuel quantity gauges.

Fuel system maintenance

In terms of fuel system maintenance, the operator reported that its approved SOM was based on the aircraft manufacturer's instructions. The SOM included functional checks of fuel control valves and the fuel dump system. There was no requirement for a scheduled check of the fuel quantity indicating system or the fuel flow indicating system. In other words, these systems were only checked if a problem was reported or if a relevant component was being repaired or replaced.

Table 17 lists aircraft maintenance events related to VH-NGA's fuel quantity indicating system, fuel flow indicating system and fuel status indicating system during the period from September 2008 to November 2009.

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[77] The 1124 and 1124A shared the same serial number range.

[78] Although the fuel status indicating system indicated fuel quantity in multiples of 10 lb, the indicating tolerance applied when calibrating the fuel status indicating system was about ± 50 lb.

[79] For 1124 or 1124A aircraft with a serial number of 308 or earlier, the fuel status indicating system operated differently. The fuel remaining figure was initially sampled from the fuel quantity gauges, and then derived from the initial fuel remaining figure minus the fuel consumed figure (based on the sum of inputs from the fuel flow gauges). The fuel remaining function could be reset during flight to again sample from the fuel quantity gauges. Some of the operator's Westwind fleet had the older system and some had the newer system.

[80] The relocation of the fuel status indicator panel was completed under provision of an engineering order, authorising the panel's relocation.

Table 17: Maintenance activities related to fuel quantity and fuel flow indications on VH-NGA

Maintenance date	Event
11 Sep 2008	Pilot reported (5 Sep 2008) 'fuel gauges inaccurate', with details indicating that the left gauge was indicating more fuel than the right gauge. Maintenance recorded that adjustments were made to the fuel quantity indicators. Pilot also reported the fuel flow status indicator readings were erratic and the display had segments missing. Maintenance recorded that the status display was removed, repaired (by external contractor), tested satisfactorily and reinstalled.
3 Dec 2008	Pilot requested (1 Dec 2008) a fuel quantity gauge calibration. The reason was not recorded. Maintenance recorded that a 'dry' fuel quantity gauge calibration was conducted satisfactorily.
3 Aug 2009	Wing tanks inspected for leaks, rivets repaired. Fuselage bladder tanks inspected for leaks, and all four tanks replaced.[81] This included a 'dry' fuel quantity gauge calibration and a check of the FUEL LEVEL LOW warning system.
18 Sep 2009	Pilot reported (11 Sep 2009) that the left fuel quantity gauge underread by up to 800 lb when tank was full. Maintenance recorded that an indicator test was conducted, the left-side lower fuselage tank fuel probe was replaced, and a 'wet' fuel quantity gauge calibration was conducted satisfactorily. Pilot also reported right fuel flow gauge dropped to about 300–400 lb/hour, fluctuated and then returned to normal. Maintenance recorded that several ground runs were conducted and no fault was found.
14 Oct 2009	Pilot reported (9 Oct 2009) fuel quantity gauges were underreading. Maintenance recorded that the gauges were calibrated. The maintenance record referred to the work completed as an 'indicator test'.

As indicated in Table 17, the fuel quantity gauges on VH-NGA were last subject to maintenance activity on 14 October 2009, and they had been calibrated three other times in the previous 12 months. The operator reported the frequency of such maintenance activities was similar to that for other Westwind aircraft in its fleet.

The aircraft manufacturer stated the fuel quantity gauges, when appropriately calibrated, were accurate to within ± 5 per cent. It also noted it was possible for the fuel quantity gauges to underread by a constant amount throughout the full range of the gauges, including at an indicated value of 0 lb. This would occur if, during the calibration process, the adjustment for the 0 lb indication was incorrect.

According to the manufacturer's *Aircraft Maintenance Manual* (AMM), fuel quantity gauge calibrations could be conducted using two different types of equipment. The operator conducted its calibrations using the Barfield 2548-GA Tester. According to the AMM, the process involved conducting an indicator test, insulation test, capacitance test and then a calibration. There were two types of calibration:

- A 'dry' calibration method was conducted without fuel in the tanks and, consequently, the capacitance probes were dry. This enabled the 0 lb gauge indication to be set to the actual capacitance value of the aircraft's fuel probes when the tanks were empty. The test equipment substituted a capacitance equivalent for full fuel and the fuel quantity indicator was adjusted to display full fuel. Capacitance values could also be substituted for intermediate tank quantities.

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81 The operator reported that, based on its experience, the bladder tanks in the fuselage deteriorated over time and it was common practice to remove them during heavy maintenance tasks. In this case, VH-NGA had been removed from line service for an extended period of time for other maintenance work, and engineers used the downtime to remove and inspect the bladder tanks.

- A 'wet' calibration method was conducted with the existing fuel in the tanks and the capacitance probes isolated from the fuel quantity indicating system. This procedure used simulated capacitance values for both empty and full fuel indications.

The AMM stated a dry calibration was the preferred method. It also stated:

> The preferred [dry method] calibration requires that the fuel tanks be drained.[82] If time or facilities are not available for draining, the alternate calibration … [wet method] may be substituted. This should only be used as a temporary measure, and the preferred method employed at the earliest convenience.

An indicator test involved a similar process to a wet calibration. It examined the response of the fuel quantity gauges to simulated inputs, and enabled the gauges to be adjusted in response to such inputs. As with a wet calibration, it did not check the accuracy of the gauge readings in response to actual inputs from the aircraft's fuel probes.

A licenced aircraft maintenance engineer from the operator reported a dry calibration was known to produce more accurate results than a wet calibration. A dry calibration was the preferred method, provided there was time to complete the method.

The AMM also contained a procedure to calibrate the fuel flow indicating system. The operator advised that the fuel flow indicating system on VH-NGA was last calibrated in April 2007.

The FUEL LEVEL LOW warning system was last checked in August 2009. The AMM check of the warning system involved removing fuel from the left fuel tank until the light illuminated, and checking that the left fuel quantity gauge read about 415 lb (± 25 lb). The process was then repeated for the right tank.

Review of flight records to evaluate the accuracy of the fuel quantity gauges

On the CVR recording, at 0909:04 UTC, the crew stated the fuel quantity gauges indicated a total fuel on board of about 2,000 lb prior to refuelling at Apia. The amount of fuel added at Apia to get full main tanks was 2,780 L. Based on the specific gravity of the added fuel, the fuel added was estimated to be about 4,810 lb and the total fuel on board (for full main tanks) was estimated to be 7,190 lb (appendix E). Therefore, the amount of fuel on board prior to refuelling was estimated to be about 2,380 lb, suggesting that the fuel quantity gauges were underreading by about 380 lb prior to refuelling.

The captain also recalled that the fuel quantity gauges were indicating about 6,800–6,900 lb after the aircraft was refuelled to full main tanks at Apia, which suggested the gauges were underreading by about 300–400 lb when the main tanks were full.

In addition, the captain reported that, during the outbound flights on 17 November 2009, he had reviewed the aircraft's flight record sheets for recent flights where the aircraft had been refuelled to full main tanks. He found that the fuel quantity gauges appeared to be underreading on those flights by about 300 lb.

The ATSB reviewed VH-NGA's flight records for previous flights to compare recorded fuel quantities prior to refuelling with estimated fuel quantities (appendix F). There was some variability in the results due to a range of factors. Nevertheless, it was apparent that there were changes in the fuel quantity gauge readings following gauge calibrations or related maintenance actions.

In terms of the flights since the last maintenance action of the fuel system (14 October 2009):

- There were 10 relevant flights that could be used for comparisons (23 October to 18 November 2009).

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[82] Instructions for defuelling the aircraft was contained in the AMM. That procedure included disconnecting an engine's main fuel flex hose and attaching it to a defuelling hose. External power was then connected to the aircraft and used to operate the engine's fuel boost pump, transferring fuel from the aircraft's tank(s) to the defuelling receptacle/tank.

- The average difference between the recorded and estimated fuel on board was about -260 lb (underreading).
- The amount of underreading did not decrease as the fuel on board decreased.

The estimated amount of underreading on the accident flight (-380 lb) was more than the average for the previous nine flights (-240 lb). There was no known change in the aircraft's fuel system that would suggest that the amount of underreading should have increased for this flight compared to the other flights since the last calibration. Therefore, it was concluded that the best estimate of the underreading since the last maintenance activity was about 260 lb.

The last maintenance action, on 14 October 2009, was recorded as an indicator test (which was similar to a wet calibration). A review of the flight records for previous periods indicated that, when a dry calibration was conducted in December 2008, subsequent fuel gauge readings were more accurate, particularly as the fuel remaining approached 0 lb (appendix F).

At the time the FUEL LEVEL LOW warning light was last checked on VH-NGA (August 2009), a dry calibration of the fuel quantity indicating system had recently been conducted, and the fuel gauges appeared to be relatively accurate.

A review of flight records for the operator's other Westwind aircraft identified that these aircraft appeared to have a smaller difference between the recorded fuel on board and the estimated fuel on board.

The ATSB requested fuel quantity indicating system maintenance records for two of the operator's other Westwind aircraft that were generally maintained at the same base as VH-NGA during 2008–2009. Across the two aircraft, there were four maintenance activities where some form of calibration was conducted. There was no indication of a problem similar to that involving VH-NGA following the maintenance conducted after 9 October 2017 (see appendix F).

Review of flight records to evaluate the accuracy of the fuel flow indicators

Both flight crew recalled that the total fuel flow after the aircraft was established in cruise at FL 390 was 1,100 lb/hour (or 550 lb/hour for each engine). The ATSB fuel analysis estimated that the fuel flow was probably about 1,310 lb/hour (appendix E). Therefore, the crew's recalled fuel flow figure was about 16 per cent less than the estimated fuel flow.

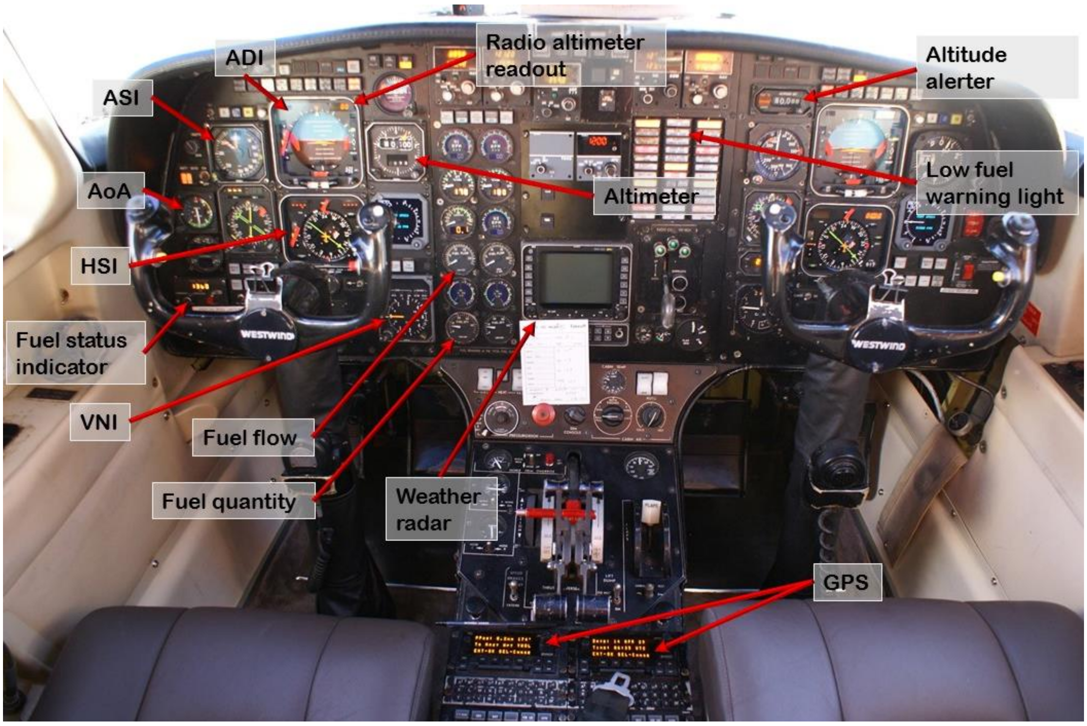
The ATSB reviewed the aircraft's flight records for previous flights to compare recorded fuel flows with estimated fuel flows based on flight crews' manual recording of engine trend monitoring data. There was significant variability associated with the estimated fuel flows. However, there was sufficient evidence to conclude that the aircraft's fuel flow indicators were consistently underreading. Although the amount of underreading could not be reliably established, the difference reported on the accident flight was within the range of values estimated for previous flights.

A review of records for the operator's other Westwind aircraft identified these aircraft had less difference between recorded and estimated fuel flows.

Flight instruments, navigation and autoflight systems

Figure 13 shows the layout of VH-NGA's cockpit, depicting the location of relevant instruments and systems.

Figure 13: Photograph of VH-NGA cockpit taken September 2009, annotated with various instruments, annunciators and displays



Source: Pel-Air Aviation, annotated by ATSB.

Flight instruments

Each crew member had an attitude director indicator (ADI) that provided a three-dimensional display of aircraft attitude and flight control steering commands, localiser and glideslope deviation, radio altitude and speed command.

Each crew member also had a horizontal situation indicator (HSI) that was directly below each ADI and provided a plan view of the aircraft's navigation situation. The captain also had a vertical navigation indicator (VNI) that displayed the vertical speed of the aircraft,[83] and which also displayed other parameters for vertical management of the aircraft's flight path (see *Autoflight system)*.

Westwind 1124A aircraft were fitted with a combined display indicating Mach[84] and airspeed. The AFM noted a small position and instrument correction is applied to the indicated Mach number when calculating the true Mach number, with the indicated Mach slightly overreading. The correction applied to calculate the true Mach number depended on altitude and indicated Mach number, but ranged from -0.014 to -0.018.[85]

At cruising altitude, the maximum operating speed for the Westwind 1124A was Mach 0.785 (Mach 0.80 indicated). The AFM for the Westwind 1124 indicated there was no correction required

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83 In addition to the VNI, the aircraft's vertical speed was also indicated on the display of each crew member's Traffic Alert and Collision Avoidance System.

84 Mach is a number expressing the ratio between the true airspeed and the local speed of sound. It is used to express the speed of the aircraft during high speed/altitude flight. The local speed of sound in air varies as a square root of absolute temperature. Under standard sea-level conditions, the speed of sound is 661 kt (1,225 km/h) and in the troposphere, progressively reduces with increasing altitude. Under standard conditions at 36,089 ft (the tropopause), the local speed of sound is 574 kt (1,063 km/hour).

85 The Mach correction tended towards 0.014 at altitudes below FL 200 and at lower Mach numbers. As the Mach number increased towards 0.70 the correction approached 0.018. When rounded to two significant figures, the correction was closest to 0.02 Mach.

between indicated and true Mach numbers, and the maximum operating speed was Mach 0.765.[86]

In addition to the conventional cockpit flight instruments (such as Mach/airspeed indicator, vertical speed indicator, altimeter), VH-NGA was also equipped with an indicator that displayed true airspeed, total air temperature and static air temperature.

Angle of attack indicator

An angle of attack (AoA) indicator was situated on the far left of the cockpit instrument panel. The position of the indicator on the left side of the cockpit (Figure 13) made it impractical for the first officer to read.

The captain could set a target speed on the left side of the AoA indicator display (in terms of a multiple of stall speed, for example 1.3 V_S). The indicator would display the current AoA and an indicator bug referencing the target AoA to achieve the selected target speed. This was particularly useful for emergency landing situations, such as a ditching (see *Ditching procedures and guidance*).

In addition to the AoA indicator, each crew member's ADI included a fast/slow speed indicator, referencing the aircraft's current speed to the target AoA. There was also a fast/slow speed indicator display mounted on the glare shield of the captain's instrument panel.

Stall warning system

The aircraft was not equipped with an aural stall warning system. Flight crew warning of an approaching stall was provided by an increasing AoA indication on the cockpit display and aerodynamic pre-stall airframe buffeting.

The tactile nature of the pre-stall buffeting, in accordance with certification regulations, did not require an aural stall warning system to be fitted to the aircraft. Similarly, the aircraft's aerodynamic pre stall handling and stall recovery qualities were such that neither a stick shaker tactile stall warning device, nor stick pusher stall recovery system, were required.

Autoflight system

The aircraft was fitted with an autoflight system (or 'flight control system') that comprised a flight computer system, autopilot system, yaw damper and various system sensors. The autopilot could provide steering commands in response to the flight director or crew input. The autopilot system and yaw damper could control the aircraft in the axes of pitch, roll and yaw.

The VNI installed on the captain's instrument panel provided an interface for the flight crew to manage the aircraft's vertical flight path. That included automatic flight path capture at a selected angle, automatic flight path capture at a selected vertical rate or manual flight path capture direct to an aim point.[87]

The AFM stated the autopilot was not to be used during take-off or during landing below the Category 1 [ILS] landing minima.[88]

The operator's Sydney-based Westwind pilots reported that for many years it had been common practice to not use the autopilot below FL 200. The Westwind standards manager reported the

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86 The aircraft manufacturer reported there were differences in the air data computer and avionics system of the 1124 and the 1124A. During the development of the 1124, flight testing identified that the Mach indications were accurate. However, during the development of the 1124A, flight testing identified that Mach indications were overreading.

87 The AFM indicated that the vertical guidance mode may not be used as a primary means of altitude control and may not be used during climb. The VNI could compute flight paths that exceeded the limitations or performance capabilities of the aircraft. It was the flight crew's responsibility to ensure such limits were not exceeded.

88 A Category 1 (CAT 1) instrument landing system runway approach has a decision height not lower than 200 ft and a visibility either not less than 800 m or a runway visual range not less than 550 m.

autopilot was fully capable of controlling the aircraft at lower levels. He noted the normal practice was associated with ensuring pilots maintained adequate manual handling skills. It was also associated with the operator's concern that the autopilot system did not provide an aural warning when the autopilot disconnected.[89] There was no formal policy in the OM regarding when or when not to use the autopilot.

GPS receivers

The aircraft was fitted with a II Morrow Apollo Navigation Management System (NMS). The system comprised two independent Apollo 2101 Navigation Management Computers (NMCs), each with an Apollo 2102 keypad and GPS sensor. The Number 1 NMC received data from an Apollo 2030 fuel/air data sensor and an altitude encoder provided the Number 2 NMC with automatic barometric aiding from the pilot's altimeter. Output from the NMS could be displayed on the flight crew's HSI display and autopilot system using navigation source selectors and annunciators.

The system was approved for IFR en route oceanic and remote, en route domestic, terminal and non-precision approach operations and as a supplemental aid for flight under the VFR.

The operator reported that, although the aircraft's systems could technically be used to conduct RNAV-GNSS approaches, it did not think they were suitable for such approaches due to ergonomic issues when using the installed equipment. Accordingly, it elected not to train or approve pilots to conduct RNAV-GNSS approaches in its Westwind aircraft.

In addition to navigation information, the installation of the Apollo 2030 fuel/air data sensor also enabled the NMS to display advisory, non-navigation information. That information included:

- true and indicated airspeed
- air temperature
- density and pressure altitude
- magnetic heading
- true and magnetic wind direction and wind speed.

The aircraft maintenance records indicated the international navigation database cards for both GPS receivers were updated on 20 October 2009.[90]

Radio navigation system receivers

The aircraft was fitted with two radio navigation system receivers, which included capability to receive signals from VOR and DME ground stations. The VOR/DME ground stations transmitted signals that represented the aircraft's magnetic radial and distance from the navigation aid. The flight crew selected the relevant ground track to or from the VOR ground station they intended to use for navigation and the track information was displayed on the HSI. The track information from the VOR could also be used as an autopilot input to automatically fly the aircraft along the selected course.

Barometric altimeters

The aircraft was fitted with two independent barometric altimeters. The altimeters were counter drum pointer types that indicated the height of the aircraft above the pressure datum selected by the crew.

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89 An autopilot disengaged warning light was included with a series of autoflight status lights, which were situated on the cockpit panel, immediately above each crew members' ADI. At the time the aircraft was certified, there was no regulatory requirement for an autopilot system to provide an auditory alert when it was disconnected.

90 The navigation data was updated by the vendor on a 4-weekly cycle. The data contained on the cards installed to the GPS receivers of VH-NGA were cycle 0911, effective 22 October 2009. The next cycle 0912 was effective 19 November 2009 and would have been available on the download server from approximately 09 November 2009.

When set to the aerodrome QNH, the altimeters indicate the aircraft's height above mean sea level in the standard atmosphere. The CVR recording confirmed that, during the descent to Norfolk Island on 18 November 2009, the crew verified the correct setting of the aerodrome QNH during the descent and the altimeter indications were cross-checked.

Significant temperature deviations from the standard atmosphere can cause the indicated altitude to deviate from the true altitude. If the temperature is significantly warmer than standard, the altimeter will underread and if significantly cooler than standard, the altimeter will overread. The temperature at Norfolk Island at the time of the aircraft's arrival was slightly above the standard temperature, with a resultant error of less than 10 ft.

Radio altimeter

A radio altimeter system augmented the information provided to the flight crew by the barometric altimeters, indicating the aircraft's vertical height above terrain and water, from ground level to 2,500 ft. This information was displayed on a four-digit digital display on the top right corner of each crew member's ADI. The height above terrain was depicted in 10-ft increments between ground level and 1,000 ft, and 50-ft increments between 1,000 and 2,500 ft.

Decision heights could be set by the flight crew in 10-ft increments between 0 and 950 ft. When the aircraft descended to the decision height selected by the crew, an annunciator illuminated on the top left corner of each crewmember's ADI. The enhanced ground proximity warning system (EGPWS) also provided a 'minimums' aural advisory callout, indicating that the selected decision height had been reached.

Altitude alerter

An altitude preselector alerter system was available to alert the flight crew when the aircraft was approaching or deviating from the selected altitude. On VH-NGA, the altitude preselector panel was located just below the glareshield on the first officer's instrument panel and comprised an altitude selector knob,[91] a display to indicate the selected altitude and an amber button light.

The button light illuminated steady when the aircraft was within 1,000 ft of the selected altitude, and it would extinguish when the aircraft was within 300 ft of the selected altitude. After the button light extinguished within 300 ft of the selected altitude, an audible alert tone would sound and the button light would flash if there was more than 300 ft difference between the selected and aircraft altitude. Pushing the amber button light cancelled any active alert. The altitude preselector alerter was barometrically corrected for the subscale setting on the altimeter.

Part A of the operator's OM indicated flight crews were required to use the altitude alerter. During an instrument approach and after the aircraft had passed the initial approach fix, the next altitude restriction was to be selected on the preselector panel. This procedure was repeated until the aircraft reached the appropriate MDA. If the flight crew was visual, the aerodrome elevation could be set. If the aircraft was not visual at the missed approach point, the missed approach altitude was to be selected.

Weather radar

The aircraft was equipped with a single Collins WXR-300 colour weather radar with additional functionality to also display navigation data. The system comprised a single radar receiver-transmitter, a single antenna and a single cockpit display. Any rainfall ahead of the aircraft reflected some of the transmitted radar pulses back to the aircraft.

The flight crew could incrementally adjust the antenna tilt between -10 and +10°, enabling interpretation of the vertical development of any precipitation ahead and its relationship to the aircraft's projected flight path. The strength of the radar return depended on the droplet size and precipitation intensity. That information was colour coded and displayed to the crew on the cockpit

[91] The target altitude could be adjusted in 1,000 and 100 ft increments.

display. The display range could be adjusted in increments between 10 and 300 NM. Correct use of the radar controls and interpretation of the information enabled crews to identify and avoid areas of heavy precipitation and the turbulence associated with convective weather such as cumulonimbus cloud.

The weather radar could also be used in a mode to detect and map radar returns from the ground. That technique could be helpful in identifying coastal features or other terrain/obstacles ahead with unique radar-reflecting characteristics. Similarly, when operating in mapping mode, the strength of the reflected radar return was colour coded, depending on the reflectivity of the ground/terrain.

Enhanced ground proximity warning system

System overview

The aircraft was fitted with a Honeywell Mk VIII Enhanced Ground Proximity Warning System (EGPWS). The operator installed the EGPWS, as well as Rockwell Collins Traffic Alert and Collision Avoidance System (TCAS), in VH-NGA in August 2009 in order the facilitate approval for ongoing operations into Noumea (see *Suitable alternate aerodromes for flights to Norfolk Island*). None of the operator's other Westwind aircraft were fitted with an EGPWS, GPWS or TCAS, nor where they required under Australian regulatory requirements.[92]

The EGPWS was a terrain awareness and warning system (TAWS), which provided the basic functions of a ground proximity warning system (GPWS) as well as additional terrain alerting and display features. It used data from the aircraft's GPS, radio altimeter and other systems, as well as a terrain and airport database. It provided the flight crew advice regarding when the aircraft descended too low in terms of its position relative to the airport and its surrounding terrain.

In addition, the EGPWS included a terrain alerting and display (TAD) function that, when selected, provided a graphical colour-coded representation of the surrounding terrain on the aircraft's weather radar display. Selection of the TAD function was by a push-button terrain display switch, located on the centre cockpit panel. The TAD did not display automatically, nor did it overlay images generated by the weather radar. The TAD used colour and intensity variations to depict terrain/obstacle height relative to the aircraft's reference altitude. The elevation of the highest and lowest terrain was also depicted, although terrain was not shown when it was within 400 ft of the elevation of the nearest runway.[93]

The EGPWS continuously calculated terrain clearance envelopes ahead of the aircraft. When it identified a potential conflict between the aircraft's flight path and the terrain or obstacles ahead, it provided visual and audio alerts:

- A caution alert was triggered if the aircraft penetrated the caution envelope boundary and the TAD simultaneously displayed the conflicting terrain areas or obstacles in a solid yellow colour. The alerts comprised an aural synthetic voice message (appropriate to the caution type) and a flashing amber visual alert on both the captain and first officer's instrument panels. Caution alerts typically provided 40–60 seconds notice of the terrain/obstacle conflict and repeated every 7 seconds for as long as the conflict remained.
- A warning alert was triggered if the aircraft penetrated the warning envelope boundary and the TAD simultaneously displayed the conflicting terrain areas or obstacles in a solid red colour. The alerts included an aural synthetic voice annunciation 'Pull-up' and flashing red visual alert on

92 CAO 20.18 stated turbine-engined aeroplanes with a maximum take-off weight more than 15,000 kg, or carrying 10 or more passengers, could not be operated under the IFR unless they were fitted with a GPWS (and the GPWS was required to have a predictive terrain hazard warning function). Although Westwind aircraft could carry 10 passengers, the operator's operations manual stated flight under the IFR was not permitted if the aircraft was carrying more than 9 passengers.

93 The TAD was intended as a tool to enhance situational awareness. A note in the limitations section of the CASA-approved AFM Supplement indicated the TAD may not provide the necessary accuracy and/or fidelity on which to solely base terrain avoidance manoeuvring.

both instrument panels. Warning alerts typically provided 30 seconds notice of the terrain/obstacle conflict and repeated continuously while the conflict remained.

In addition to the alerts, the EGPWS provided advisory callouts, including:

- A callout of ‘minimums’ when the aircraft’s radio height corresponded to the decision height set by the flight crew.
- A callout of specific heights above ground level. These were normally made when the radio altimeter indicated 500, 200, 100, 50, 40, 30, 20 and 10 ft.

EGPWS warning and caution alerts were prioritised according to criticality, with the warning alerts taking precedence over caution alerts, and caution alerts taking priority over altitude advisory callouts.

The emergency procedures section in the EGPWS AFM supplement stated that, for a ditching, the TAD and other functions should be inhibited by selecting the TERRAIN INHIBIT switch. Inhibiting these functions eliminated the EGPWS terrain awareness warning and cautions alerts, thereby preserving the utility of the altitude advisory callouts and reducing high intensity cockpit noise. The AFM supplement’s section on emergency procedures also indicated the GPWS circuit breaker may be used to deactivate the EGPWS when an emergency procedure in the basic AFM specified landing with the gear up.

The captain recalled that he was aware there was an inhibit button for the EGPWS, but during the ditching he was not concerned about the alerts.

Alerts and callouts recorded on the cockpit voice recorder

The CVR recording included ‘minimums’ callouts and 500-ft callouts during the approaches, indicating that the EGPWS was functioning normally.

During the approach to the ditching, the EGPWS provided the following alerts:

- 1025:06 (52 seconds before impact): ‘too low terrain’ caution alert (one cycle). At that time the aircraft was at an altitude of about 410 ft, directly over the water and 1.3 NM from the threshold of the nearest runway. Following this alert, the altitude increased slightly.
- 1025:20 (38 seconds before impact): ‘too low terrain’ caution alert, repeated 10 times until superseded by a higher priority alert. This alert commenced at about 390 ft, approximately 1.8 NM from the thresholds of the nearest runway.
- 1025:39 (19 seconds before impact): ‘terrain ahead pull up’ warning alert, repeated eight times until impact. This alert commenced at about 160 ft.

The EGPWS caution and warning alerts took priority over the altitude advisory callouts, and therefore there were no altitude callouts during the approach to the ditching.

Radio and communications equipment

The aircraft was equipped with the necessary radio equipment for remote flights in oceanic areas. This equipment included:

- two very high frequency (VHF) aeronautical radios, for air-ground communication
- two high frequency (HF) aeronautical radios, for long-range air-ground communication when outside VHF coverage
- one ultra high frequency (UHF) aeronautical radio, for military air-ground communication.

Propagation of radio waves in the VHF and UHF frequency bands are approximately line of sight under normal conditions (see also *HF radio communications*).

The aircraft’s radio equipment was not equipped with a selective calling (SELCAL) system, nor was there any requirement for that system to be fitted. A SELCAL system enabled ground station operators to call the flight crew of a specific aircraft over aeronautical mobile voice channels. The system utilised audible tones to activate a cockpit call system on the specific aircraft, alerting the crew of an incoming message.

Although SELCAL could assist crews to monitor frequencies with background noise and static (such as HF), the content of the radio messages between the ground station operator and the flight crew were still passed conventionally.

The aircraft was not equipped with other messaging systems, such as aircraft communications addressing and reporting system (ACARS),[94] nor was there any requirement for such systems to be fitted.

The aircraft was not fitted with a satellite phone, nor was there any requirement for it to be fitted.

Aircraft lighting

The aircraft had two landing lights, one fitted in the leading edge of each tip tank. Each light's field of coverage in front of the aircraft was 11° horizontally and 12° vertically, with the lights angled downwards such that the top of the field of coverage was slightly below the horizon when the aircraft was standing on the ground.

The aircraft was also fitted with taxi lights to provide forward illumination when taxiing and to also complement the landing lights to provide illumination of the runway area immediately ahead of the aircraft. The lights were fitted to each main landing gear strut. Each light's field of coverage was 13° vertically, centred around the horizon when the aircraft was standing on the ground. However, the lights were not available when the landing gear was selected UP.

The aircraft also had a range of other external and internal lights.

The emergency lighting system for the cabin is discussed in *Emergency lighting*.

Approach and landing speeds

Reference landing speed

The 1124A AFM defined the reference landing speed (V_{REF}) as the minimum speed at 50 ft above the runway during a normal landing. It stated this speed must not be less than 1.3 times the stall speed (V_{SO}).

V_{REF} is intended to provide adequate margin above the stall, allow for speed variations during approach in light turbulence, and provide manoeuvring capability and adequate control effectiveness/authority to complete the flare and landing. A flight crew can select a final approach speed higher than V_{REF} to account for factors such as wind gusts, windshear, icing or landing configuration (for example, less than full flaps or abnormal configuration). The resulting final approach speed provides the best compromise between handling qualities (stall margin or controllability/manoeuvrability) and landing distance.

The AFM provided a chart to calculate V_{REF} dependent on the aircraft's landing weight. The operator converted this data to a table for easier use by flight crews. The operator's operations manual (OM) also specified various additions to V_{REF} that flight crew could apply for factors such as reduced flap settings and gusts.

The flight crew calculated V_{REF} for the first approach to be 120 kt, and the nominated final approach speed they selected and bugged on the airspeed indicator was 125 kt to allow for possible wind gusts during the approach.[95] There was no subsequent discussion about adjusting the V_{REF} or target speed for subsequent instrument approaches or the ditching.

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94 ACARS: An aircraft communication addressing and reporting system, facilitating radio or satellite communication between an aircraft and ground stations using a digital data link to transmit short messages.

95 This discussion between the crew was recorded on the CVR and it related to their approach/landing the previous evening and the way the wind was swirling/gusting around.

Due to the consumption of fuel and the aircraft's reduced weight, if the crew had recalculated V_{REF} for the approach to the ditching it would have been 116 kt. The stall speed published in the AFM at that weight for flaps 40 and gear down was about 88 kt (calibrated airspeed).[96] Assuming the aircraft manufacturer calculated V_{REF} on the basis of 1.3 times the stall speed, then the indicated stall speed in that configuration would be about 89 kt.

Stable approach criteria

Approach speeds significantly higher than V_{REF} reduced the time available for a flight crew to acquire visual reference with the runway environment and assess the aircraft's relative position to safely complete the remainder of the approach and landing. Flying the approach within specified parameters reduces the risk of approach and landing accidents.[97]

To help achieve stable approaches, operators typically specify stable approach criteria, or limits of airspeed, engine thrust, aircraft configuration, rates of descent and/or displacement from the desired approach path from specified heights. If any of these requirements are not met at or below the specified height, a missed approach is required to be conducted.

The operator's OM stated that, for all aircraft types, if windshear was expected, 'use a stabilised approach speed of not more than Vref +15' when below 500 ft above the airport elevation. In addition, in a section discussing proficiency base checks, the OM stated:

> On a stabilised approach the aircraft should be:
>
> a) On glide path -3°.
>
> b) Correct configuration.
>
> c) Sink rate less than 1000 fpm [ft/minute].
>
> d) Vref +5 / -0 kt.
>
> All the above parameters should be achieved by 200 ft agl [above ground level]. If the aircraft is not stabilised by 200 ft agl, a go-around should be carried out.

In procedures applying to the operator's turboprop aircraft, the OM also stated that, at 400 ft above ground level, the airspeed must not be less than V_{REF} and should not higher than V_{REF} + 20 kt, and the descent rate must be less than 1,000 ft/minute. If the airspeed was not less than V_{REF} + 20 kt at 200 ft above ground level, a go-around must be initiated.

The OM did not specify any stabilised approach criteria for the Westwind. The OM procedures for a Westwind stated that, when crossing the outer marker or at 1,000 ft above touchdown, select flap 40 (full flap) and reduce the airspeed to V_{REF} + 10 kt. When visual, reduce the airspeed to V_{REF} + gust factor (if the gust factor was applicable).

Approach speeds specific to a ditching are discussed in *Ditching procedures and guidance*.

Weight and balance

The relevant structural weights for the Westwind 1124A were:

- maximum take-off weight (structural limit) – 10,659 kg (23,500 lb)
- maximum landing weight (structural limit) – 8,618 kg (19,000 lb)
- maximum zero fuel weight (structural limit) – 7,484 kg (16,500 lb).

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[96] The AFM data did not give the flap 40 stall speed with the landing gear in the UP position. However, the stall speed published for other flap settings did not change, irrespective of the landing gear position. Similarly, the AFM did not provide data to correct calibrated airspeed to indicated airspeed at speeds below about 110 kt. Reviewing the closest available data indicated that, with gear UP at flap 20 and 110 kt indicated airspeed, the airspeed indicator would be over-reading by about 3 kt. That is, at 110 kt indicated airspeed, the calibrated airspeed would be about 107 kt.

[97] Included in ICAO PANS-OPS Doc 8168 – Aircraft Operations, Volume 1 – Flight Procedures. Application of these techniques are also discussed in the Flight Safety Foundation Approach and Landing Accident Reduction toolkit and briefing notes.

The ATSB estimated the aircraft weight and balance based on the available information, including an estimation of baggage, medical equipment and life rafts on board. Based on these estimations:

- The aircraft's zero fuel weight was about 14,640 lb (6,640 kg), which was below the stipulated limit.
- The aircraft's take-off weight at Apia was about 21,700 lb (9,843 kg) which was below the stipulated limit. If the aircraft had been refuelled to full capacity at Apia, it would have still remained below the maximum take-off weight limit.
- There were no performance limits precluding the aircraft from departing Apia at the maximum take-off weight.
- The estimated fuel burn off to Norfolk Island meant there was no landing weight limitation, regardless of the amount of fuel on board at the start of the flight.
- The aircraft's centre of gravity was within the specified limits for the duration of the flight.

Wreckage and impact information

On 29 November 2009 the ATSB located the aircraft wreckage using a sonar receiver to localise the ultrasonic signal emitted from the battery-operated underwater locator beacon attached to the aircraft's flight data recorder (FDR).[98]

During December 2009, and with the assistance of Victoria Police's water police squad, a remotely operated vehicle (ROV) made several dives on the aircraft wreckage. The ROV was equipped with a camera and the dives were video recorded. Analysis of the images indicated:[99]

- The aircraft had separated into two sections (Figure 14 and Figure 15), the forward fuselage separating from the rest of the aircraft just aft of the rear cabin pressure bulkhead (and just forward of the main wing spar). The two sections remained connected by the underfloor cables for the control surfaces and electrical wiring. The separation of the two sections was likely the consequence of damage sustained during the ditching, and the subsequent action of waves and other forces acting on the weakened fuselage structure. The forward fuselage section was resting on its left side on the sandy seabed, and underneath the left wing.
- There was extensive damage in the vicinity of the broken fuselage cross-section, forward of the rear pressure bulkhead (Figure 16 and Figure 17). This damage was consistent with significant longitudinal bending of the fuselage (that is, the forward and aft sections of the fuselage bending downwards relative to the middle). There was also significant underfloor crushing and compression damage between the two sections of the fuselage, consistent with the lower structures being impressed inward against each other. Damage to the rear pressure bulkhead was also evident.
- The top part of the main entry door was still visible, and it appeared to be flush with the fuselage (Figure 18). However, the lower part of the door was obscured from view and, as such, the security and condition of the door in this position could not be ascertained.
- The left and right emergency exit hatches were both missing, consistent with those exits being used during the evacuation of the aircraft (Figure 19).
- The aircraft's nose cone had detached from the aircraft (Figure 20). The lower half of the forward baggage compartment door (located on the left side, aft of the rear pressure bulkhead) had been forced open and folded back upon itself (Figure 21), although the latch (located in the middle on

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98 ICAO recommended practices are for an underwater locator beacon (ULB) to be fitted to both the CVR and the FDR. However, Australian regulations only require a ULB to be fitted to the FDR. Although the CVR was equipped with a ULB when fitted to the aircraft, maintenance records indicated its removal in January 2009. There was no ULB fitted to the CVR when it was recovered from the wreckage in November 2015.

99 An edited version of the underwater video was released as part of the original ATSB investigation, available at http://www.atsb.gov.au/media/782199/vh-nga_underwater.mp4. As such, the video is subject to the same restrictions of use as the final investigation report itself.

the right side of the door) appeared to be secure. This pattern of damage may have been associated with the hydrodynamic action of water on the left side of the aircraft during the impact sequence, or the forceful hydraulic action of water flowing through the inside of the fuselage during the impact sequence. The rear baggage compartment door was also open (Figure 22), but did not appear to be significantly damaged.

- The left and right main landing gear appeared to be in the extended position and the nose gear partially extended. Analysis of the CVR recording confirmed retraction of the landing gear before impact. As such, the gear position 'as found' on the seabed was most probably due to the post-impact separation of the forward fuselage, which resulted in the loss of the hydraulic system pressure holding the landing gear in the retracted position.
- The wing flaps were extended and appeared to have been damaged due to impact forces during the ditching and when the left wing settled on the forward section of the fuselage. Although there was an apparent asymmetry in the flap position between the left and right wing, this was consistent with impact effects and post-impact damage.
- Both the left and right tip tanks exhibited crush damage (Figure 23), consistent with water pressure acting on and collapsing the empty tanks as the aircraft submerged.

Figure 14: Disposition of the aircraft wreckage on the seabed

Source: Screen capture from Victoria Police ROV.

Figure 15: Overhead view of wreckage on the seabed, showing location of separation from forward fuselage ahead of the main wing spar

Source: Screen capture from Victoria Police ROV.

Figure 16: Front-on view of forward fuselage separation point, showing wing spar carry-through structure, main fuselage fuel tanks and damage to the underfloor fuselage section

Source: Screen capture from Victoria Police ROV.

Figure 17: Fuselage separation location and damage to the forward lower fuselage section

Source: Screen capture from Victoria Police ROV.

Figure 18: Top of main entry door, left cockpit side and left upper window

Source: Screen capture from Victoria Police ROV.

Figure 19: Right side of forward fuselage, showing open emergency exit.

Source: Screen capture from Victoria Police ROV.

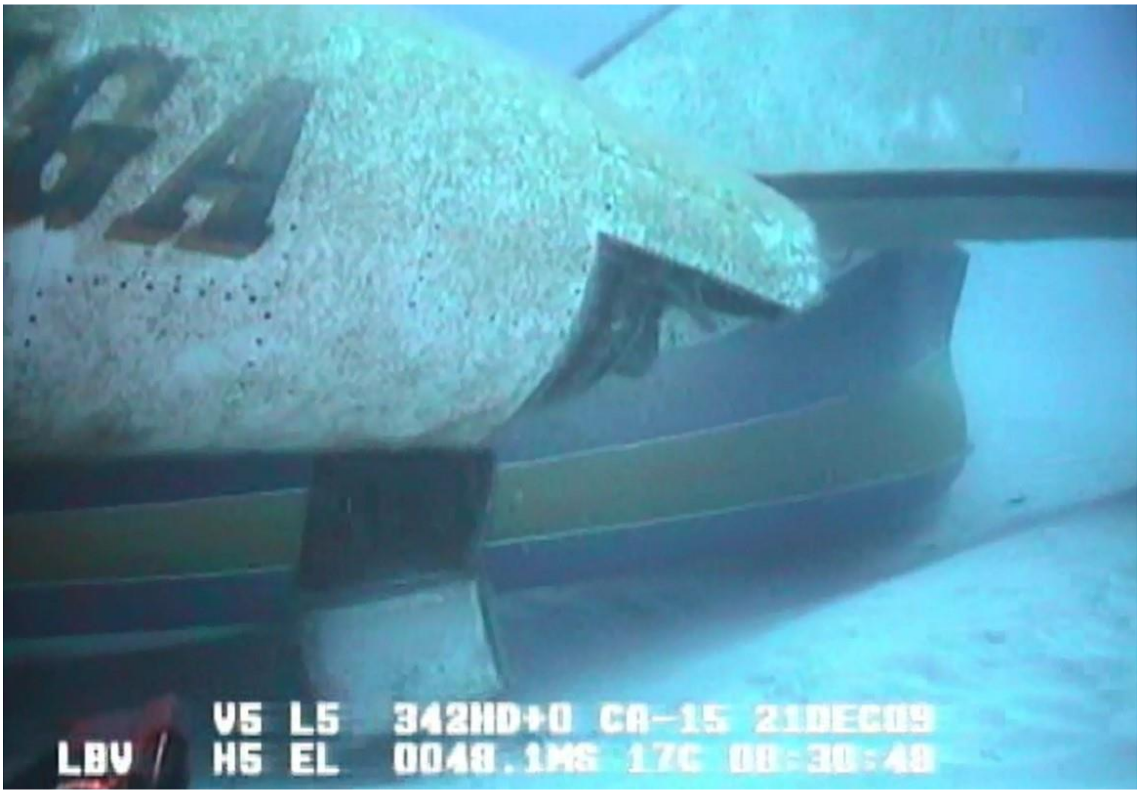
Figure 20: Forward fuselage resting on the seabed on its left side

Source: Screen capture from Victoria Water Police ROV.

Figure 21: View looking forward from under left engine showing hydraulic damage to lower half of forward baggage compartment door.

Source: Screen capture from Victoria Water Police ROV.

Figure 22: View from left side of rear fuselage, showing open rear baggage compartment door



Source: Screen capture from Victoria Police ROV.

Figure 23: View of left tip tank, showing crushing damage due to water pressure

Source: Screen capture from Victoria Police ROV.

Flight recorders

The aircraft was equipped with:

- an L3 Communications FA2100 solid-state cockpit voice recorder (CVR)
- a Fairchild F1000 solid-state flight data recorder (FDR).

Both units were installed in the tail section of the aircraft, aft of the rear pressure bulkhead.

During the original investigation, after conducting the underwater survey in December 2009, the ATSB decided to not recover the aircraft's recorders. This decision was based on a consideration of a range of factors, including:

- all the occupants had survived and were able to be interviewed
- the depth of the wreckage (48 m) and the logistical difficulty and associated high cost of recovery from that depth, which was beyond conventional diving range
- the knowledge that some key items of evidence, such as communications about weather and potential discussions about fuel management prior to about 0826 (2 hours before impact), would not be on the CVR
- the FDR only recorded a small number of parameters.

After reopening the investigation in December 2014, the ATSB evaluated the feasibility of recovering the recorders to ensure the investigation had access to all potentially relevant information. An underwater survey of the wreckage was conducted in March 2015. That survey found that the tail section of the aircraft was partially buried by the movement of sand, which had the potential to complicate the recovery.

An extensive tender request process was conducted, in accordance with federal government procurement requirements. The request for tender was released in June 2015, and in October 2015 a specialised salvage contractor was engaged for the recovery operation. The operation required sand excavation at the wreckage location, specialised diving to prepare the tail section of the aircraft for recovery and then lifting of the tail section to the surface to effect the recorder recovery.

The salvage team recovered the recorders in November 2015, under the direct supervision of ATSB investigators and officers from the Australian Federal Police. The recorders were transported to ATSB facilities in Canberra and a team of flight recorder specialists downloaded the data. In addition to ATSB specialists, the download team also included two specialists from the Directorate of Defence Aviation and Air Force Safety (DDAAFS).

The memory modules from both recorders were in excellent condition. Data was successfully downloaded from the CVR for the period from 0821:55 until the third impact at 1026:02. Although there were some problems with aspects of the audio quality, most of the crew conversations were able to be transcribed. Appendix A provides further details.

Data was successfully downloaded from the FDR for the accident flight and the two outbound flights. The available data included:

- pressure altitude
- indicated airspeed
- magnetic heading
- vertical acceleration.

From this data and other information, other parameters could be derived, such as Mach, true airspeed (TAS) and the aircraft's ground track. Appendix B provides further details.

Information from the recorders is included in *The Occurrence* and other sections as required.[100]

Airport information

General information

Norfolk Island is a table-top island about 8 km long and 5 km wide. It is bounded on most sides by cliffs or steep slopes, but has no high mountains.

The airport was situated on the south-western side of the island (Figure 10). The elevation of the highest point of the landing area was 371 ft (113 m) above mean sea level.

There was rising terrain to the north of the airport. The highest obstruction, at 1,067 ft (325 m) above mean sea level, was approximately 1.5 NM (2.8 km) north of the airport. This obstruction, and two other obstructions of similar height nearby, were equipped with aeronautical obstruction or beacon lighting and were depicted on instrument approach charts (for example, Figure 25).

In addition, the Norfolk Island World Aeronautical Chart provided detailed information about the terrain relief and topography at Norfolk Island, including terrain spot heights, contour lines and hypsometric tint information. The chart indicated there was no notable terrain or spot heights near either end of the main runway (runway 11/29).

The airport was a certified aerodrome.[101] An aircraft operator and/or the flight crew of a non-regular public transport flight needed prior approval from the airport operator before conducting a flight to the airport.

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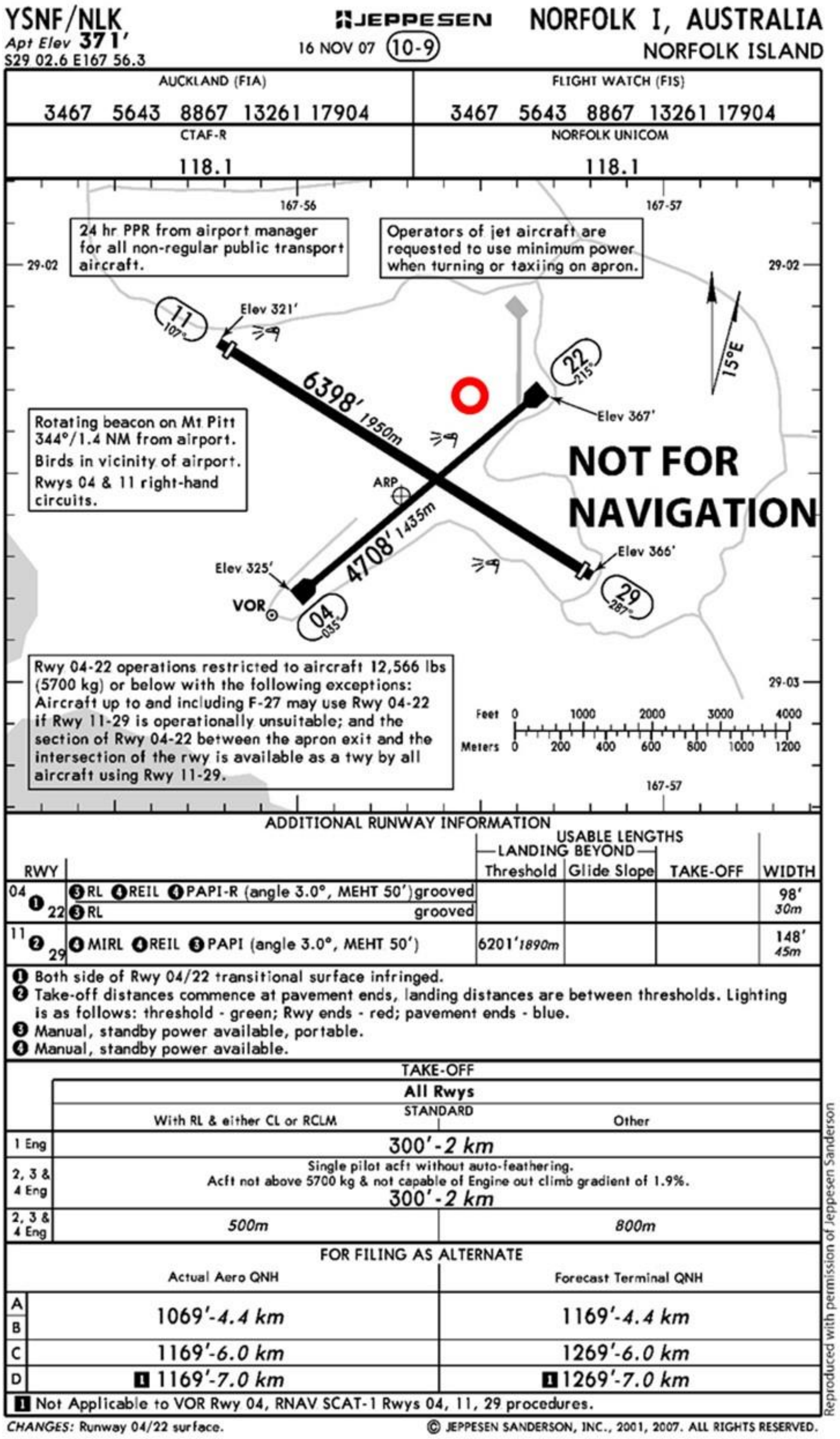
[100] Consistent with the provisions of ICAO Annex 13, information contained in cockpit voice recordings have been included in the report where they are pertinent to the analysis of the accident circumstances and where the disclosure is necessary in the interest of safety. Parts of the recording not relevant to the analysis have not been disclosed.

[101] CASA issued aerodrome certificates under Civil Aviation Safety Regulation 139.050. The certificate was issued on the basis that the aerodrome's facilities, equipment and procedures met the specified standards.

Runways

Figure 24 shows the two runways available at Norfolk Island. The main east-south-east/west-north-west runway (runway 11/29) intersected a smaller north-east/south-west runway (runway 04/22). Both runways were sealed surfaces.

Figure 24: Aerodrome chart for Norfolk Island, with approximate location of meteorological instruments annotated with a red circle



Source: Chart reproduced with permission of Jeppesen, annotated by ATSB

Runway 11/29 was 1,950 m long and 45 m wide. The width of the runway strip was 150 m, and extended each side of the sealed runway. The runway strip was a graded surface and was free of obstructions. The landing distance available was 1,890 m and the runway slope was 0.7 per cent down to the west.

Runway 11/29 was equipped with medium-intensity runway lighting, switchable through three stages of intensity. Each end of the runway was fitted with a precision approach path indicator (PAPI), comprising guidance lights each side of the runway. This provided a visual indication of the aircraft's position relative to a nominal 3° approach path at a threshold crossing height of 50 ft. The thresholds of runway 11/29 were also equipped with flashing white runway threshold identification lights (strobes).

The sealed surface of runway 04/22 was 1,435 m long and 30 m wide. The width of the runway strip was 90 m. The landing distance available was 1,435 m and the runway sloped 0.9 per cent down towards the south-west. Runway 04/22 was equipped with low-intensity runway lighting operating at a fixed intensity. Runway 04 was also equipped with a PAPI on the right side of the runway and flashing runway threshold identification lights.

On 18 November 2009, airport staff manually activated the runway lighting prior to VH-NGA's arrival and standby power was available. The medium intensity runway lighting on runway 11/29 was set to maximum intensity and the single-stage lighting on runway 04/22 was on. The runway threshold identification lighting and PAPI were operating for runways 11, 29 and 04.

The airport operator restricted operations on runway 04/22 to aircraft below 5,700 kg, unless runway 11/29 was operationally unsuitable.

Runway 11/29 was a suitable length for normal operations in a Westwind 1124A. The suitability of the length of runway 04 depended on the wind conditions. At the time of the accident, with a tailwind, it was only suitable for an emergency landing rather than a normal landing. Data contained in the Westwind 1124A AFM indicated an unfactored landing distance of about 920 m on a wet runway with a 10-kt tailwind component.

Alternate minima for Norfolk Island

Alternate minima are a set of ceiling and visibility conditions that are published for each aerodrome that has a published instrument approach procedure. If the forecast conditions are below the alternate minima, the flight crew is required to plan the flight with sufficient fuel to be able to divert to a suitable alternate aerodrome, or hold until 30 minutes after the conditions were forecast to improve (see also *Weather-related requirements for an alternate aerodrome*).

For IFR flights to Australian aerodromes, the relevant aerodrome chart or instrument approach chart specifies the alternate minima in terms of ceiling and visibility (for example, see bottom of Figure 24).[102]

Consistent with the Westwind's normal approach speeds, the operator classified it as a Category C aircraft. The types of approaches the operator's flight crews could conduct at Norfolk Island were non-precision, ground-based navigation aid approaches. Accordingly, when planning a flight to Norfolk Island in a Westwind, the alternate minima were:

- ceiling of 1,269 ft above the aerodrome elevation (based on a forecast QNH)
- visibility of 6,000 m.

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[102] Pilots were also required to plan for an alternate aerodrome when the crosswind or tailwind exceeded the limitations specified in the approved flight manual for the relevant aircraft type. For the Westwind, the crosswind limitation was 23 kt and the tailwind limitation was 10 kt. The forecast and actual wind velocity did not create an operational restriction for the accident flight.

Navigation aids

Several ground-based navigation aids were available at Norfolk Island. These aids could be used by pilots for en route navigation when within the aid's rated coverage and to conduct the prescribed instrument approach procedures.

The VOR and DME at Norfolk Island were co-located, on the extended runway centreline and in the undershoot area of runway 04. When an aircraft's VOR receiver was tuned to the VOR frequency, cockpit instruments would display information about the selected track, the aircraft's distance and groundspeed to/from the VOR/DME.

The non-directional beacon (NDB) was situated on the north-western tip of the island, about 2 NM (4 km) north-west of the airport. When an aircraft's automatic direction finder (ADF) was tuned to the NDB station, a cockpit instrument would indicate the direction to the station.

The VOR, DME and NDB were subject to a recurrent program of checking, with an annual performance inspection (ground inspection and testing of equipment) and a 3-yearly flight inspection. Prior to the accident, the navigation aids had completed their performance inspection in January 2009 and flight inspection in April 2007.

The operational status of the navigation aids were pilot monitored. There were no faults reported to the Airservices Australia technical operations centre during 1–23 November 2009. Furthermore, soon after the ditching an overflying aircraft checked and found the navigation aids at Norfolk Island were operating normally.

Published instrument approach procedures

Overview

Instrument approach procedures were published for Norfolk Island airport and facilitated the arrival of aircraft operating under the IFR. All of the procedures were non-precision approaches and provided flight crews with lateral navigational guidance as they approached the airport.

Ceiling and visibility minima are prescribed for the meteorological conditions under which an aircraft may land at an aerodrome. Meteorological conditions for a particular aerodrome are below the landing minima when in the airspace encompassing the intended flight path either:

- the total cloud amount below the specified ceiling minimum is continuously greater than scattered, or
- the visibility is continuously below the specified visibility minimum.

The minimum descent altitude (MDA) is equal to the ceiling minimum plus the runway elevation.

In order for a flight crew to land at an aerodrome, the actual weather conditions need to be at or above the prescribed ceiling and visibility minima.

Except in an emergency, a flight crew could not descend below the MDA during the approach unless:

- the aircraft remained within the circling area,
- the visibility along the intended flight path was greater than the specified minimum,
- visual contact could be maintained with the landing runway environment,[103]
- the aircraft could complete a continuous descent to the runway threshold using rates of descent and landing manoeuvres which were normal for the aircraft type, and
- prescribed clearance from obstacles along the flight path was maintained until the aircraft was aligned with the landing runway.

[103] This includes the runway threshold, approach lighting or other markings identifiable with the runway.

The landing (ceiling and visibility) minima for an instrument approach are published on the relevant instrument approach chart (for example, see bottom of Figure 25). Most instrument approach procedures include landing minima for a straight-in approach and a circling approach. In either case, a flight crew is required to descend visually with reference to the runway environment from an altitude at or above the MDA.

For a Category C aircraft such as a Westwind at aerodromes where an ILS approach was not available, flight crews would almost always use the straight-in runway approach if that was available, as the approach involved less workload and the landing minima were lower.

The design procedures for an instrument approach ensured that an aircraft would remain a specified distance and/or height away from terrain and/or obstructions. The design procedure for a Category C aircraft conducting a non-precision approach, with the final approach track displaced from the extended runway centreline, required a minimum obstacle clearance for the final approach segment of 125 m (410 ft).

Although unlikely to be used for a Westwind, the MDA for a circling approach provided an assurance of obstacle clearance within the circling area.[104] At Norfolk Island, the circling MDA for most approaches was 1,040 ft and the visibility minima was 4.0 km. Due to the higher terrain to the north, circling was not permitted in the sector north-west of runways 04/22 and 11/29.

The most suitable approaches at Norfolk Island for the operator's Westwind operations were VOR approaches. Norfolk Island had VOR instrument approach procedures published for runways 29, 11, and 04.

VOR approach to runway 29

Figure 25 shows the chart for the VOR approach to runway 29. The initial approach fix was located either overhead the VOR commencing the outbound leg for a base turn reversal procedure, or at 10 NM from the VOR/DME (either on the DME arc or on the final approach track). The final approach fix was located on the final approach track at 5 NM.

The VOR was located on the extended centreline of runway 04, just prior to that runway's landing threshold. Consequently, it was left of the extended centreline and about 1,400 m from the landing threshold of runway 29. The final approach track to the VOR (273° M) was offset 14° from the runway centreline due to the location of the VOR. The final approach track passed through the extended runway centreline approximately 1.5 NM from the aiming point markings,[105] and at an altitude of about 840 ft on the recommended 3° descent profile.

The MDA for a straight-in approach to runway 29 was 850 ft above mean sea level, 484 ft above the runway at the landing threshold and 479 ft above the aerodrome elevation. If the recommended descent profile was flown, the aircraft would reach the MDA at about the same time it was passing through the extended runway centreline, at a distance of 2.0 NM from the VOR/DME (or about 2,400 m from the runway threshold).

To continue the approach and descend below the MDA, the flight crew needed to be able to maintain visual reference to land on the intended runway, with a minimum visibility of 3,300 m. The final approach track passed to the south of the runway threshold and the missed approach point was overhead the VOR.

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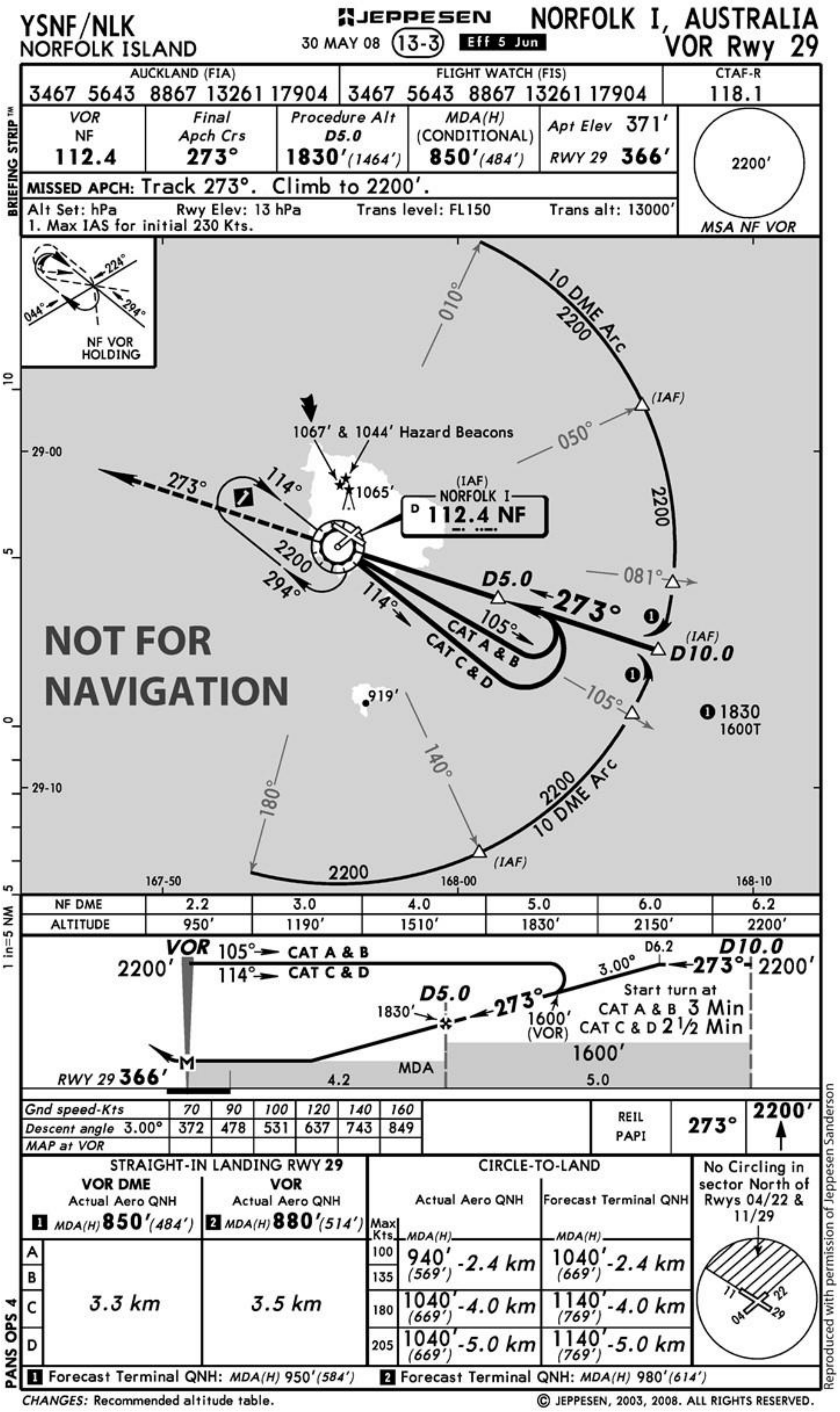
[104] The relevant circling area for a Category C aircraft landing at Norfolk Island airport was based on 4.20 NM (7,778 m) arcs centred on each runway threshold and joined by tangents. The design procedure for a circling approach could not have an obstacle clearance height less than 180 m (591 ft), and a minimum obstacle clearance of 120 m (394 ft) within the circling area.

[105] Aiming point and touchdown zone markings are used on sealed runways to provide pilots with visual guidance during landing.

Figure 25: VOR instrument approach procedure to runway 29

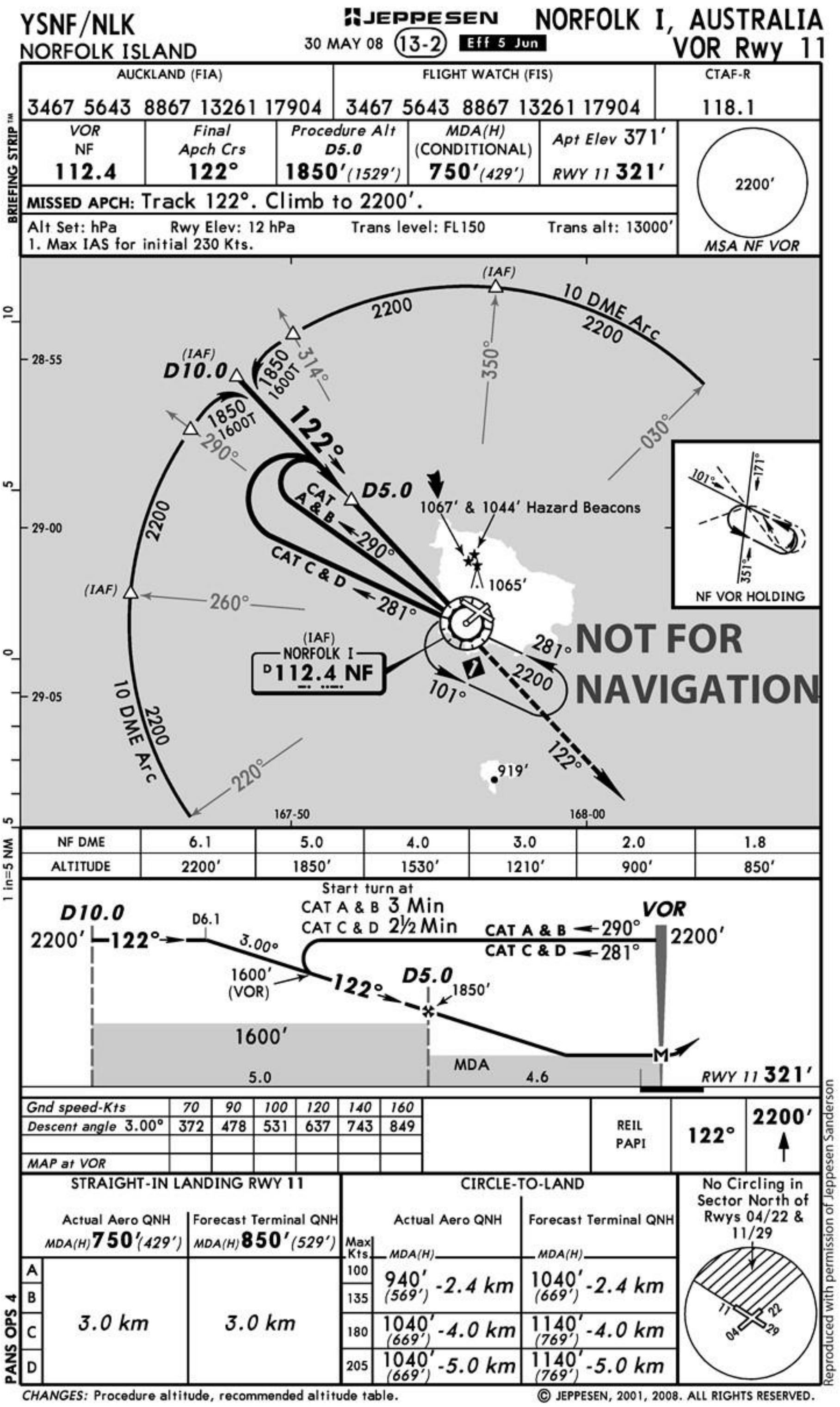


Source: Chart reproduced with permission of Jeppesen

VOR approach to runway 11

Figure 26 shows the chart for the VOR approach to runway 11. The initial approach fix was located either overhead the VOR commencing the outbound leg for a base turn reversal procedure, or at 10 NM (either on the DME arc or on the final approach track). The final approach fix was located on the final approach track at 5 NM.

Figure 26: VOR instrument approach procedure to runway 11



Source: Chart reproduced with permission of Jeppesen

The VOR was located to the right of the extended centreline of runway 11 and about 1,200 m south of the threshold of runway 11. The final approach track to the VOR (122° M) was offset 15° from the runway centreline. This track passed through the extended runway centreline approximately 1.6 NM from the aiming point markings. For an aircraft on the recommended 3° descent profile, this would be at an altitude of about 820 ft.

The MDA for a straight-in approach to runway 11 was 750 ft above mean sea level, 429 ft above the runway at the landing threshold and 379 ft above the aerodrome elevation. If the recommended descent profile was flown, the aircraft would reach the MDA soon after passing through the extended runway centreline, at a distance of 1.9 NM from the VOR/DME (or about 2,600 m from the runway threshold).

To continue the approach and descend below the MDA, the flight crew needed to be able to maintain visual reference to land on the intended runway, with a minimum visibility of 3,000 m. The final approach track passed to the south of the runway threshold and the missed approach point was overhead the VOR.

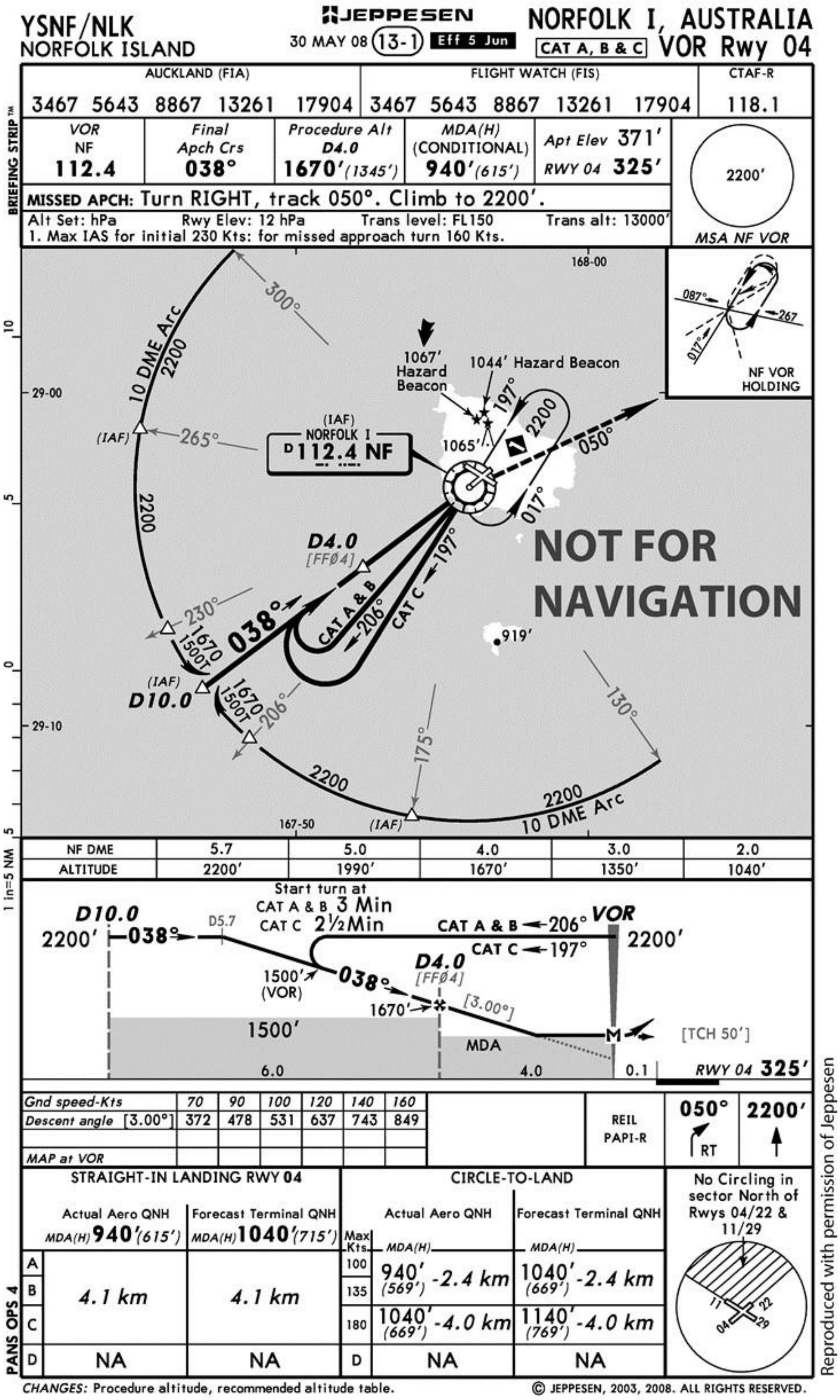
VOR approach to runway 04

Figure 27 shows the chart for the VOR approach to runway 04. The final approach track for the runway 04 procedure was runway aligned by virtue of the VOR transmitter being located on the extended runway centreline, in the undershoot area of runway 04.

The MDA for a straight-in approach to runway 04 was 940 ft above mean sea level, 615 ft above the runway at the landing threshold and 569 ft above the aerodrome elevation.

To continue the approach and descend below the MDA, the flight crew needed to be able to maintain visual reference to land on the intended runway, with a minimum visibility of 4,100 m. The missed approach point for the procedure was overhead the VOR, which was on the runway centreline, 185 m from the runway threshold.

Figure 27: VOR instrument approach procedure to runway 04



Source: Chart reproduced with permission of Jeppesen.

Other approaches

In addition to the VOR approaches at Norfolk Island, there were other published approaches that were available for the operator's Westwind operations, but were less suitable. These included:

- NDB-A and NDB-B approaches. Each of these approaches comprised an overwater descent to the procedure's MDA and neither procedure was runway-aligned. In each case, the circling MDA was 1,040 ft (669 ft above aerodrome elevation) and required 4,000 m visibility to complete the circling approach.

- A DME or GPS Arrival procedure. The circling MDA for this procedure was significantly higher than the other approaches and the procedure did not align the aircraft with a runway. Consequently, it was not suitable for the weather conditions reported at the time of the aircraft's arrival.

Due to the difficulties associated with Norfolk Island's weather (see *General climatological information for Norfolk Island*), in the late 1990s the Norfolk Island government and a regular public transport operator examined options for an instrument approach system that would provide for a lower MDA. This resulted in the installation of relevant ground-based equipment and the design of instrument approach procedures for runways 04, 11 and 29 based on an augmented global navigation satellite system (GNSS) landing system known as a radio navigation (RNAV) special category-1 (SCAT-1) approach system. These approaches were introduced at Norfolk Island in about 2000.

To be permitted to conduct SCAT-1 approaches, an aircraft had to be equipped with the necessary, specialised equipment. Once approved for SCAT-1 approaches, flight crews were able to descend 130 ft lower than the published MDA for the runway 11 VOR instrument approach procedure, and 190 ft lower than the published MDA for the runway 29 VOR instrument approach procedure. The operator of VH-NGA was not approved to conduct SCAT-1 approaches and none of the Westwind fleet were fitted with the equipment required to receive the differentially-corrected GPS (DGPS) signal from the airport's DGPS ground station.

Effective 19 November 2009, there were minor amendments to several of the airport's existing approach procedures. The amendment to the existing approach procedures comprised a 100-ft increase to the 25-NM minimum sector altitude and the commencement altitude for each of the approaches. However, there was no change to the MDA or visibility criteria. During the approaches on 18 November 2009, the flight crew were using VOR instrument approach charts that became effective on 19 November 2009.

The 19 November 2009 changes also included the introduction of new RNAV GNSS approaches for runways 04, 11 and 29. The new RNAV GNSS procedures did not require the use of the airport's DGPS ground station. Utilising these procedures did not require specific CASA approval, but did require flight crews to hold an endorsement to conduct GNSS approaches. The procedure comprised a series of waypoints that provided track guidance towards the runway and the final approach path was runway aligned. However, due to the navigational tolerances applied to the GNSS procedure, the MDA for the RNAV GNSS approaches at Norfolk Island were higher than the corresponding runway approaches using the ground-based navigation aids. In addition, the navigation data card installed in the GPS equipment fitted to VH-NGA would not have been programmed with the waypoints for the RNAV GNSS procedure. The operator did not use RNAV GNSS approaches on its Westwind fleet and its crews did not receive training in these procedures (see *GPS receivers*).

Table 18 lists the landing minima for the Norfolk Island instrument approaches for a Category C aircraft with actual QNH. The procedures the flight crew were authorised to conduct are highlighted in green.

Table 18: Summary of landing minima for Norfolk Island Airport for Category C aircraft with actual QNH (green highlighted rows show approaches available to the flight crew)

Instrument approach procedure	Straight-in approach				Circling approach		
	MDA	Height of MDA above runway	Height of MDA above aerodrome elevation	Visibility	MDA	Height of MDA above aerodrome elevation	Visibility
VOR runway 29	850 ft	484 ft	479 ft	3.3 km	1,040 ft	669 ft	4.0 km
VOR runway 11	750 ft	429 ft	379 ft	3.0 km	1,040 ft	669 ft	4.0 km
VOR runway 04	940 ft	615 ft	569 ft	4.1 km	1,040 ft	669 ft	4.0 km
NDB A and NDB B	N/A	N/A	N/A	N/A	1,040 ft	669 ft	4.0 km
DME or GPS arrival	N/A	N/A	N/A	N/A	1,480 ft	1,109 ft	4.0 km
RNAV-Y (GNSS) runway 04	960 ft	635 ft	589 ft	4.1 km	1,060 ft	689 ft	4.0 km
RNAV-Y (GNSS) runway 11	990 ft	669 ft	619 ft	4.3 km	1,060 ft	689 ft	4.0 km
RNAV-Z (GNSS) runway 29	900 ft	534 ft	529 ft	3.5 km	1,060 ft	689 ft	4.0 km
RNAV SCAT-1 runway 04	660 ft	335 ft	289 ft	1.8 km	1,040 ft	669 ft	4.0 km
RNAV-Z SCAT-1 runway 11	620 ft	299 ft	249 ft	1.6 km	1,040 ft	669 ft	4.0 km
RNAV-Z SCAT-1 runway 29	660 ft	294 ft	289 ft	1.6 km	1,040 ft	669 ft	4.0 km

Note: The RNAV (GNSS) approaches became effective on 19 November 2009, the day after the accident. The aircraft was not equipped to conduct RNAV SCAT-1 approaches. The flight crew was not authorised to conduct RNAV (GNSS) or RNAV SCAT-1 approaches.

Unicom service

The operator of Norfolk Island airport provided a Unicom (Universal Communications) service on the airport's common traffic advisory frequency (CTAF).[106] The service enabled the Unicom operator and flight crews of inbound aircraft to exchange basic operational information. The antenna for the Unicom transmitter was located on Mt Pitt, to the north of the aerodrome. As the CTAF was in the VHF band, communications under normal atmospheric conditions were approximately line of sight. For example, at an altitude of 39,000 ft, the distance to the VHF radio horizon for the Norfolk Island Unicom was about 280 NM.[107]

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106 In 2009, Norfolk Island was designated as a CTAF-R, requiring all aircraft operating in the vicinity of the airport to be equipped with a VHF radio.

107 This calculation accounts for the slight refraction of the VHF signal under normal conditions due to the layers of the atmosphere, and the elevation of the Unicom antenna at Norfolk Island. The geometric maximum line-of-sight distance between an antenna on Mt Pitt and an aircraft at FL 390 was about 245 NM.

The Norfolk Island Unicom operators were not authorised to communicate with aircraft on air traffic services (ATS) frequencies, including the HF frequencies used by ATS for long-range communication. However, the Unicom operators were in regular contact with the Auckland Oceanic controller via telephone when an aircraft was known to be approaching Norfolk Island (see also *Provision of flight information service in the Auckland Oceanic FIR*).

A flight crew could also contact the Unicom operator by telephone if required. When in flight, this generally meant the flight crew needed access to an appropriate satellite phone.

The Unicom operator had access to a console displaying the instantaneous readout of the weather observations made by the airport's AWS. This console was used on the night of the accident to relay current AWS observations to the crew of VH-NGA. The Unicom operators at Norfolk Island Airport were not trained weather observers and had not been issued approvals to make weather observations.[108] However, the Unicom operator was able to provide simple, factual statements about the weather conditions at the airport.

Additional information about the operation of the Norfolk Island Airport AWS is provided in *Norfolk Island weather observations.*

Aircraft movements

Norfolk Island was an infrequently used airport, particularly for non-regular public transport flights. Based on movement data provided by Airservices Australia, there was an average of 458.5 aircraft landings at Norfolk Island per year during 2008–2009.[109] The average landings per year consisted of:

- 396 landings in high-capacity civil air transport aircraft, primarily conducting regular public transport (RPT) flights
- 20.5 landings in low-capacity civil air transport aircraft (maximum take-off weight of 5,700–25,000 kg)
- 15.5 landings in civil aircraft with a maximum take-off weight of 2,250–5,700 kg
- 4.0 landings in aircraft with a maximum take-off weight less than 2,250 kg
- 8.0 landings by military aircraft
- 14.5 landings where the aircraft type and weight was not recorded.

The 20.5 landings each year involving low-capacity air transport aircraft included 7.5 flights each year by the operator's Westwind aircraft, of which 6.5 each year were known to be air ambulance flights.[110] At most 6.0 flights per year by other operators would have been air ambulance flights. However, it is likely that at least some of these flights were charter rather than air ambulance flights.

Meteorological information

Roles and responsibilities

The Bureau of Meteorology (BoM) is the designated meteorological authority in Australia for the provision of a meteorological service for international air navigation in accordance with International Civil Aviation Organization (ICAO) Annex 3 (Meteorological Service for International

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108 Civil Aviation Regulation 120 prevented the operator or the pilot in command from using weather reports of actual or forecasted meteorological conditions in the planning, conduct and control of the flight if the observations, forecasts or reports were not made with authority.

109 The fractional number of landings reported is due to an uneven number of total landings over the 2-year period which were then averaged. It is possible that not all landings were recorded.

110 Based on the operator's flight records, it conducted an average of 9.0 landings per year, 8.0 of which were air ambulance flights.

Air Navigation). The objective of this service is to contribute to the safety, regularity and efficiency of air navigation.

To achieve that objective, BoM produces and supplies relevant operational meteorological information to operators, flight crew, ATS units, search and rescue services, aerodrome operators and others concerned with the conduct of air navigation.

In accordance with the core standards and recommended practices outlined in Annex 3, BoM had implemented a quality management system that was certified in accordance with the standards contained in AS/NZS ISO 9001:2008.[111]

Airservices Australia provided the Aeronautical Information Service within the Australian flight information regions (FIRs), and distributed BoM's meteorological products to aviation users. BoM products were also sent via AFTN[112] to relevant overseas ATS providers.

Norfolk Island is an Australian external territory, located within the Auckland Oceanic FIR. BoM was responsible for providing aerodrome forecasts (TAF), observations (METAR/SPECI) and aerodrome warnings[113] for Norfolk Island airport. The New Zealand Meteorological Service was responsible for providing other meteorological services, such as SIGMETs[114] affecting aircraft operations within the Auckland Oceanic FIR.

Norfolk Island weather facilities

There was a BoM-staffed meteorological office and an automated weather station (AWS) at the Norfolk Island airport. In November 2009, there were two BoM qualified observing staff stationed at the island, typically achieving coverage each day from 1930 to 0630 UTC (0700 to 1800 local time). During those hours the staff provided supplementary input for the surface observations and facilitated balloon launches for the upper-air observations.

The AWS was situated on the airport grounds, approximately 270 m west of the threshold for runway 22 at an elevation of 367 ft (see Figure 24). The installed equipment comprised:

- rain gauge – measurement of rainfall and rainfall rate
- dry bulb temperature probe – measurement of ambient temperature and calculation of humidity and dewpoint
- wet bulb temperature probe – calculation of humidity and dewpoint
- anemometer – measurement of wind direction and speed, including gusts
- barometer – measurement of atmospheric pressure
- ceilometer – estimation of cloud height and amount overhead
- visibility meter – estimation of visibility.

The ceilometer estimated cloud height based on the continuous sampling of single points at least once every 30 seconds. It sampled the sky directly overhead and could detect up to three layers

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111 AS/NZS ISO 9001:2008: Specified the requirements for quality management systems, focussing on the systems' effectiveness in meeting customer requirements, which includes preventing nonconformity and addresses customer satisfaction and quality improvements. The document was published by Standards Australia.

112 Aeronautical fixed telecommunication network (AFTN): a worldwide system for the exchange of messages and data between aeronautical fixed stations having the same or compatible communication characteristics

113 Aerodrome warnings are issued to provide information about meteorological conditions that could affect the aerodrome's facilities and services, as well as aircraft on the ground.

114 Significant meteorological information (SIGMET): a weather advisory service that provides the location, extent, expected movement and change in intensity of potentially hazardous (significant) or extreme en route meteorological conditions that are dangerous to most aircraft, such as thunderstorms or severe turbulence.

of cloud.[115] The variations in measurements as the cloud layers passed overhead enabled the system to make an estimation of the amount of cloud covering the sky.

The sensor outputs were sorted into 100-ft height 'bins', with all cloud heights above 50 ft rounded to the nearest 100 ft. Processing algorithms further sorted the data where the lower height of an adjacent data pair was equal to or less than 1,000 ft and the difference between heights was less than 300 ft. This had the effect of combining the 100-ft bins together and aggregating the overall output.

The AWS ceilometer output was updated every minute. The last 30-minutes of integrated ceilometer output were outputted in the METAR/SPECI reports. To improve the ceilometer's response time in changing conditions, a double weighting was given to data collected during the previous 10 minutes.

BoM stated ceilometers can outperform human observers at night, particularly with the onset of low cloud below other cloud or the lowering of existing cloud.[116] However, a number of factors can affect the accuracy of the cloud base reported by a ceilometer. These include:

- misreporting stationary cloud amounts due to the ceilometer's single point sampling
- lagging of ceilometer observations in rapidly changing conditions
- spurious reporting of cloud bases due to precipitation, virga,[117] dust particles or other atmospheric discontinuities
- fluctuating cloud bases with cumuliform cloud in moderate to strong airstreams
- conditions preventing the ceilometer detecting a cloud base, such as shallow fog, blowing dust or snow, or very low cloud bases being improperly reported due to fog, precipitation or blowing dust.

The visibility meter estimated atmospheric visibility based on the continuous sampling of single points. It provided a measurement of the prevailing visibility at the sensor. However, it sampled a relatively small volume of air in the immediate vicinity of the instrument and, unlike a human observer, was not capable of estimating visibility in different directions or over longer distances.

One-minute data was reported by the AWS based on the last 60 seconds of sensor output, as an average based on a processing algorithm. The last 10-minutes of visibility meter output were also processed by an algorithm and used to report the METAR/SPECI visibility. Where the 10-minute visibility average was less than 500 m, the visibility output was rounded down to the nearest 50 m. Between 500 m to less than 5 km, the visibility output was rounded down to the nearest 100 m and between 5 km and less than 10 km, the visibility output was rounded down to the nearest 1,000 m.

BoM stated visibility meters may outperform human observers at night in situations of uniform reduced visibility. However, other factors could affect the accuracy of the reported visibility, including:

- discrete air masses, such as a shower of rain or a bank of fog, will not be identified unless the sensor is engulfed, and if the phenomenon is not of uniform density, the visibility will be misreported
- stationary localised patches of fog will remain undetected if the sensor is clear of fog, or if the sensor is within the patch of fog the reported visibility may be less than actual.

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115 The ceilometer measured cloud height using a pulsed diode laser light detection and ranging system, which measured the backscatter caused by cloud and other atmospheric particles. The height of various layers was indicated by the timing of the returned laser pulses as a function of distance.

116 In May 2012, BoM published a pamphlet Ceilometers and Visibility Meters as part of their aviation reference material series (available from www.bom.gov.au). The pamphlet provided information about the measurements made by these instruments and the associated advantages and limitations of the equipment.

117 Virga is a meteorological term used to describe precipitation (ice crystals or rain) falling from a cloud and which sublimates or evaporates before reaching the ground.

At the time of the accident, the Australian Aeronautical Information Publication (AIP) (GEN 3.5 Meteorological Services, paragraph 12.5.2) included a note cautioning pilots about interpreting automated visibility, present weather and cloud information, as data from those instruments may not be equivalent to human observations. As noted above, the limitations did not necessarily apply to the accuracy of the measurements being made, but rather the nature of single sensors measuring conditions that could be dynamically changing around the airport environment.

Observations made by the Norfolk Island AWS were displayed on a console at the Norfolk Island meteorological station and on a duplicate console that was accessible by the Norfolk Island Unicom operator. The real-time AWS data was also accessible using a telephone-based, automatic weather information service (AWIS). At Norfolk Island there was no automatic retransmission of the AWS observations on any discrete radio frequency.[118]

BoM checked the accuracy of the meteorological instruments about twice each year. Around the time of the accident, the ceilometer and visibility meter were checked on 22 August 2009 and 5 March 2010. There were no discrepancies identified with the instruments during those checks.

In addition to the AWS, there was a weather watch radar at the airport, which detected radar echoes from rainfall up to 256 km from the island. Trees close to the site reduced the radar range to the north. The weather watch radar was unavailable at scheduled times during the day, as the radar was also used to track atmospheric sounding balloons, which were released to measure the upper atmosphere winds in the vicinity of Norfolk Island. There was no scheduled or other outage affecting the Norfolk Island weather watch radar during the accident flight.

Aerodrome weather forecasts

An aerodrome forecast (TAF) is a statement of the expected meteorological conditions within 5 NM (9 km) of an aerodrome during a specific period of time. It provides a forecast for wind (speed and directions), visibility, weather (such as rain or fog), cloud amount and height, temperature, QNH and the existence of turbulence.

BoM advised:

> To produce a TAF forecasters use information from various sources, including past and present in situ observations, radar and satellite imagery, climate information and weather forecasting models. Forecasting for a specific point and time is a continuous process that involves forecasters monitoring observations and forecast guidance, and updating forecasts according to standard criteria. Amendments to a TAF are issued in the event that one or more of the forecast elements described above varies by an amount that is significant to operations at the aerodrome.

For example, BoM's criteria for issuing a new forecast due to changes in cloud included:

- the amount of cloud below 1,500 ft was forecast to change from few/scattered to broken/ overcast (or from broken/overcast to few/scattered)
- the height of the base of the lowest broken/overcast cloud layer was forecast to lower and pass through the highest alternate minima, 1,500 ft, 1,000 ft, 500 ft, 200 ft or 100 ft (or lift and pass through one of these heights).

The BoM had Regional Forecasting Centres (RFCs) established in capital cities around Australia. Meteorologists in the RFCs could remotely access the real-time observations from AWSs in their network. Forecasters in BoM's NSW RFC routinely issued the TAF for Norfolk Island every 6 hours, valid for a further 18 hours.

Aerodrome weather reports

A METAR is a routine report of current meteorological conditions at an aerodrome. These include wind, visibility, cloud, rainfall, air temperature, dewpoint and air pressure information. If

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[118] For Christmas, Lord Howe and the Cocos Islands, pilots could access the AWIS broadcast via a VHF radio frequency (if they were within VHF coverage). However, for Norfolk Island, the Unicom operator was available to dial the AWIS station and relay the same data to aircraft crew.

meteorological observers were present at an aerodrome, they would make regular observations of the weather conditions and use those to augment the data provided by the AWS before the METAR was issued. In that case, the METAR could include additional information such as directional visibility, the presence of cumulonimbus cloud, supplementary information and other remarks.

A SPECI is a special report of current meteorological conditions at an aerodrome. BoM issued a SPECI when one or more of the observed elements met specified criteria significant to aviation operations. Included in those criteria were:

- horizontal visibility below the aerodrome's highest alternate minimum visibility (for Norfolk Island this was 7.0 km)
- broken or overcast cloud below the aerodrome's highest alternate minimum cloud base (for Norfolk Island this was 1,269 ft)
- presence of certain weather phenomena, including thunderstorms, fog, squalls and moderate or heavy precipitation
- change in temperature, pressure or wind by defined amounts
- improvements in visibility, weather or cloud, above SPECI conditions.

The use of 'AUTO' in a METAR or SPECI indicated the report contained only automated observations, with the AWS output used to report present weather, cloud and visibility.

BoM issued METARs at fixed times, hourly or half hourly depending on the aerodrome. For Norfolk Island, METARs were usually issued every 30 minutes. A SPECI issued at about the time of a scheduled METAR would replace the METAR.

The cloud heights provided in METARs/SPECIs were rounded to the nearest 100 ft. All cloud heights in METARs/SPECIs (and TAFs) referred to the height of the cloud above the aerodrome.

The temperatures provided in the METAR and SPECI weather reports were rounded to the nearest whole degree. The significance of this rounding could be an important consideration, particularly if the temperature had been rounded up and the dewpoint[119] rounded down, thereby increasing the apparent split in temperature and dewpoint.

The BoM *Manual of Aviation Meteorology* contained reference to a rule of thumb for estimating cloud base, based on the surface dewpoint temperature, the dewpoint temperature lapse rate and the surface temperature. That rule of thumb uses the relationship between the rate at which a parcel of unsaturated air cools as it ascends in the atmosphere and, similarly, the rate at which the dewpoint temperature reduces as altitude increases. As that difference between the respective lapse rates is about 2.4°C per 1,000 ft or 1°C per 417 ft, the cloud base can be estimated. As noted in *Approach briefing*, the captain discussed a similar rule with the first officer during the flight involving the use of 500 ft for every 1°C difference.

Significantly, the BoM rule of thumb could be used in conjunction with other information contained in the METAR/SPECI reports (such as the ceilometer's measurement of the cloud base) to help assess the validity of the information. The BoM manual indicates this can be a useful approximation and especially handy where no direct observations are available. However, like all rules of thumb, care in its use was advised. Table 19 (in *Weather events at Norfolk Island on 18 November 2009*) compares the cloud base reported by the ceilometer and the application of the rule of thumb.

The QNH provided in METARs and SPECIs is rounded down to the nearest hPa. This helped to minimise the risk that an aircraft's barometric altimeters will underread altitude when the flight crew have set the altimeters to the latest available QNH.

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119 Dewpoint temperature is the temperature at which a sample of moist air becomes saturated when cooled at constant pressure. If the temperature of the air is cooled below the dewpoint, condensation will occur.

General climatological information for Norfolk Island

The ocean surrounding Norfolk Island influences its sub-tropical climate. Relative humidity is generally high and the daily and annual temperature variations are small.

According to BoM, fog is a rare phenomenon and thunderstorms are relatively infrequent at Norfolk Island. However, low cloud is a frequent occurrence in humid airflows, particularly from the north-east to east. More specifically, BoM stated:[120]

> Low cloud is one of the most common weather phenomena to affect Norfolk Island. Low cloud is most common during summer and early autumn when moist easterly trade winds are most prevalent, bringing relatively high maritime moisture. The slight orographic lift provided by the island combined with a consistent supply of advected moisture can often result in prolonged periods of low cloud.
>
> Advected moisture in the easterly winds combined with the island's topography provide the most common mechanism for the formation of low cloud; however precipitation in the vicinity often causes intermittent periods of low cloud. This is relatively common with anti-cyclonic southeasterly winds producing passing showers.
>
> Low cloud with heavy continuous precipitation is often seen during the passage of a front particularly during the winter months. Low cloud ceiling in the southwesterly airstream following a frontal passage is rarely seen below 1500 ft; however, there are some occasions when low cloud has been detected with relatively low bases, especially when there is continuous precipitation in the area. Low cloud events associated with frontal passages are often shorter in duration due to the entrainment of drier post-frontal air masses. The onset and cessation times of low cloud associated with the passage of a front are often hard to forecast…
>
> When low cloud forms on the island it seldom lowers into a fog. This is in-part due to the cloud forming at the height of the terrain, Mount Bates being 1047 ft above mean sea level, and the fact that radiational cooling is hard to achieve in a maritime environment.

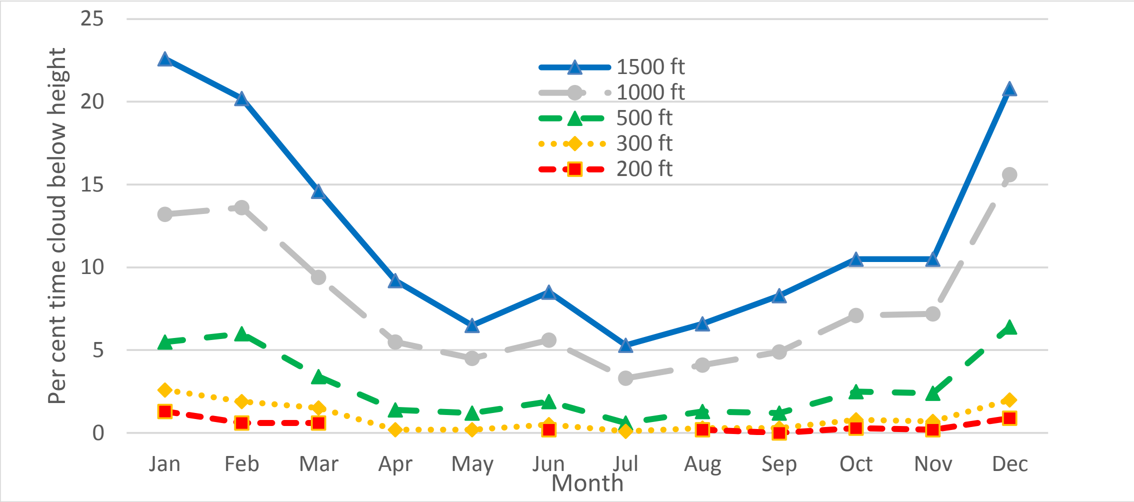
BoM stated average data showed that significant cloud (broken or overcast) below the alternate minima occurred about 10.2 per cent of the time at Norfolk Island.

Figure 28 shows significant cloud data for Norfolk Island averaged over the period 1995–2013. As indicated in the figure, significant cloud occurred:

- below 500 ft (above the aerodrome) about 3 per cent of the time overall, 6 per cent of the time during December to February, and 2.4 per cent of the time in November (equating to 17 hours in November)
- below 300 ft about 1 per cent of the time overall, 2 per cent of the time during December to February, and 0.7 per cent of the time in November (equating to 5 hours in November)
- below 200 ft about 1 per cent of the time during December to February, and 0.2 per cent of the time in November (equating to less than 2 hours in November).

[120] Bureau of Meteorology, 2014, Aviation weather hazards: Norfolk Island (YSNF). Available from www.bom.gov.au.

Figure 28: Percentage of time significant cloud was below specified heights at Norfolk Island airport from 1995 to 2013



Source: ATSB derived from climatological data provided on the Bureau of Meteorology website.

Compared to other Australian remote islands with an aerodrome, Norfolk Island and Christmas Island have significantly more days with low cloud than either Lord Howe Island or the Cocos Islands. This is due to both Norfolk Island and Christmas Island airports being situated at geographically-elevated locations, whereas the airports at the other islands are located close to sea level. Appendix H provides further information about average weather data for the four remote island aerodromes.

The ATSB obtained and examined observational data regarding weather conditions at Norfolk Island from 2009–2014, other remote islands from 2009–2013 and selected capital city airports from 2009–2013. When assessing this data, the ATSB used the alternate minima that was relevant for a Category C aircraft (such as a Westwind 1124/1124A). It also used the landing minima that was relevant to a Category C aircraft that was unable to conduct RNAV approaches, but was able to conduct other non-precision approaches and ILS approaches (that is, as per the operator's Westwind fleet).

Detailed results of the ATSB analysis are provided in appendix J. In summary:

- Overall, there was about 288 hours per year from 2009–2014 at Norfolk Island where the observed conditions were below the landing minima.
- Low cloud was the most common type of weather below the landing minima at Norfolk Island (about 200 hours per year), although low visibility was also notable. Low cloud was also observed for the longest durations, with a median duration of 119 minutes. In addition, low cloud was most prevalent at night, and it was most prevalent during summer months.
- Compared to other Australian remote islands during 2009–2013, Norfolk Island had a similar amount of weather below the landing minima as Lord Howe Island (just under 300 hours per year), which was lower than the amount for Christmas Island (about 580 hours per year) and higher than the Cocos Islands (about 180 hours per year). Remote islands had substantially more time per year below the landing minima than the five busiest capital city airports in Australia.

Reliability of weather forecasting at Australian remote islands

The BoM *Manual of Aviation Meteorology* stated:

> When a forecaster makes a prediction, the most probable conditions on the basis of the available information are described. The confidence the forecaster has in the prediction will depend on a number of factors, such as the location, season, complexity of the particular situation, the elements being forecast, and the period of the forecast.

> A forecast may be deficient because basic information is inadequate. Usually errors are due to a combination of factors. Elements, such as fog or low cloud, are usually more difficult to predict with precision than others, such as upper wind and temperature.
>
> Pilots who make the most effective use of weather services are usually those who understand the limitations. These pilots look upon forecasts as professional advice rather than categorical statements and take every opportunity to secure amendments and update their forecasts. Complete faith is almost as bad as no faith at all.
>
> Recognising that errors can occur, forecasters review their predictions in the light of later information and, if changes of significance are likely, they amend the forecasts.
>
> Amendments are usually not made unless expected changes from the original forecast are operationally significant, since there is a need to stress important amendments and eliminate unnecessary communication loads.

Between January 1998 and 31 March 1999, there was a series of RPT flights affected by unforecast weather conditions at Norfolk Island. Three flights departed when the forecast conditions were above the alternate minima but arrived at Norfolk Island when the actual conditions were close to or below the landing minima. Each flight did not have sufficient fuel to divert to an alternate aerodrome. More specifically:

- In April 1998 a British Aerospace BAe146 flight crew became visual at about 950 ft above mean sea level and landed off the first approach to runway 11.
- In April 1998 a Piper Chieftain PA31 pilot reported that he held at Norfolk Island for 45 minutes for the cloud to clear before landing.
- In February 1999 a Piper Chieftain PA31 pilot conducted several missed approaches before successfully landing on runway 04 in conditions below the landing minima.[121]

Appendix I provides further details of these occurrences. There were no reports of other similar occurrences prior to 18 November 2009, although there were several diversions associated with the weather conditions at Norfolk Island.

At the time of the 1998–1999 occurrences, there was no weather radar at Norfolk Island and the AWS was not equipped with a ceilometer or visibility meter. Weather observers provided coverage from 0400–2400 local time (or 0700 to 2400 local time if an observer was on leave). Hourly observations were communicated to the forecasting office in Sydney by the observers or, when the weather station was not staffed, by the AWS. However, the AWS did not provide cloud or visibility information.

Following these occurrences:

- In August 1999 CASA amended the fuel planning requirements for passenger-carrying charter flights to Australian remote islands, such that passenger-carrying charter flights were required to carry sufficient fuel to divert to an alternate aerodrome (see *Australian requirements for remote islands* and appendix L).
- In February 2000 the ATSB recommended that BoM review the methods and resources allocated to forecasting at Norfolk Island with a view to making the forecasts more reliable.[122]

The ATSB report associated with the recommendation noted:

> A delay of one hour or more can exist between a change occurring in the weather conditions and advice of that change reaching a pilot. The change has to be detected by the observer or automatic weather station and the information passed to the Forecasting Office. After some analysis of the new information in conjunction with information from other sources, the forecaster may decide to amend

[121] In addition, there was an occurrence in October 1998 where a BAe146 flight from Brisbane to Norfolk Island had to divert due to wind gusts at Norfolk Island, and the strength of the wind was not accurately forecast in the TAF issued prior to the flight's departure. However, the forecast did include thunderstorm conditions for periods up to 60 minutes.

[122] ATSB safety recommendation R20000040, issued 22 February 2000 to the Bureau of Meteorology. Details are available on the ATSB website www.atsb.gov.au.

> the forecast. The new forecast is then issued to Airservices Australia [and other relevant ATS providers] and disseminated to the Air Traffic Services (ATS) staff who are in radio contact with the pilot…

In its response to the recommendation in February 2000, BoM stated:

> There are several factors which determine the accuracy and reliability of the forecasts. The first is the quality and timeliness of the baseline observational data from Norfolk Island itself. The second is the information base (including both conventional surface observational data and information from meteorological satellites and other sources) in the larger Eastern Australia-Southwest Pacific region. The third is the overall scientific capability of the Bureau's forecast models and systems and, in particular, their skill in forecasting the behaviour of the highly localised influences which can impact on conditions on Norfolk Island. And the fourth relates to the speed and responsiveness with which critical information on changing weather conditions (forecast or observed) can be conveyed to those who need it for immediate decision making.
>
> As you are aware, the Bureau commits significant resources to maintaining its observing program at Norfolk Island. While the primary purpose of those observations is to support the overall large-scale monitoring and modelling of meteorological conditions in the Western Pacific, and the operation of the observing station is funded by the Bureau on that basis, it is staffed by highly trained observers with long experience in support of aviation. As far as is possible with available staff numbers, the observers are rostered to cover arrivals of regular flights and rosters are adjusted to cover the arrival of notified delayed flights…
>
> Despite the best efforts of the Bureau's observing and forecasting staff, it is clear that it is not always possible to get vital information to the right place as quickly as it is needed and the inherent scientific complexity of weather forecasting means that occasional serious forecast errors will continue to be unavoidable. That said, the Bureau has carefully reviewed the Norfolk Island situation in order to find ways of improving the accuracy and reliability of its forecasts for aviation through a range of short and longer-term means…

In terms of specific measures considered to improve the situation, BoM stated:

- it had issued instructions to observing staff to ensure forecasters are directly notified by telephone of any discrepancies between the current forecast and actual conditions
- it had provided the airport manager (Unicom operator) with access to a display of the latest observations to ensure the most up to date information could be communicated to flights
- it was considering the installation of a weather radar.

Since 2000, there were a number of enhancements to the weather observation capabilities at Norfolk Island:

- In 2001 BoM commissioned wind finding and part-time weather watch radar at the Norfolk Island airport.
- In November 2002 BoM installed ceilometer and visibility meters, providing a continuous monitoring capability of those parameters, including at times when weather observers were not on duty.
- From 2004, forecasters had access to minute-by-minute data from Norfolk Island's AWS.

In terms of forecast accuracy and reliability, in 2012 BoM stated:

> There are many factors which determine the accuracy and reliability of weather forecasts. These include the forecast location, observations from the forecast location, the observations in the surrounding area, the season, the complexity of the particular situation, the elements being forecast, the period of the forecast, the quality of the forecast models and systems available to forecasters, and the timeliness of updates to changing weather conditions (both forecasts and observations)...
>
> Even with advancements in the science of weather forecasting guidance in recent years, weather forecasting for remote islands will continue to be a forecasting challenge. Given the highly localised influences which can impact on conditions, and the current level of scientific knowledge for forecasting low cloud and fog at specific locations, weather forecasts, for the foreseeable future, will not be 100% accurate. This is particularly so in remote locations where there is little surface data in the surrounding area to effectively monitor approaching weather systems.

BoM advised a primary limitation with forecasting weather at locations such as Norfolk Island was the limited surface observation data available for the area around Norfolk Island. It advised that increasing the number of observation sites at Norfolk Island would have minimal influence on its forecasting reliability.

Reliability information from the TAF verification system

BoM regularly reviewed the reliability of its aerodrome forecasting processes. Evaluating the reliability of weather forecasting is a difficult process, and there is no single parameter that is effective. BoM used a range of parameters as part of its TAF verification system.

Two of the key parameters for evaluating forecasting are the probability of detection (POD) and the false alarm ratio (FAR). The POD percentage is the percentage of hours correctly forecast to be below a specified threshold (normally the alternate minima) divided by the total hours observed below the threshold. The FAR percentage is the percentage of hours incorrectly forecast to be below the threshold divided by the total hours forecast below the threshold.

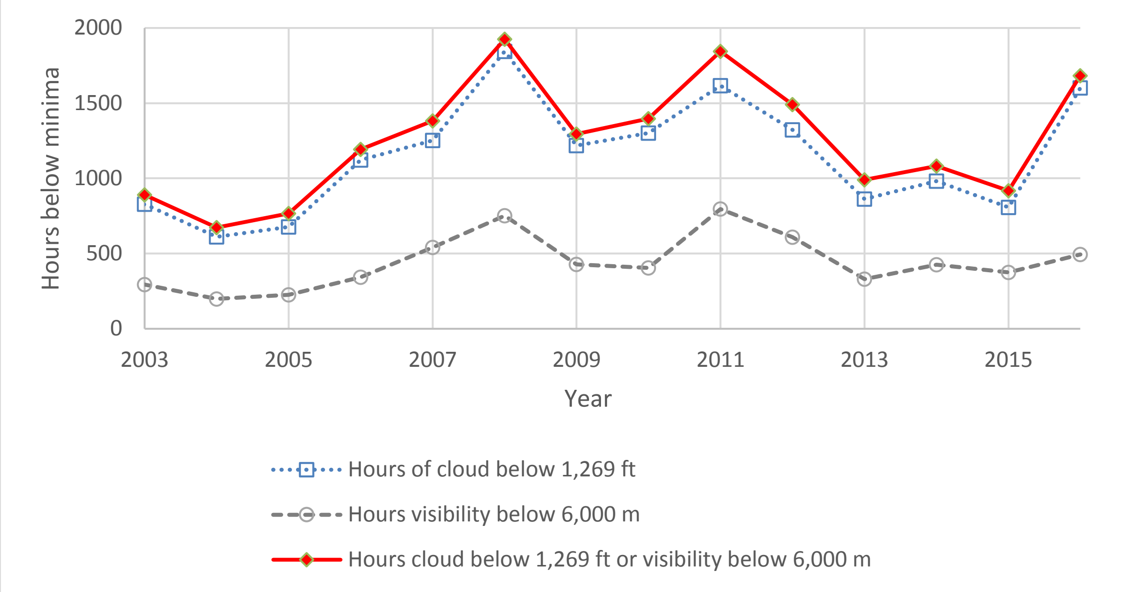
Ideally the POD will be as high as possible and the FAR will be as low as possible. A POD of nearly 100 per cent can be achieved by being extremely conservative, but this will be associated with a high FAR. BoM advised a FAR of 80 per cent was considered good.[123] If the POD increased and the FAR stayed the same or decreased over a period of time, then the overall reliability of forecasting improved. However, an increase in the POD with an increase in the FAR is more difficult to evaluate, as the increase in the POD could be associated with improved forecasting models and practices and/or a more conservative approach to forecasting.

Figure 29 provides the TAF hours[124] each year where the cloud and/or visibility was recorded below the alternate minima at Norfolk Island from 2003 to 2016. As indicated, low cloud was more commonly associated with conditions below the landing minima than visibility. When visibility was below the alternate minima, cloud was also generally below the alternate minima. Overall, for the period from 2007–2009, there were about 1,530 TAF hours per year when either the cloud or visibility was below the alternate minima (or about 18 per cent of the time). For the period 2003–2006 this figure was 880 TAF hours per year.

[123] An FAR of 80 per cent means that for every 5 hours forecast below the minima, only one of these hours was actually observed to be below the minima. The lower the FAR, the better. Some publications refer to a false alarm rate, which is defined differently to a false alarm ratio.

[124] Each TAF and each amended TAF was evaluated for a period of 6 hours. In other words, if an amended TAF was issued, the amended TAF would be evaluated for a period of 6 hours and the original TAF would also be evaluated for a period of 6 hours. Therefore, the total TAF hours involved in such analyses is more than the actual hours.

Figure 29: TAF hours per year of cloud and visibility below alternate minima at Norfolk Island

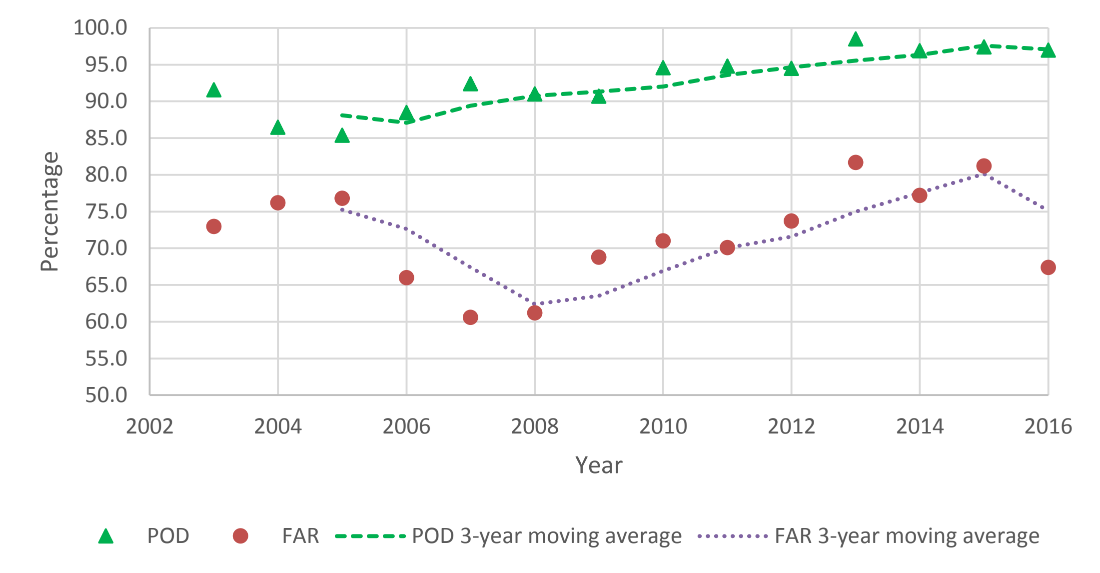


Source: ATSB based on data provided by BoM. The data was based on observations recorded in METARs and SPECIs.

Figure 30 shows the POD and FAR associated with TAFs at Norfolk Island for each year from 2003 to 2016. With regard to this figure:

- The two parameters used are cloud (alternate minima of 1,269 ft) and visibility (alternate minima of 6,000 ft), with the data reflecting if either of these parameters was observed or forecast to be below the alternate minima. Low cloud below the minima was significantly more common than visibility, and provided similar results as the combination of low cloud and visibility (see Figure 29).
- Data for years prior to 2003 were not included as the observed data during that period was collected in a different manner, using human observers rather than automatic sensors and with observations not collected for several hours each day.
- The data involves comparing the accuracy of recorded observations (in METARs and SPECIs) with the TAF over the first 6 hours of the validity period of each TAF. All TAFs and amended TAFs are included.
- The figure also shows the 3-year moving average of both POD and FAR. A moving average over 3 years provides more stable data for comparisons than examining data on a year-by-year basis.

Figure 30: POD and FAR for forecasting cloud and visibility at Norfolk Island from 2003–2016



Source: ATSB based on data provided by BoM.

As indicated in the figure, the POD increased from an average of about 88 per cent during 2003–2005 to about 91 per cent in 2007–2009. This increase in POD was associated with a decrease in the FAR from 75 per cent to 64 per cent, indicating that forecasting reliability increased between 2005 and 2009. However, because the total number of TAF hours below the alternate minima increased from 2003–2005 (776 hours per year) to 2007–2009 (1,534 hours per year), the number of TAF hours below the alternate minima that was not forecast (or 'missed') increased from 92 hours per year in 2003–2005 to 133 hours per year in 2007–2009.

Figure 30 also shows that the POD increased from 2007–2009 to about 95 per cent during 2010–2012 and 97 per cent during 2014–2016. These increases were associated with an increase in the FAR (72 per cent in 2010–2012 and 75 per cent in 2014–2016). Because the FAR increased, it was difficult to determine the extent to which the improvement in the POD was associated with improved forecasting models and practices or a more conservative approach to forecasting during this period. However, the POD significantly improved while the FAR remained below 80 per cent.

A POD of 91 per cent in 2007–2009 means that the miss rate (probability of actual conditions below the alternate minima not being forecast) was 9 per cent (which equated to 92 TAF hours per year). This miss rate decreased to 5 per cent in 2010–2012 (84 TAF hours per year) and 3 per cent in 2014–2016 (36 TAF hours per year).

Reliability information from the ATSB predictive weather analysis algorithm

Resulting from another ATSB investigation (AO-2013-100), the ATSB developed a predictive weather analysis algorithm. This algorithm was applied to examine reported weather observations (METARs and SPECIs) and TAFs at Norfolk Island, as well as other remote islands and selected capital city airports (see appendix J).

In contrast to the BoM TAF verification system, the ATSB algorithm examined the likelihood of an observation being below the landing minima and the TAF predicting conditions above the alternate minima. In addition, the ATSB algorithm examined this likelihood based on retrieving a TAF 1–3 hours prior to arriving at an aerodrome.

Detailed results of the ATSB analysis are provided in appendix J. In summary:

- Unforecast observations below the landing minima (when a TAF forecast conditions above the alternate minima) were rare at Norfolk Island during 2009–2014, occurring about 5.5 hours per year (or 0.06 per cent of the total time). In 2009, the amount was about 10.5 hours per year (0.12 per cent of the total time).[125]

- Overall, remote islands had a similar amount of unforecast weather below the landing minima as capital city airports. The overall average was about 11.5 hours per year per airport (about 0.13 per cent of the total time), but there was significant variability between airports and across years.
- The number of weather episodes below the landing minima at Norfolk Island was about the same in 2009 (52) as it was during 2010–2013 (56 per year). However the proportion of these episodes that were unforecast was significantly higher in 2009 (29 per cent) compared with 2010–2013 (13 per cent).
- During 2009, the proportion of episodes below the landing minima that were unforecast was similar at Norfolk Island compared to the other remote islands (25 per cent), and significantly lower than the capital city airports (45 per cent).
- False alarms (where conditions were above the alternate minima but were forecast to be below the alternate minima) occurred about 37 per cent of the total time at Norfolk Island during 2009–2014. This rate appeared to increase from 2009 (31 per cent) to subsequent years (43 per cent).
- Overall, false alarms were more prevalent at remote islands than at capital city airports, particularly at Christmas Island and the Cocos Islands. This, combined with the lower proportion of unforecast observations below the landing minima, suggests that forecasting for remote islands was more conservative than forecasting for capital city airports.
- The relative extent to which the apparent improvement in the forecasting of weather conditions below the landing minima at Norfolk Island was due to improved forecasting models and practices and/or a more conservative approach (as shown by false alarms) could not be determined.
- From the perspective of operational decision-making, forecasts retrieved at the latest possible time (before the point of no return) provided a better warning of potential conditions below the landing minima at Norfolk Island during 2009–2014. In other words, as the time between retrieving a TAF and arriving at the airport increased, the likelihood of encountering unforecast weather increased. This was particularly applicable for aircraft arrivals in the evening between 1800 and 0000 local time (0630 and 1230 UTC) for a TAF retrieved up to 6 hours prior to arrival.

Guidance information provided to forecasters

The forecaster(s) preparing TAFs and other aviation forecasts were qualified meteorologists. They developed forecasts using guidance from numerical weather prediction models, TAF climatological information and real-time observational data.

TAFs were prepared using a generic ‘top down’ process that relied on the application of meteorological knowledge and expertise when making forecasting decisions. The analysis of that information was conceptual and relied on a series of decisions based on the application of local information.

This technique was routinely applied during a shift and forecasters continually assessed their conceptual model of the atmosphere (and hence the accuracy of the forecasts) using the observations received. If the observations were not consistent with the original forecasting decisions, the forecast would be revised.

BoM advised that the forecaster who developed the TAFs during the afternoon and evening of 18 November 2009 had used the available guidance information. The meteorological conditions

[125] The ATSB obtained data from the period 2009–2013 to match the data for other locations obtained for other investigations. As noted in the previous section, data from BoM’s TAF verification system indicated 2009 was similar to the years just prior to 2009.

affecting the accident flight and forecasting decisions are further discussed in *Weather events at Norfolk Island on 18 November 2009*.

Prior to the accident, BoM had commenced developing a flowchart to assist the process of forecasting low cloud at Norfolk Island. The development of the flowchart was part of BoM's continuous improvement program.[126] The flowchart was finalised in April 2010 (see *Safety issues and actions*).

Advisory material regarding meteorological conditions at Norfolk Island

Civil Aviation Safety Regulation (CASR) 139 required an aerodrome operator to ensure there was adequate particulars about the aerodrome published in the *En Route Supplement Australia* (ERSA).[127] The types of information required included telephone numbers, runway specifications, lighting, visual aids, available ground services, special procedures and local precautions.

The Manual of Standards (MOS) for Part 139 provided more details regarding the types of information to be included in the ERSA. This included 'important cautionary or administrative information relating to the use of the aerodrome'. The 'Additional information' section of the ERSA for the aerodrome was also required to include 'significant local data', such as animal or bird hazards or areas to avoid overflying. There was no requirement to include the general meteorological conditions likely to be encountered at the aerodrome.

The ERSA information for many Australian aerodromes includes some types of hazards in the 'Additional information' section, such as birds, weather balloon launches, or the likelihood of turbulence on approach to particular runways. There was no information about general weather patterns or the potential for hazards associated with low cloud or visibility.[128]

For example, the ERSA information for Lord Howe Island airport stated that, due to the topography of the island, certain wind conditions could generate severe turbulence during approach and landing. Accordingly, the only safe course of action was to divert to an aerodrome on the Australian mainland. Christmas Island had an additional information note warning of moderate turbulence on late final approach when the surface wind was above 15 kt.

At the time of the accident, there was no advisory material provided in the ERSA for Norfolk Island or Christmas Island about the relatively high frequency of adverse weather associated with low cloud or reduced visibility, or the difficulty of forecasting adverse weather at these airports. As noted above, such information was not required to be included under CASR 139 or the MOS for CASR 139. CASA advised the adverse weather experienced at Norfolk Island lacked the specificity required to enable an ERSA entry, as opposed to the specific turbulent conditions associated with Lord Howe Island and Christmas Island.

The ATSB reviewed the AIP for several overseas aerodromes, including some generally known to be associated with frequent adverse weather conditions. Information about general weather conditions was not routinely included in the AIP for those locations.

As noted in *Information about specific aerodromes*, an aircraft operator was required to ensure flight crew of RPT and charter flights had adequate knowledge of the seasonal meteorological conditions of routes being flown.

ICAO Annex 3 (Meteorological service for international air navigation) stated:

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126 At about the same time, a similar process had also commenced for the forecasting of low-level turbulence at Lord Howe Island.

127 The ERSA was part of the AIP. It was published by Airservices Australia. However, the details for each aerodrome were provided by the aerodrome operator.

128 For some aerodromes, information was provided about hazards that may arise if low cloud existed. For example, for Mackay airport, the ERSA stated that in conditions of light mist or fog, high intensity floodlighting adjacent to the final approach to a runway could 'cause distraction'.

> 8.1.1 Aeronautical climatological information required for the planning of flight operations shall be prepared in the form of aerodrome climatological tables and aerodrome climatological summaries. Such information shall be supplied to aeronautical users as agreed between the meteorological authority and those users.

Annex 3 also included recommendations for each State to prepare climatological tables for each regular and alternate aerodrome and make these tables available to an aeronautical user within a time period as agreed between the meteorological authority and that user.

BoM advised the ATSB that as of 2009 this type of data could be provided to users on request.

Weather events at Norfolk Island on 17 November 2009 (outbound flight)

During VH-NGA's outbound flight from Sydney to Norfolk Island on the night of 17 November 2009, the flight crew were provided with weather reports that indicated there was broken cloud at 500 ft (just above the landing minima) and overcast cloud at 800 ft. The Unicom operator advised the crew that the conditions on the threshold for runway 29 were better than that reported by the AWS.

During the night of 17 November, the weather at Norfolk Island was influenced by a moist north-west airstream that was lifted from the surface of the sea as it passed over the island. This orographic lifting of the airstream enabled the formation of broken low level cloud at the centre of the airport throughout the night, with a cloud base between 400 and 600 ft.

The terrain descends to the south-east of the airport, which allows cloud formed by the orographic uplift in the north-westerly airflow to dissipate to the south-east of the airport as the airstream descends. The approach to runway 29 is to the south-east of the airport.

As noted in *Outbound flight from Sydney to Norfolk Island*, the Unicom operator on duty on 17 November 2009 advised the ATSB that the conditions resulting in low cloud confined to the high terrain north of the aerodrome were infrequent. Because he had noted the AWS was overstating the amount of cloud when compared to his observation of stars from the runway 29 threshold and along the aircraft's likely approach path, he had mentioned seeing stars from the threshold to the crew on the radio while they were on descent.

Appendix C provides further information on the TAFs and METARS/SPECIs issued for Norfolk Island relevant to the outbound flight on 17 November 2009 and the accident flight on 18 November 2009.

Weather events at Norfolk Island on 18 November 2009

Overview

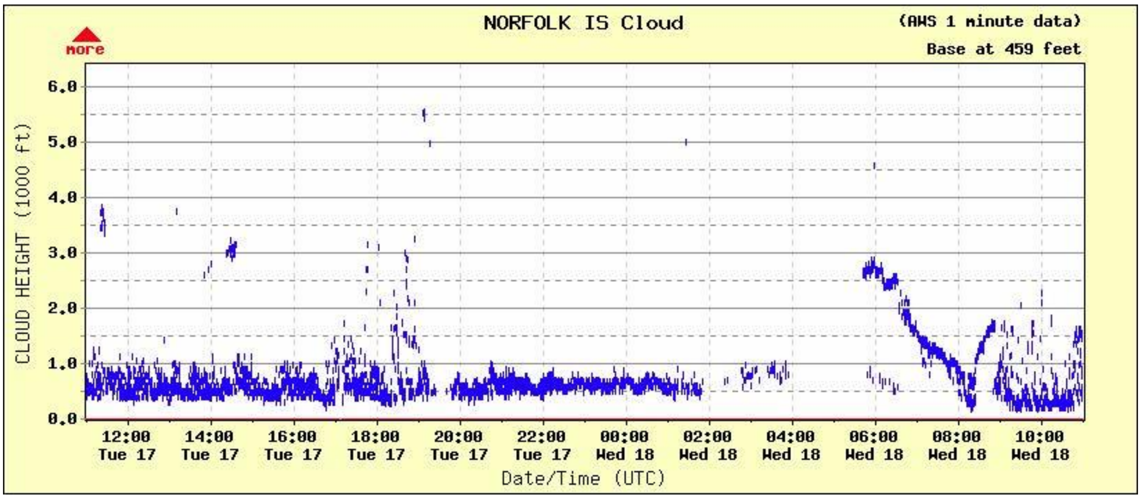
Table 19 provides a summary of key data from the METARs and SPECIs for Norfolk Island issued during the accident flight. Appendix C provides further information on the TAFs and METARS/SPECIs issued for Norfolk Island relevant to the accident flight on 18 November 2009.

BoM provided data outputs of information recorded by the ceilometer and visibility meter. The illustration of cloud height (Figure 31) and horizontal visibility (Figure 32) was based on 1-minute data outputs by the AWS between 1100 on 17 November 2009 and 1100 on 18 November 2009. This data was not subject to BoM's quality control procedures and this limitation should be taken into account when interpreting the data.

Table 19: Selected data from METARs and SPECIs during accident flight and actual data

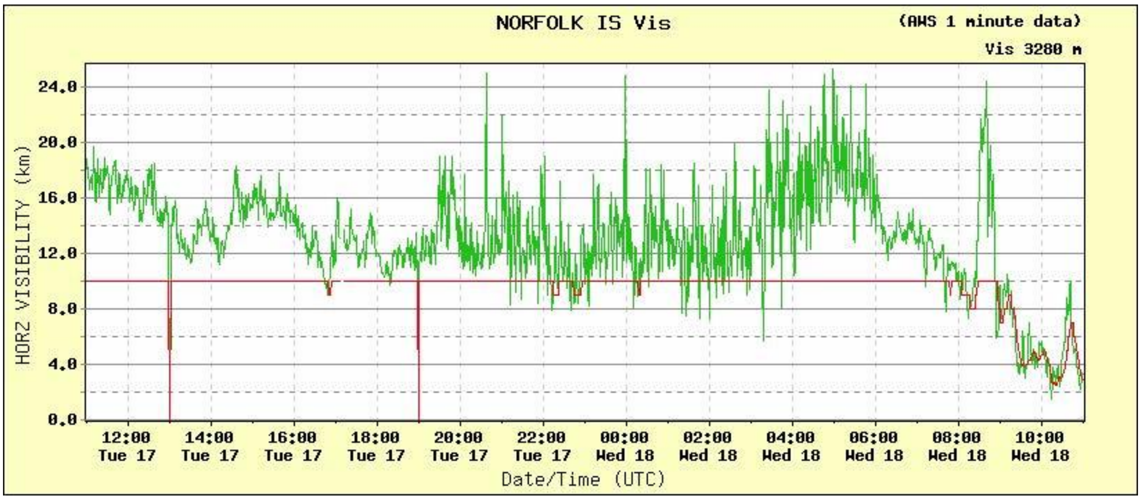
Issue time (UTC)	Type	AUTO	Visibility	Lowest cloud level	Lowest cloud height	QNH (hPa)	Temperature (°C)	Dewpoint (°C)	Rule of thumb estimate of cloud height	Actual temperature (°C)	Actual dewpoint (°C)	Estimate of cloud height (from actual temperature)
0600	METAR		9,999 m	few	800 ft	1011	21	19	834 ft	21.2	18.7	1,043 ft
0630	METAR		9,999 m	few	600 ft	1011	21	19	834 ft	20.9	19.0	792 ft
0700	METAR	AUTO	9,999 m	broken	1,700 ft	1011	21	19	834 ft	20.9	19.1	751 ft
0730	METAR	AUTO	9,999 m	overcast	1,300 ft	1012	21	19	834 ft	20.8	19.1	709 ft
0739	SPECI	AUTO	9,999 m	overcast	1,100 ft	1012	21	19	834 ft	20.8	19.1	709 ft
0800	SPECI	AUTO	9,999 m	overcast	1,100 ft	1012	21	19	834 ft	20.7	19.3	584 ft
0830	SPECI	AUTO	9,999 m	broken	300 ft	1013	20	19	417 ft	19.9	18.8	459 ft
0856	SPECI	AUTO	9,999 m	scattered	500 ft	1013	20	19	417 ft	19.9	18.6	542 ft
0900	METAR	AUTO	8,000 m	scattered	500 ft	1013	20	19	417 ft	19.9	18.6	542 ft
0902	SPECI	AUTO	7,000 m	scattered	500 ft	1013	20	19	417 ft	19.9	18.6	542 ft
0925	SPECI	AUTO	6,000 m	broken	300 ft	1013	20	19	417 ft	19.7	18.7	417 ft
0930	SPECI	AUTO	4,500 m	broken	200 ft	1013	20	19	417 ft	19.6	18.8	334 ft
1000	SPECI	AUTO	4,500 m	overcast	200 ft	1013	19	19	0 ft	19.1	18.5	250 ft
1030	SPECI	AUTO	3,000 m	overcast	200 ft	1013	19	18	417 ft	18.8	18.2	250 ft
1053	SPECI		5,000 m	broken	200 ft	1014	18	18	0 ft	18.4	17.7	292 ft
1100	SPECI		5,000 m	broken	500 ft	1014	18	18	0 ft	18.4	17.7	292 f
1111	SPECI	AUTO	3,200 m	scattered	300 ft	1014	19	18	417 ft	18.6	17.8	334 ft
1128	SPECI	AUTO	7,000 m	scattered	500 ft	1014	19	18	417 ft	18.5	17.5	417 ft
1134	SPECI		8,000 m	few	600 ft	1014	19	17	834 ft	18.6	17.3	542 ft
1200	SPECI		9,999 m	few	800 ft	1014	19	17	834 ft	18.8	17.3	626 ft

Figure 31: Norfolk Island ceilometer output, depicting the measurement of low cloud at the aerodrome as reported by the AWS during the period 1100 UTC on 17 November and 1100 UTC on 18 November 2009



Source: Bureau of Meteorology

Figure 32: Norfolk Island visibility meter output, depicting the measurement of visibility at the aerodrome as reported by the AWS during the period 1100 UTC on 17 November and 1100 UTC on 18 November 2009



Source: Bureau of Meteorology. Green line is the minute-by-minute AWS output, the red line is the 10-minute average (METAR/SPECI source), with truncation of visibility data exceeding 10 km.

As indicated in Figure 31, the lowest cloud (as minute-by-minute ceilometer output integrated over a 30-minute period) was about 200–300 ft above the AWS between 1000 and 1030 UTC when the four approaches and the ditching were conducted. Allowing for possible rounding of the ceilometer measurements to the nearest 100 ft, this could represent cloud at heights potentially as low as 150–250 ft above the airport. As indicated in Figure 30, visibility (as a minute-by-minute output) reduced during the same period to between about 2,000 and 3,000 m.

Events prior to departure

There was some early low cloud at Norfolk Island on the day of the accident. As the day progressed, the temperature increased and the low cloud broke up and the weather conditions during the afternoon were good. There was no rain, visibility was greater than 10 km and only scattered low cloud. The wind was generally north-westerly during the early to mid afternoon

The 0430 UTC infrared satellite image[129] showed a band of cloud associated with a weak, slow moving cold front that was approaching the island.

BoM reported that the numerical weather prediction models used by the forecaster showed only a weak change associated with the passage of the front. The forecaster's experience was also that low cloud at the aerodrome was more often associated with airstreams from the north-west through to the east, rather from the southern sectors from which the front was approaching. BoM indicated the forecaster's assessment was supported by climatological models, which indicated cloud ceilings below 1,500 ft were rarely seen in south-westerly airstreams following frontal passage. The north-westerly winds were expected to back to the west as the front passed the island and to continue backing to the south.

The TAF issued 0437 on the afternoon of 18 November was for the generally fine conditions to persist during the afternoon and early evening. The forecast indicated westerly winds persisting ahead of a southerly wind change and some light showers early the following morning. The forecast was based on the expectation that the front to the south of the island would remain weak and not cause any significant weather. Consistent with the numerical weather prediction models and BoM's climatological experience at the island, it was expected that the backing winds would reduce the moisture content of the surface airflow at the island and significant low cloud was not expected.

Prior to departing Apia, the captain obtained basic meteorological data from the 0437 TAF, which was a routine TAF valid from 0600 to 2400. The Brisbane briefing officer provided the following information:

- wind from 260°T at 8 kt
- visibility at least 10 km
- scattered cloud at 2,000 ft.

Other elements from the TAF were offered by the briefing officer, but the captain indicated these were not required. These included:

- from 1500 UTC, wind backing to 160°T at 12 kt, visibility at least 10 km, light showers of rain, scattered cloud at 1,000 ft and broken cloud at 2,000 ft
- forecast temperature at 3-hourly intervals from the commencement of the TAF validity of 21°C (0600), 19°C (0900), 18°C (1200) and 18°C (1500)
- forecast sea-level atmospheric pressure at 3-hourly intervals from the commencement of the TAF validity of 1010 hPa (0600), 1013 hPa (0900), 1013 hPa (1200) and 1012 hPa (1500).

No element of the TAF created an operational requirement for the specification of an alternate aerodrome or a requirement for the carriage of holding fuel.

Events after departure until 0900 UTC

The METARs issued during the late afternoon local time (0430–0630 UTC) indicated there was consistently 1–2 oktas[130] of cloud observed below 1,000 ft above ground level (AGL) and haze, and then later (commencing 0600 UTC) a gradually lowering ceiling of broken and overcast cloud and a split of 2°C between the current temperature and dewpoint. However, the main cloud base initially remained above the alternate minima and around the height forecast for the 3–4 oktas on the 0437 TAF. The last weather observation input made by the BoM observer at Norfolk Island on 18 November 2009 was at 0630. After that time, the weather reports were generated automatically by the AWS.

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[129] This image was taken by the geostationary satellite MTSAT-1R, operated by the Japanese Meteorological Agency.

[130] Okta: unit of measurement to describe the amount of cloud cover, with 1 okta equalling one eighth of the sky being covered by cloud.

The first weather observation indicating conditions at Norfolk Island were significantly worse than forecast was the 0730 METAR, when the cloud measured by the ceilometer had increased to overcast coverage at a height of 1,300 ft. That was followed by the 0739 SPECI, when the cloud had lowered to overcast coverage at a height of 1,100 ft. This was below the aerodrome's alternate minima but above the MDA for the runway approaches. The reported visibility was at least 10 km and the SPECI indicated there was still a 2°C split between the current and dewpoint temperatures (actual temperature split was 1.7°C).

The scheduled 0800 observation was also issued as a SPECI, indicating that the base of the cloud remained below the alternate minima, although it had not worsened since the 0739 SPECI. The reported visibility was still at least 10 km and there was still a 2°C split between the current and dewpoint temperatures (actual temperature split had reduced to 1.4°C).

In response to the 0739 SPECI, the NSW RFC forecaster issued an amended TAF at 0803 to include broken cloud at 1,000 ft. Because this cloud was below the alternate minima for the aerodrome, it created a planning requirement for the specification of an alternate aerodrome for flights planning to land at Norfolk Island.

The scheduled observation at 0830 was issued as a SPECI, indicating a further lowering in the cloud base, with broken cloud reported by the AWS at 300 ft, overcast cloud at 900 ft and a split of 1°C between the current temperature and dewpoint (actual temperature split was 1.1°C). The wind was backing towards the south and, although the reported visibility was still at least 10 km, the broken cloud at 300 ft was significantly below the landing minima for the instrument approaches.

However, soon after the 0830 SPECI, the ceilometer and visibility meter showed an improving trend at the airport and this information was also available to the duty forecaster in the NSW RFC. BoM advised that although the 0830 SPECI indicated broken cloud at 300 ft the TAF was not amended because of the improving trend, which was consistent with the forecaster's expectation of improved conditions after the frontal passage and with a southerly airflow.

By 0830 the cloud band and front had moved over the island, where it remained stationary for several hours - encompassing the time of the accident. Images from the Norfolk Island weather radar depicted patches of precipitation approaching the island from the south-west, arriving over the aerodrome between 0830 and 0930 and persisting until after the ditching.

A SPECI issued at 0856 confirmed the improvement in the AWS-reported conditions, which were now above the aerodrome's alternate minima. The observation indicated there was scattered cloud at 500 ft, scattered cloud at 1,200 ft and overcast cloud at 1,500 ft. The visibility was still greater than 10 km and the split between the current temperature and dewpoint remained 1°C (actual temperature split was 1.3°C). Although the observed weather conditions had improved above the aerodrome's alternate minima, the amended 0803 TAF remained valid and still required provision of an alternate aerodrome.

Events after 0900 UTC

The scheduled 0900 observation was issued as a METAR. The AWS reported scattered cloud at 500 ft and overcast cloud at 1,500 ft. Although still above the aerodrome's alternate minima, the reported visibility had reduced to 8,000 m and the dewpoint/temperature split was 1°C (the actual temperature split was 1.3°C).

The deterioration of the AWS-observed visibility continued and the amount of cloud increased, with a lowering of the cloud base. At 0902 a SPECI was triggered, which reported scattered cloud at 500 ft, broken cloud at 1,100 ft, overcast cloud at 1,500 ft, visibility 7,000 m visibility with the dewpoint/temperature split being 1°C (actual temperature split was still 1.3°C). The layer of broken cloud at 1,100 ft was below the alternate minima. The air in the post-frontal surface airflow was more humid than anticipated by the BoM forecaster or indicated by the climatological models and, consequently, the cloud was lower than forecast.

Conditions at Norfolk Island then continued to deteriorate. At 0925 another SPECI was issued with the AWS reporting broken cloud at 300 ft, broken at 800 ft and overcast at 1,100 ft, visibility 6,000 m and a dewpoint/temperature split of 1°C (actual temperature split was 1.0°C). The scheduled 0930 observation was also issued as a SPECI, with broken cloud at 200 ft, broken cloud at 600 ft, overcast cloud at 1,100 ft, visibility of 4,500 m and a dewpoint/temperature split of 1°C (actual temperature split was 0.8°C). The first rainfall was also recorded, with 0.2 mm falling in the previous 10 minutes.

At 0958 the Norfolk Island TAF was amended, to include temporary deteriorations of weather, up to 1 hour in duration, for the remainder of the forecast validity period (that is, until 2400). During these temporary deteriorations, visibility was forecast to reduce to 4,000 m, with showers of rain and broken cloud at 500 ft.

The 1000 scheduled observation, issued as a SPECI, indicated overcast cloud at 200 ft, visibility of 4,500 m and the temperature and dewpoint were both reported as 19°C (actual temperature split was 0.6°C). The scheduled observation at 1030 was a SPECI that indicated overcast cloud at 200 ft, visibility of 3,000 m, and a temperature dewpoint difference of 1°C (actual temperature split was 0.6°C).

At 1033, the airport manager radioed the Unicom operator from the threshold of runway 29, reporting that he could see a residential dwelling, on the higher terrain to the north-west of the airport. That dwelling was a distance about 1,900 m away and 90 ft above the airport elevation.

At 1053 a SPECI was issued indicating an improvement in visibility to 5,000 m. There was still broken cloud at 200 ft, broken cloud at 900 ft and overcast cloud at 1,400 ft.

One of the BoM observers attended the BoM meteorological office at Norfolk Island airport as part of the emergency response, to assist with real-time weather observations and the 1100 SPECI was issued with input from the BoM observer. The visibility was reported as 5,000 m, light rain showers and mist, broken cloud at 500 ft, broken cloud at 1,400 ft and dewpoint and current temperature both being reported as 18°C (actual temperature split was 0.7°C). Conditions generally improved after 1100.

Just over an hour after the ditching, at 1128, a SPECI was automatically issued indicating the weather conditions reported at the aerodrome by the AWS had improved above the alternate minima for a Category C aircraft. A total of 3 mm of rain was recorded during the prior 3 hours.

For SPECIs issued between 0930 and 1053, the cloud was at least 230 ft below the runway 11, and 290 ft below the runway 29 straight in approach landing minima. Although the visibility measured by the visibility meter was also reduced during this period, it had remained at or above the minima for a straight in approach to runway 11. For a straight in approach to runway 29, the visibility had remained above the minima, except for the 1030 SPECI, where the visibility had dropped marginally below.

Sunset and moon illumination

The end of civil twilight (last light) at Norfolk Island on 18 November 2009 was 0747 UTC. For the aircraft en route from Apia to Norfolk Island, the end of civil twilight would have occurred between the waypoints KILAN and APASI.

There was a new moon on 17 November 2009. Consequently, during the accident flight on 18 November, there was no significant illumination from the moon.

Sea surface conditions

The public weather forecast for Norfolk Island issued during the afternoon of 18 November 2009 indicated mostly fine conditions under the influence of a ridge of high pressure. A shallow trough of low pressure brought the possibility of a brief rain shower later in the day and early the following morning. Winds were forecast to be north-westerly at 10–15 kt, before shifting west to south-westerly later. Seas were forecast to be moderate on a moderate south to south-westerly swell.[131]

The captain reported that, just after the ditching, the swell was 1–1.5 m, with 2 ft (60 cm) of chop and no white water or breeze. The doctor and passenger reported the swell was 1–1.5 m, and the flight nurse reported the swell was 1.5 m to possibly 2.5 m.

The aircraft's heading at the time of the ditching was 230°M (245°T). Therefore with a forecast swell from the south to south-west, the aircraft was not flying parallel to the forecast swell when it ditched. At 1030, about 4 minutes after the ditching, the wind at the airport was about 9 kt from 160°T.

Aerodrome forecasts for potential alternate aerodromes

During the flight from Apia to Norfolk, the captain reported that he was considering both Nadi and Noumea as potential alternate aerodromes for an en route diversion if it became required.

With regard to Noumea:

- The captain nominated Noumea as the alternate for the flight from Sydney to Norfolk Island on 17 November 2009. He obtained the current TAF and NOTAMs during his pre-flight planning for this flight. The TAF for Noumea indicated there was a TEMPO that applied from 1200–2400 on 17 November, which applied for the period of the flight from Sydney to Norfolk Island. The TEMPO was associated with a visibility of 6,000 m, few cloud at 1,000 ft and scattered cloud at 2,000 ft, but it did not indicate any conditions below the landing minima. However, this TEMPO did not create an operational requirement for additional fuel for the planned flight.
- The captain did not obtain an updated TAF or NOTAMs for the flight from Apia to Norfolk Island on 18 November 2009. The TAF that was current during the period when he was planning the flight stated there was a TEMPO for the period from 0200–0800. However, this TEMPO did not create an operational requirement for additional fuel for the planned flight.
- A subsequent TAF was issued at 0500, soon after the captain finished flight planning. This TAF had no holding requirements.
- The METARs available during the flight from Apia to Norfolk Island indicated fine conditions at Noumea.

For Nadi:

- The captain did not obtain a TAF or NOTAMs for Nadi prior to the flight from Sydney to Norfolk Island, nor were any required.
- He also did not obtain a TAF or NOTAMs prior to the flight from Apia to Norfolk Island. The TAF that was current at the time of planning the flight from Apia to Norfolk Island stated there was a TEMPO for the period 0800 to 2400. The TEMPO was associated with periods of reduced visibility (5,000 m) and broken cloud at 1,200 ft due to thunderstorms, but conditions were not forecast to be below the landing minima. This TEMPO meant that if the flight was planned to arrive at Nadi after 0730, it required 60 minutes holding fuel.
- The METARs available during the flight from Apia to Norfolk Island indicated fine conditions at Nadi.

Further details of the TAFs and METARs for Noumea and Nadi are provided in appendix C.

[131] The Bureau of Meteorology used 'moderate' to describe waves that were generated by the local prevailing winds, 1.25–2.5 m and the sea becoming furrowed. A moderate swell was 2–4 m and used to describe regular, longer period waves, generated by distant weather systems.

Air traffic services information

Flight information regions

During the accident flight, the aircraft operated in the Auckland Oceanic FIR from Apia to waypoint APASI, the Nadi FIR from APASI to waypoint DOLSI, and the Auckland Oceanic FIR from DOLSI to Norfolk Island (Figure 3). In both FIRs, radio communications between flight crews and air traffic services (ATS) were usually conducted using high frequency (HF) radio, with air traffic controllers' instructions being relayed through a third-party operator.

In the Auckland Oceanic FIR, ATS was provided by Airways (the New Zealand air navigation service provider). The Auckland Oceanic controller provided aircraft separation services and coordinated with controllers in nearby centres. Flight crews communicated on HF radio with the Auckland air/ground (A/G) operator, who coordinated with the Auckland Oceanic controller.

In the Nadi FIR, ATS was provided by Airports Fiji (the Fijian air navigation services provider). The Nadi Oceanic controller provided aircraft separation services and coordinated with controllers in nearby centres. Flight crews communicated on HF radio with the Nadi international flight information service officer (IFISO), who coordinated with the Nadi Oceanic controller.

The Auckland A/G operator and Nadi IFISO utilised the same South Pacific HF frequencies. Airways reported that, at night, it was common for both operators to use the same frequency for aircraft operating in the region near the accident flight. On 18 November 2009, Auckland A/G operators and Nadi IFISOs communicated with the crew of VH-NGA on the same primary HF frequency (5,643 kHz) during the accident flight. Accordingly, both the Nadi IFISO and Auckland A/G operator could hear the other operator's communications, and both operators could not effectively broadcast simultaneously.

Flight information service

International standards

ICAO specifies standards and recommended practices (SARPS) for international aviation operations in a series of Annexes. ICAO Annex 11 (Air Traffic Services) outlined SARPS regarding the provision of ATS, including flight information service (FIS). It defined FIS as:

> A service provided for the purpose of giving advice and information useful; for the safe and efficient conduct of flights.

Annex 11 stated:

> 4.1.1 Flight information service shall be provided to all aircraft which are likely to be affected by the information and which are:
>
> a) provided with air traffic control service; or
>
> b) otherwise known to the relevant air traffic services units.
>
> *Note.— Flight information service does not relieve the pilot-in-command of an aircraft of any responsibilities and the pilot-in-command has to make the final decision regarding any suggested alteration of flight plan.*
>
> 4.1.2 Where air traffic services units provide both flight information service and air traffic control service, the provision of air traffic control service shall have precedence over the provision of flight information service whenever the provision of air traffic control service so requires…

Section 4.2.1 stated FIS shall include the provision of pertinent information of various types, including SIGMET information (for en route meteorological conditions), changes in the availability of radio navigation services and changes in the condition of aerodromes. In terms of aerodrome weather information, Annex 11 stated:

> 4.2.2 Flight information service provided to flights shall include, in addition to that outlined in 4.2.1, the provision of information concerning:
>
> a) weather conditions reported or forecast at departure, destination and alternate aerodromes…

ICAO document 4444 (Procedures for Air Navigation Services - Air Traffic Management) supplemented the Annex 11 SARPS. With regard to SPECIs and amended TAFs, it stated:

> 9.1.3.5.1 Special reports in the SPECI code form and amended TAF shall be transmitted on request and supplemented by:
>
> a) directed transmission from the appropriate air traffic services unit of selected special reports and amended TAF for the departure, destination and its alternate aerodromes, as listed in the flight plan; or
>
> b) a general call on appropriate frequencies for the unacknowledged transmission to affected aircraft of selected special reports and amended TAF; or
>
> c) continuous or frequent broadcast or the use of data link to make available current METAR and TAF in areas determined on the basis of regional air navigation agreements where traffic congestion dictates…
>
> 9.1.3.5.2 The passing of amended aerodrome forecasts to aircraft on the initiative of the appropriate air traffic services unit should be limited to that portion of the flight where the aircraft is within a specified time from the aerodrome of destination, such time being established on the basis of regional air navigation agreements.

ICAO document 7030 (Regional Supplementary Procedures) provided agreed air navigation procedures in eight regions around the world. For most regions, the following procedure clarified the scope of ICAO document 4444 paragraph 9.1.3.5.2:

> Amended aerodrome forecasts shall be passed to aircraft within 60 minutes from the aerodrome of destination, unless the information has been made available through other means.

The regions with this procedure included the Middle East / Asia, which included the Australian FIRs and the Auckland Oceanic FIR west of longitude 180° (that is, from approximately the area to the west of waypoint DUNAK, Figure 3). The Pacific region, which included the Nadi FIR and the eastern part of the Auckland Oceanic FIR, did not have this procedure.

Provision of flight information service in the Nadi FIR

The AIP Fiji Islands (GEN 3.3 Area Flight Information Service) stated:

> 3.3.1 FIS will be provided whenever practicable to all aircraft that are known to be affected by the information…
>
> 3.3.4 For aircraft in flight, flight information is normally confined to information concerning the route being flown up to and including the next attended aerodrome. This includes available information regarding nominated alternate aerodromes and unattended aerodromes enroute at which a landing is planned.
>
> 3.3.5 FIS does not diminish the responsibilities normally vested in the pilot of an aircraft, including that for making a final decision regarding any suggested alteration to flight plan.
>
> 3.3.6 Where ATC [air traffic control] units provide both FIS and ATC service, the provision of ATC service will take precedence over the provision of FIS whenever the provision of ATC service so requires.
>
> 3.3.7. FIS will include the provision of available and relevant information concerning…
>
> (b) weather conditions reported or forcasted, at departure, destination, and alternate aerodromes…

The Fiji Manual of Air Traffic Services (MATS) outlined requirements for the provision of FIS by the Fijian ATS provider. It stated:

> The purpose of the Flight Information Service (FIS) is the provision of such advice and information as may be required for the safe and efficient conduct of flight. An integral party of this service is the continuous application of initiative and anticipation in assessing the degree of hazard to which an aircraft may be expose [sic], and then coordinating with other units to alleviate the situation…
>
> A flight information service shall be provided to all aircraft which are likely to be affected by the information and which are:

a) provided by an air traffic control service; or

b) otherwise known to the relevant air traffic services…

An ATC service shall have precedence over the provision of a flight information service.

For en route aircraft, the manual stated FIS included the provision of:

- SPECI reports for destination or alternate aerodromes
- amendments to TAFs
- routine METARS and forecasts on request.

The Civil Aviation Authority of Fiji (CAAF) confirmed that the procedures required that the IFISO pass on SPECIs and amended TAFs to the crew of VH-NGA while the aircraft was in the Nadi FIR.

CAAF also reported:

- The Nadi Air Traffic Management Centre normally received METARs/SPECIs and TAFs within a few minutes of them being sent by the disseminating station.
- METARs/SPECIs and TAFs were delivered automatically to two printers, including one at the IFISO's workstation.
- The IFISO's workstation was enclosed in a soundproof booth.
- When SPECIs were received, they were displayed to both the IFISO and the controller.

On 20 November 2009, the ATSB asked CAAF for ATS records for the flight and the weather information that was provided to the flight crew of VH-NGA. CAAF forwarded the request to the ATS provider and then obtained the records in December 2009 to pass on to the ATSB. This included copies of the 0630 METAR, 0800 SPECI and 0830 SPECI.

CAAF advised it was not aware of the 0739 SPECI and the 0803 amended TAF until it received the ATSB's investigation report in 2012. CAAF contacted the ATS provider, who advised it had provided CAAF with all the weather reports it had received at the time (in 2009). The ATS provider advised CAAF it no longer held the hard copy print outs and therefore CAAF could not verify whether the 0739 SPECI or the 0803 amended TAF had been received.

The copy of the 0630 METAR indicated it had been retrieved within the Nadi ATS centre at 0757, consistent with the Nadi IFISO stating that it was the latest he had when queried about the time by the captain at 0802.[132] However, this did not mean that other METARs (such as the 0700 and 0730 METAR) and the 0739 SPECI were not available at that time.

During the reopened ATSB investigation, CAAF advised the ATSB that it had no record of any cases where SPECIs or amended TAFs were known to be issued for Norfolk Island (or any other aerodrome) but not received by the ATS provider. Similarly, Airways and Airservices Australia advised they were not aware of any cases where SPECIs or amended TAFs for Norfolk Island had been issued but not received by their agencies. AFTN messages received by Airways and Airservices Australia associated with the accident flight showed that the 0739 SPECI and 0803 amended TAF were received by those agencies at the time they were issued. Accordingly, the ATSB concluded that it was highly likely that the 0739 SPECI and the 0803 amended TAF were also received by the Nadi ATS provider.

Regarding why the Nadi IFISO did not pass on the 0830 SPECI, CAAF noted the provision of weather information is dependent on workload. If the IFISO was busy with HF communications with other aircraft, the officer would deal with addressing incoming messages such as weather reports after completing those communications. Based on the limited information available in

[132] The Nadi IFISO who received the request from the captain for the latest METAR at 0756 was different to the IFISO who provided the 0630 METAR at 0801, indicating that a handover had occurred during this period.

2015, the ATS provider was not able to provide advice about the workload of the IFISO during the relevant period.

AFTN messages showed that control of VH-NGA was transferred from the Nadi Oceanic controller to the Auckland Oceanic controller at 0835 UTC, just prior to the aircraft's expected arrival at waypoint DOLSI. The CVR recording from VH-NGA indicated the IFISO was involved in communications regarding position reports with another aircraft for about 90 seconds during 0830–0835. However, transmissions on the HF frequency being used by the flight crew (and recorded on the CVR) only provided a partial picture of the IFISO's workload.

The ATSB examined the extent to which there had been other cases where the Nadi IFISO position had not passed appropriate weather information to flight crews. The obtained evidence included:

- CAAF advised that the ATS provider conducted internal audits on its operations, including the provision of FIS via HF radio in the Nadi FIR. Such audits included random sampling of HF recordings. CAAF was not aware of any findings pertaining to the non-issue of pertinent weather information to flight crews. The matter had also not been identified in any previous investigations.
- Airservices Australia and Airways New Zealand advised they were not aware of any previous cases where Nadi ATS had not provided relevant weather information to a flight crew.
- The operator's Westwind pilots reported they could not recall receiving proactive advice about SPECIs or amended TAFs from Nadi ATS or other ATS providers in the Oceanic/South Pacific region. However, they also could not recall whether there had been any occasions where SPECIs or amended TAFs had been issued for an aerodrome and not passed on by the ATS provider.

Provision of flight information service in the Auckland Oceanic FIR

The AIP New Zealand (GEN 3.3 Area Flight Information Service) included the same statements as above in the AIP Fiji Islands.

For the provision of FIS in the Auckland Oceanic FIR, Airways also had similar procedures as the Nadi ATS provider. In addition, the New Zealand MATS stated:

> On first contact with ATS, IFR flights shall be informed of relevant MET and other information that has been issued during the preceding 90 minutes.
>
> New or amended flight information shall be offered to active flights within a sector/unit's area of responsibility and to flights entering the area within 10 minutes of receipt.

Airways confirmed that, although the Nadi IFISO was responsible for passing advice of the amended TAF at 0803 and the SPECI at 0830 (while the aircraft was under Nadi ATS' control), its procedures required the Auckland A/G operator to confirm that the flight crew of VH-NGA was aware of this amended TAF and SPECI.

For most aerodromes in the Auckland Oceanic FIR, routine weather reports were issued every hour rather than every 30 minutes. Soon after each hour, a weather bulletin was printed and provided to relevant personnel, including the Auckland A/G operator. This included the latest weather report for each location. In addition, all important messages, such as SPECIs and amended TAFs, were automatically sent to the A/G operator's console printer. One of the operator's priorities was to review and clear these messages.

As noted above, control responsibility for VH-NGA was transferred from the Nadi Oceanic controller to the Auckland Oceanic controller at 0835. The Auckland A/G operator initiated communication with VH-NGA's flight crew at 0841. Regarding why the A/G operator did not confirm the flight crew had received the 0803 amended TAF and the 0830 SPECI, Airways advised that she heard the Nadi IFISO pass on the 0800 SPECI to the crew and thought the IFISO had also passed on the amended TAF at the same time. It also advised that the A/G operator had planned to update the crew with the 0900 weather report when that was available.

Based on the limited information available in 2015, Airways was not able to provide any advice about the workload of the A/G operator during the relevant period. The CVR recording indicated she was involved in communications with several other aircraft during 0841–0900. There were also several periods where no transmissions occurred on the HF frequency being used by the crew of VH-NGA (and recorded on the CVR). However, the frequency used by the flight crew only provided a partial picture of the A/G operator's workload.

Airways advised the procedure to confirm that flight crews had received any significant weather information issued in the last 90 minutes was normally followed. It stated the A/G operator's lapse on this occasion was a rare event. It also reported that problems complying with the procedure had not been noted in other occurrence investigations, and the provision of FIS (and compliance with the procedure) was examined during routine performance assessments of A/G operators. As indicated in *Outbound flight from Sydney to Norfolk Island*, an Auckland A/G operator correctly applied the procedure during VH-NGA's flight from Sydney to Norfolk Island on 17 November 2009.

The Civil Aviation Authority of New Zealand advised it had no occurrence reports indicating problems with the application of the Airways procedure during 2010–2014.

The ATSB identified one previous case where an Auckland A/G operator did not pass on relevant weather information to a pilot. That occurred during a flight of a Piper Chieftain from Lord Howe Island (in the Brisbane FIR) to Norfolk Island in February 1999 (appendix I). In that case, an A/G operator did not pass on relevant SPECIs to the pilot. However, that A/G operator was aware the pilot had received a previous SPECI from Brisbane ATS that was similar in nature.

Provision of flight information service in Australian FIRs

Although Norfolk Island was an external territory of Australia, it was not located in the Australian FIRs. Therefore Airservices Australia (the Australian air navigation services provider) was not responsible for providing ATS at any stage during the accident flight.

The Australian AIP provided advice on the provision of FIS in the Australian FIRs. Although not specifically relevant to the accident flight, it provided useful context for Australian pilots or pilots operating in the Australian FIRs. The AIP (GEN 3.3 Air Traffic Services, paragraph 2.1.1) stated:

> Pilots are responsible for obtaining information necessary to make operational decisions. To ensure that accurate information is obtained in adequate time, pilots must take into consideration that ATC initiated FIS is limited to aircraft within one hours flight time of the condition or destination at time of receipt of the information by ATC. The only exception to this is SIGMET information, which shall cover a portion of the route up to two hours flying time ahead of the aircraft.

Paragraph 2.4.1 stated:

> The in-flight information services are structured to support the responsibility of pilots to obtain information in-flight on which to base operational decisions relating to the continuation or diversion of a flight…

Further details regarding the provision of FIS in Australian is provided in ATSB report AO-2013-100.[133]

Routine broadcasts of meteorological information on discrete HF radio

Routine broadcasts of selected operational meteorological information (VOLMET) are made on discrete HF ground-to-air frequencies. Those broadcasts are regularly made at fixed times and include notification of current SIGMET warnings, aerodrome reports (SPECI/METAR), trend forecasts and TAF.

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133 ATSB AO-2013-100, Landing below minima due to fog involving Boeing 737s, VH-YIR and VH-VYK, Mildura Airport, Victoria, 18 June 2013. Available from www.atsb.gov.au.

Included in the Auckland VOLMET broadcast was meteorological information relevant for Auckland, Christchurch, Faleolo, Nadi, Noumea, Pago Pago, Tahiti, Rarotonga and Wellington. These broadcasts were made on multiple HF frequencies, commencing at 10 minutes after the start of each hour and each half hour (and did not exceed 5 minutes duration).

In terms of Australian aerodromes, VOLMET broadcasts provided meteorological information for Australian major international airports (Sydney, Melbourne, Brisbane, Adelaide, Darwin, Perth and Cairns) and Townsville. These broadcasts were made on multiple HF frequencies, commencing at the start of each hour and each half hour (and did not exceed 5 minutes duration).

There was no indication on the CVR recording that the flight crew of the 18 November 2009 flight sought to obtain weather information using VOLMET for Nadi, Noumea or Auckland. The crew also did not report attempting to obtain such information.

Hazard alerts

The Australian AIP (GEN 3.3 Air Traffic Services, paragraph 2.5.4) described a hazard alerting service, provided as part of ATS-initiated FIS. It stated such alerts were used to notify flight crew of a 'sudden change to a component of FIS, not described in a current MET product or NOTAM, having an immediate and detrimental effect on the safety of an aircraft…'. Such ATS transmissions were prefixed by 'Hazard Alert'.

In other words, hazard alerts related to meteorological conditions at an aerodrome were required to be issued by ATS if ATS became aware of these conditions from another source other than an amended TAF or SPECI, and the information was different to that contained in the available TAFs and SPECIs.

Airways (New Zealand) advised it did not use the term 'hazard alert', and such a term was not included in its procedures or documentation. The term was also not included in the AIP Fiji or Fiji MATS, or relevant ICAO documents. However, those documents also included general requirements for the FIS to provide advice of significant information received from other aircraft or other sources.

At 0833 on 18 November 2009, the Norfolk Island Unicom operator contacted the Auckland Oceanic controller to inquire about the location of VH-NGA. The controller advised him that the aircraft was now due to arrive at 0955, and the Unicom operator noted it was late.[134] The controller asked the Unicom operator for the latest cloud information, and the operator stated there was 3 oktas [scattered] cloud at 300 ft, 4 oktas [scattered] at 600 ft and 8 oktas [overcast] at 1,100 ft. These conditions were below the alternate minima for planning a flight but not below the landing minima.

Based on the available information, there was no indication the Auckland Oceanic controller passed this information to the Auckland A/G operator. Airways advised that, given the information from the Unicom operator was not materially different to that contained in the available weather products (that is, the 0830 SPECI), it was most likely the Auckland Oceanic controller did not think it was necessary to pass it on to the flight crew (in addition to the 0830 SPECI).

HF radio communications

As noted in *Cruise from APASI reporting point (0709)*, the captain reported that he did not recall hearing some of the details of the 0800 SPEC provided by the Nadi IFISO. Accordingly, the ATSB examined aspects associated with HF radio transmissions.

The flight crew communicated via VHF radio with the Samoa ATS when departing Apia and the Norfolk Island Unicom operator when nearing Norfolk Island. VHF radio provides high quality, line-

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[134] The Unicom operator later reported that Auckland Oceanic controllers normally contacted the Unicom operator when an aircraft was 60-90 minutes from arriving at Norfolk Island. On this occasion the Unicom operator expected the aircraft to arrive between 0900 and 0930 UTC.

of-sight communications under normal conditions. However, such communications are only effective over relatively short distances, with the range between stations dependent on altitude. At an altitude of 39,000 ft and under normal atmospheric conditions, the distance to the sea-level VHF radio horizon at Norfolk Island is about 240 NM. At an altitude of 35,000 ft, it is about 230 NM.

In contrast, HF radio provides a longer range with propagation of the radio waves over much longer distances. It is therefore used for communications in large areas of the world, particularly where the installation of significant numbers of radio transmitters is not practicable. The HF frequency band is from 3,000 to 30,000 kHz.

Propagation of HF radio waves over long distances is possible due to energised particles in the ionosphere[135] refracting some radio waves in the HF spectrum back towards the surface of the Earth. A number of factors affect the propagation of HF radio waves through the atmosphere and their usability for long-range communication. The optimum HF frequency depends on the time of day, time of year, solar activity and the location of ionospheric refraction points relative to the transmitting and receiving stations.[136] The layers of the ionosphere vary in height and density depending on the time of day.

Although HF provides a longer range, it is affected by radio noise, including signal interference from both natural and human-made sources. For example, thunderstorms are a significant source of natural radio noise within the HF frequency spectrum, with lightning discharges producing broad spectrum atmospheric noise. The noise may display some directionality depending on the location and spread of storms relative to the receiving antenna. The effects of atmospheric noise are more significant in the lower HF spectrum, and consequently they are more likely to affect signal quality during the hours of darkness when the lower frequencies are in use (see below). Other sources of potential interference include solar events such as flares, coronal holes and coronal mass ejections. Those factors can disrupt the ionosphere and affect the reliability of the HF radio spectrum.

Government agencies worldwide continuously monitor solar activity and other factors that could affect the propagation of radio waves in the HF frequency spectrum. In Australia, that function is performed by BoM's Space Weather Services (formerly known as IPS Radio and Space Services). The agency monitors propagation conditions for HF communications and issues warnings for HF communication disruptions, current HF fadeout and HF fadeout warnings and regional ionospheric conditions.

During the accident flight, the Nadi IFISO provided the flight crew with weather information from 0801 to 0803 UTC via HF radio, which included the 0800 SPECI. The ATSB obtained a copy of these communications recorded on the 5,643 kHz frequency by Airways. The transmissions on this recording from the Nadi IFISO and the captain were clearly audible.

Exactly how the Nadi IFISOs transmissions would have sounded to the flight crew could not be determined as the CVR recording started at 0822, about 20 minutes later. However, there were no known circumstances that would indicate that HF transmissions would have been adversely affected at the time. More specifically:

- CAAF advised the south-east portion of the Nadi FIR was not a known problem area for HF transmissions. At times, HF problems are experienced and when these occur they are logged. CAAF reviewed the log book and there were no reported problems in the area at the time the aircraft transited.

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[135] The ionosphere comprises atoms and molecules that have been electrically charged (ionised) by radiation from the sun, extending from a height of about 50 km to over 500 km. The density of ionised particles within this band is not uniform and fluctuates depending on a number of factors, including time of day, season and solar activity.

[136] A comprehensive introduction to HF radio propagation can be downloaded from the BoM website http://www.sws.bom.gov.au/Educational/5/2/2.

- Around sunrise and sunset, rapid changes occur in the lower layers of the ionosphere that can affect the reliability of the HF spectrum. On 18 November 2009, at the position the aircraft was at 0800, last light (civil twilight) occurred at about 0655 at ground level and at about 0722 at FL 390.
- In general, the lower HF frequencies are more usable at night due to reduced attenuation of these frequencies by the ionosphere's D-layer, which disappears at night. The 5,643 kHz frequency the flight crew were using would be typical for night-time operations, with higher frequencies being used during the day.
- BoM reported normal ionospheric conditions were present at the relevant time and location on 18 November 2009. It noted there was no significant solar flare activity capable of impacting HF communications, and solar activity was low (consistent with the season and phase of the solar activity cycle). Overall, it concluded that it was unlikely that ordinary HF communications were compromised by any significant ionospheric or solar disturbance.

The CVR recording commenced at 0822 UTC. The flight crew had the HF frequency 5,643 kHz selected from that time until the crew completed communications with the Auckland A/G operator at 0947. During that time:

- When there were no transmissions on the frequency, there were periods of static noise. These varied from much less than 1 second to several seconds, and they were separated by pauses that varied from much less than 1 second to several seconds. Overall, this noise was typical of that encountered during normal HF radio communications and typical of atmospheric-induced noise. The noise was relatively consistent throughout the period from 0822 to 0940.
- There were several transmissions from the Auckland A/G operator to the VH-NGA flight crew from 0841 to 0947. There were also transmissions from the A/G operator to other flight crews from 0827 to 0947. All of the transmissions were audible above the background noise. During many of the transmissions, the background noise was less discernible, consistent with this noise being effectively suppressed by the aircraft's HF receiver.
- There were transmissions from the Nadi IFISO to other flight crews from 0832 to 0902. The transmissions were audible above the background noise. During some of the transmissions, including the transmissions at 0832, the background noise was less discernible.
- In transmissions from the HF operators or other flight crews and recorded on the CVR, there was no indication of any intermittent skipping or fading in and out of the signal that was significant or made the HF radio transmission unreadable. There were instances where a party did not respond to another party's transmission. However, whether this was due to the transmission not being received or whether it was due to the receiving party being busy with other tasks could not be determined.

It is not uncommon during HF communications between flight service operators and flight crews that one or more elements of a transmission will not be clearly heard. In such cases, the receiving party will ask for the element(s) to be repeated. This occurred during several of the transmissions between the VH-NGA flight crew and the HF operators during the flights on 17 and 18 November 2009. During the communications at 0801 to 0803 on 18 November 2009, the only item of information that either party asked to be repeated was the time of the 0630 METAR. The captain had heard the time correctly, but was surprised about the time, as it meant the METAR was 90 minutes old.

Given the potential for disrupted communications in the HF spectrum, ATS nominate a primary and secondary HF frequency to flight crews. This frequency nomination is based on space weather monitoring agencies' predictions of the most reliable frequency, given the expected conditions. In the event that communication is not established on the primary frequency, flight crews can attempt to call on the secondary frequency.

At 0711 on 18 November 2009, the captain initially attempted to contact the Nadi IFISO on the primary frequency and did not receive a response. At 0715 he attempted to contact the IFISO on the secondary frequency and did not receive a response. One minute later, the IFISO contacted the flight crew and advised them to use the primary frequency. This sequence of events suggests the IFISO was not able to respond to the flight crew immediately due to workload rather than due to HF transmission difficulties.

In summary, although there can be issues with conveying information by HF transmission, the available evidence indicates the level of static and interference on the HF frequency at the time of the 0801–0803 transmissions was not abnormal.

Reduced vertical separation minima

The captain reported one of the reasons he decided to depart with full main tanks rather than full fuel on the 18 November 2009 flight was associated with the operator's aircraft not being approved for reduced vertical separation minima (RVSM) operations. Accordingly, the ATSB examined aspects associated with RVSM.

Approvals for operating in RVSM airspace

The pressure-sensing accuracy of conventional barometric altimeters reduces as altitude increases. For that reason, the prescribed vertical separation minimum for aircraft operating above FL 290 was traditionally 2,000 ft.

At the time of the accident, ATS providers in the Auckland Oceanic FIR, Nadi FIR and Australian FIRs all applied reduced vertical separation minima (RVSM) between FL 290 and FL 410 (inclusive). This meant that ATS could apply a vertical separation standard of 1,000 ft rather than 2,000 ft between those flight levels.

For ATS to apply RVSM, the aircraft being separated have to meet specific requirements and be approved by the relevant civil aviation authority. Non-RVSM approved aircraft are able to operate in RVSM airspace under specific conditions, which vary depending on the FIR. For a non-RVSM approved aircraft, ATS have to apply a vertical separation standard of 2,000 ft between it and other aircraft.

It is generally more fuel efficient to operate a Westwind 1124/1124A at flight levels within RVSM airspace than below FL 290. In particular, the aircraft normally operates most efficiently between FL 340 and FL 410 for aircraft weights greater than 16,000 lb. During normal operations, it would be rare for the aircraft to be able to operate above FL 410. Extended flying at altitudes lower than FL 290 would normally require the carriage of additional fuel to compensate for the lower efficiency.

To be issued an RVSM airworthiness approval, an aircraft needed to be equipped with:

- two independent altitude measurement systems, capable of measuring the aircraft's altitude to a specified standard
- a secondary surveillance radar (SSR) reporting transponder
- an altitude alerting system
- an automatic altitude control system, capable of maintaining the aircraft's altitude within a specified tolerance.

There were supplemental type certificates and service bulletins that enabled the Westwind 1124/1124A to comply with the requirements of the RVSM airworthiness approval. To meet the accuracy requirements for altitude measurement typically required the aircraft's air data computer and altimeters to be upgraded.

The operator's Westwind aircraft were not approved for RVSM operations. The operator's Westwind standards manager indicated the cost of complying with the relevant requirements was substantial. It was accepted as an operational limitation that, using non-RVSM approved aircraft in RVSM airspace, they could on some occasions be required to change level or potentially be excluded from operating in RVSM airspace altogether.

The operator's OM did not provide any guidance to flight crew for flight or fuel planning in non-RVSM equipped aircraft in RVSM airspace. There was also no guidance on aircraft operating techniques to cover contingencies if access to RVSM airspace was not available.[137]

Operations in RVSM airspace in the Australian FIRs

For operations within the Australian FIRs, a flight crew of a non-RVSM approved aircraft was able to flight plan to operate within RVSM airspace. ATS clearance to operate in the RVSM band was subject to the disposition of traffic, and in general RVSM-approved aircraft had priority over non-RVSM approved aircraft, subject to other priorities.

The Australian AIP (ENR 1.10 Flight Planning) outlined requirements and guidance for submitting a flight plan for a flight in the Australian FIRs or internationally. A pilot could nominate a special handling code, which controllers could use when determining priorities for different services. For medical flights, the available special handling codes included:

> MED 1: An aircraft proceeding to pick up, or carrying, a severely ill patient, or one for whom life support measures are being provided.
>
> MED 2: An aircraft proceeding to pick up medical personnel and/or equipment urgently required for the transport of a MED 1 patient, or returning urgently required medical personnel and/or equipment at the termination of a MED 1 flight.

In addition, the AIP also referred to hospital flights (HOSP):

> Hospital Aircraft: A priority category for use by international aircraft when medical priority is required (see also Medical).

The AIP (ENR 1.4, ATS Airspace Classification, paragraph 10.1) stated a MED 1 flight or HOSP aircraft would have priority over most other types of flights. Airservices confirmed that a non-RVSM approved aircraft on a MED 1 flight or HOSP aircraft would have priority over an RVSM-approved aircraft.

Operations in RVSM airspace in the Auckland Oceanic FIR

For operations in the Auckland Oceanic FIR, the flight crew of a non-RVSM approved aircraft were able to flight plan within the RVSM band in specific circumstances. These included a flight being utilised for 'mercy or humanitarian purposes', such as an ambulance flight.

According to the AIP New Zealand (ENR 1.8 Regional Supplementary Procedures, paragraph 1.3.6), the operator of a non-RVSM approved aircraft wanting to operate in RVSM airspace in the Auckland FIR had to contact Auckland Oceanic Control by telephone 4–12 hours prior to the intended departure time. The AIP stated that submitting a flight plan was not sufficient notification.

Airways advised that, in practice, its controllers treated a flight the same regardless of whether prior approval had been sought. In either case, after a flight crew requested a clearance to enter RVSM airspace, the relevant controller analysed the situation and issued a clearance if traffic permitted. Non-RVSM approved aircraft would generally be allowed to operate within RVSM airspace subject to the other aircraft in the airspace. However, RVSM-approved aircraft would have priority.

Airways also advised a medical flight, even in a non-RVSM approved aircraft, would receive priority for its requested level subject to separation requirements being met for other aircraft. However, for the relevant controller (such as the Auckland Oceanic controller) to be aware a flight was a medical flight and the flight crew wanted priority, the flight crew needed to follow the procedures outlined in the AIP. These procedures included:

- providing advance notice by telephone of the intention to use RVSM airspace (see above)

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[137] The OM included procedures for operating RVSM-approved aircraft in RVSM airspace. These procedures included reviewing the status of mandatory equipment before entering the airspace and contingencies in the event a required system became unserviceable.

- including the relevant special handling code in the flight plan
- requesting priority on the radio (when requesting a clearance to enter controlled airspace).

Airways explained that simply including a special handling code on a flight plan was not sufficient. As of 2009, the special handling codes submitted in a flight plan were not automatically displayed on a controller's electronic flight progress strip (or the strip used by A/G operators). Accordingly, providing advance notice by telephone provided greater assurance that the purpose of the flight would be known and passed on to the relevant personnel prior to the flight, and the controller could add this information into a special comments field associated with the flight.[138] Regardless of whether a flight crew provided advance notice or included a special handling code on their flight plan, they still needed to state the nature of their flight and request priority on their first radio contact with ATS.

The AIP New Zealand listed special handling codes that pilots could include on flight plans. The only special handling code for a medical flight was 'HOSP', which meant 'ambulance flight'. Airways noted 'MED 1' was not an approved special handling code for operations in New Zealand FIRs. However, most of its controllers and A/G operators would probably understand that it meant a medical priority flight.

Captain's experience with RVSM airspace

In his initial interviews with the operator and the ATSB in November and early December 2009, the captain did not mention RVSM airspace when explaining his process for fuel planning and his reasons for not taking full fuel on the accident flight. Subsequently, with regard to airspace aspects:

- In December 2009, the captain advised CASA that one of the reasons he decided not to take full fuel was, with less fuel, the aircraft could climb quicker, which provided better access to the upper-level airspace.
- In January 2010, the captain advised the ATSB that the flight path between Apia and Norfolk Island crossed the route used by airline aircraft flying between the US and Australia. These aircraft were RVSM-approved and generally operated in the middle part of the RVSM band. He believed that New Zealand controllers did not want a non-RVSM approved aircraft at these middle flight levels, and would therefore direct such aircraft to climb higher or descend lower. He said that, with not wanting to take full fuel for the 18 November 2009 flight, it was important to be able to climb as high as they could in the early part of the flight so they could avoid the other traffic. He also noted that, if they were held down at FL 270, they could not have completed the flight, even if they had used long-range cruise settings.
- In 2012, during the Senate Inquiry, the captain said a factor in his decision to not take full fuel for the flight was that the aircraft was not RVSM-approved.

During the reopened ATSB investigation, the captain stated that a key reason he did not take full fuel was associated with the aircraft not being RVSM-approved and the requirement to operate in RVSM airspace in the New Zealand FIRs. By having a lower aircraft weight, the aircraft could climb more quickly and therefore have more chance of accessing the higher level airspace. He said he had always managed to avoid problems with reaching or maintaining suitable flight levels in the New Zealand FIRs by asserting that his flight was a MED 1 (medical priority) flight. As a result, he had never been denied access to RVSM airspace, and had never had to descend to an unsuitable flight level. However, he believed that at some stage that would happen.

The captain supplied an email he had sent to the operator's engineering manager in December 2008. The email outlined several points of concern regarding a specific aircraft (VH-KNR)

[138] The requirement to request prior approval by telephone was removed in 2012. Airways advised that, at that time, its air traffic management system was modified so that the special handling codes included on a flight plan were automatically displayed to controllers on the electronic flight progress strip.

following an air ambulance trip from Adelaide to Auckland and then return to Sydney.[139] One point stated:

> Had big issue with NZ ATC over not being RVSM again but needing to fly in RVSM airspace – I feel like we're on borrowed time with this one – soon they will just say no and put us down to 28 thousand – will be a big deal then…

Based on the operator's flight records, the captain had operated in New Zealand FIRs on the following trips:

- January 2008: Sydney-Auckland-Rarotonga, Rarotonga-Auckland-Sydney (as first officer)
- December 2008: Sydney-Norfolk Island-Sydney
- December 2008: Adelaide-Auckland-Sydney
- September 2009: Sydney-Norfolk Island-Apia, Apia-Norfolk Island-Sydney
- November 2009: Sydney-Norfolk Island-Apia.

All of these flights were air ambulance flights. Accordingly, if the flight crew had requested medical priority during communications with ATS, they would very likely have been provided priority for flight levels in RVSM airspace.

On the outbound flights from Sydney to Norfolk Island, and Norfolk Island to Apia on 17 November 2009, the flight crew had no difficulties with requesting and maintaining their desired flight levels in the Auckland Oceanic FIR. On their first contact with the Auckland A/G operator on both flights, the flight crew did not inform the operator they were conducting a MED 1 flight or seeking priority.

Other flight crew's experience with RVSM operations

When interviewed during the reopened investigation, the operator's other Westwind pilots reported the following regarding their general experience with RVSM airspace in the period prior to the 18 November 2009 accident:

- They rarely had difficulty obtaining their requested flight levels within the Australian FIRs, except perhaps sometimes on busy routes such as between Sydney and Brisbane. Therefore, they normally flight planned at FL 350 or a similar level within an Australian FIR.
- They routinely included MED 1 as a special handling code on their flight plans for air ambulance flights.[140] However, if they were returning to their home base after offloading the patient they would use MED 2.
- Several pilots reported they often had difficulties accessing RVSM flight levels when flying to or from Indonesia, Singapore or countries further north. In such situations they would generally flight plan and fuel plan to fly below RVSM airspace.
- Pilots who had operated in the Oceanic/South Pacific region did not recall any difficulties accessing their preferred flight levels. They said there was generally little traffic in this airspace, and they would not expect to be forced to fly at a lower than desired flight level. Accordingly they always flight planned at FL 350 or a similar level when operating in this region. As noted in *Operator requirements for flights to remote aerodromes*, they also generally departed with full fuel for long-distance flights in this region.
- The Westwind standards manager had operated many flights to New Zealand, in the New Zealand FIRs and in the Oceanic/South Pacific region. He said he had never encountered any difficulties accessing his desired flight levels on such flights. He recalled that on a couple of flights from Sydney to Norfolk Island, ATS asked them to descend so they were at FL 290 at the

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[139] On both of these flights, the aircraft departed with full fuel and landed with 2,800 lb (at Auckland) and 3,700 lb (in Sydney).

[140] The operator reported it did not provide guidance to captains in relation to the use of the MED 1 special handling code. It indicated the decision to use this code was generally made by captains after consulting with the medical personnel prior to departure.

FIR boundary. On those occasions, this was to facilitate a significant amount of traffic between Australia and New Zealand. Such a request was not problematic, given they needed to descend relatively soon after the boundary anyway.[141] He also noted that, if for some reason they had wanted to maintain a higher flight level and they were on a MED 1 flight, he believed they would have been given priority and been able to maintain their flight level.

- Most of the other pilots who had operated to or from New Zealand could not recall encountering any difficulties with access to their desired flight levels. One captain, who had conducted two flights from Sydney to New Zealand, reported he had encountered difficulties in getting access to suitable flights levels when flying to or from New Zealand. For such flights he would plan to fly at FL 270–280 and then seek access to FL 350 if he could. One first officer also recalled being held down at a lower than normal level on a flight departing from New Zealand. It is likely that these two pilots' were recalling the same flight, and one of the flights they had conducted to New Zealand together was not an air ambulance flight.
- The Westwind standards manager stated it was a captain's responsibility to provide New Zealand ATS advance notice by telephone of their intention to access RVSM airspace in the New Zealand FIRs. Some captains who operated flights to and from New Zealand reported they were aware of this requirement, whereas other captains (including the captain of the accident flight) could not recall being aware of the requirement. The captain who had encountered difficulties accessing RVSM airspace on flights to and from New Zealand reported that obtaining prior approval had improved his chances of getting access to RVSM airspace.

Incidents involving the operator's Westwind aircraft associated with RVSM airspace

Airways (New Zealand) advised it had never expressed any concern to the operator, CASA or Airservices about the operator's flight planning and seeking access to RVSM airspace in non-RVSM approved aircraft. It had only submitted one incident report associated with the operator's aircraft during 2004–2009, and this was associated with position reporting (see *Position reports*) and unrelated to RVSM. It also had no data available on occasions when the operator's flight crew had requested but been denied access to RVSM airspace. However, it noted that if the flight crew of an air ambulance flight had requested priority via the radio, access to RVSM airspace would have been provided as soon as practicable.

Airservices advised it had never expressed any concern to the operator or CASA associated with the operator flight planning and seeking access to RVSM airspace in non-RVSM approved aircraft. Similarly, it had no record of other ATS providers expressing concern associated with the operator's aircraft in RVSM airspace.

Airservices provided information about occurrences in 2005 and 2008 involving the operator's Westwind aircraft where the aircraft were not able to maintain the assigned level in RVSM airspace and therefore had to descend. The Westwind standards manager reported that when operating flights near the jetstream, an aircraft could encounter significant temperature changes. If the aircraft was operating at higher flight levels and/or at high operating weights, a sudden increase in temperature could result in the aircraft no longer being able to maintain its altitude.[142]

Airservices also advised there were five events during 2007–2009 where a flight plan for one of the operator's Westwind aircraft incorrectly indicated the aircraft was RVSM-approved. All of these events were associated with flights departing from Indonesia to Australia. After a review of these events, the operator issued a notice to its pilots on 12 October 2009. This notice stated that the operator's review found its ground handling agent in Indonesia had incorrectly inserted a 'W' into the equipment box on some flight plans, indicating the aircraft was RVSM-approved. The notice reminded pilots to complete an International Flight Plan Preparation Form and hand it to the agent

141 The FIR boundary was at waypoint TEKEP, located 636 NM north-east of Sydney or 272 NM south-west of Norfolk Island.

142 Turbulence associated with the jetstream could also increase the aircraft g-loading/stall speed with a consequent reduction in the buffet boundary (the difference between high and low speed buffet).

when operating from an Indonesian port. It also required pilots to check all details of their flight plans were correct.

The operator advised it had not received any occurrence or hazard reports from any flight crew in 2008–2009 where concern had been expressed regarding problems with accessing RVSM airspace.

The Westwind standards manager advised he was not aware of the email sent by the captain of the accident flight in December 2008 to the maintenance manager expressing concerns with operating in RVSM airspace on flights to New Zealand. He could not recall receiving any other email submitted by the captain regarding concerns about RVSM airspace.

Access to RVSM airspace during the accident flight

For the accident flight from Apia to Norfolk Island on 18 November 2009:

- The captain’s submitted flight plan requested FL 360, and the flight crew were initially cleared to FL 310.
- On first contact with the Auckland A/G operator (at 0600 UTC), and in all subsequent communications, the captain did not advise the A/G operator they were conducting a medical or hospital flight or seeking priority on that basis.
- At 0620, the A/G operator advised the flight crew they were cleared to climb to FL 350 with a requirement to reach this level by 0630.
- At 0625, the Auckland Oceanic controller contacted the A/G operator to ask where VH-NGA was in its climb, as he may have to push the aircraft back down due to ‘Nadi traffic’. The A/G operator contacted the flight crew and requested their flight level, which was passing FL 330.
- At 0628, following a request from the Oceanic controller, the A/G operator instructed the flight crew descend to FL 270 and report reaching this level by 0650 due to Nadi traffic.
- At 0628, the captain advised the A/G operator that descent below FL 310 would make it ‘difficult for us fuel wise’. He then informed the A/G operator they could climb to FL 390. After passing these messages on to the Auckland Oceanic controller, the controller cleared the flight crew to climb to FL 390 by 0650, and the A/G operator provided this clearance to the flight crew.

During the reopened investigation, the ATSB asked Airways for further information about the reasons for the requested descent to FL 270. It stated it no longer held the relevant traffic data and therefore could not state what the traffic restriction was or where it was, or for how long the restriction may have lasted. Airways noted generally a decision to hold an aircraft down at a low level occurred whenever there was a separation requirement, and the level restriction would apply until that requirement no longer existed. In this case it appeared either the Nadi controller had coordinated another flight with the Auckland controller that was at a conflicting level to VH-NGA’s climb, or Nadi ATS had advised it could not accept VH-NGA at FL 350. Airways stated the flight crew were not asked to descend simply because they were operating a non-RVSM approved aircraft.

Airways advised it did not know what the traffic levels were on the night of the accident. However, the traffic potentially affecting a flight between Apia and Norfolk Island at that time of night would predominately be high-capacity airline flights from the east coast of Australia to the US. The operators of such flights file user-preferred routes to utilise the winds in the region, which change each day, resulting in a daily variation of the planned routes of these flights.

Based on a review of the CVR recording (from 0822 UTC), there was only one flight that was identified as a potential traffic conflict for VH-NGA during the period just prior to 0822 until the top of descent at 0940. This was a B737 flying from Sydney to Apia on the same route as VH-NGA. It passed underneath VH-NGA at about 0820 and was operating at FL 370 at that time (while VH-NGA was at FL 390).

In summary, there was other traffic near VH-NGA during the initial part of the flight that resulted in a potential traffic conflict at some flight levels. VH-NGA climbing to FL 390 resolved this conflict. It is unclear whether other flight level or tracking options were available that could have resolved this conflict and avoided a descent to FL 270. Given Airways procedures and reported normal practices, and the experiences of the operator's flight crews, if the flight crew had requested priority because they were on a medical or hospital flight, the likelihood of descending to FL 270 would have been significantly reduced.

Classification of operations

International standards

ICAO Annex 6 (Operation of Aircraft) specified standards and recommended practices (SARPS) for the operation of aircraft. Part I applied to international commercial air transport operations in aeroplanes, Part II applied to international general aviation operations in aeroplanes, and Part III applied to international helicopter operations. The SARPS for air transport operations are more extensive and at a higher standard than those for general aviation operations.

None of the three parts of Annex 6 were applicable to aerial work operations. To date, ICAO has not seen the need to develop SARPS for aerial work due to the limited extent of international aerial work activity.

Up to 1990, the Annex 6 definition of aerial work was:

> Specialized commercial aviation operations, not including air transport operations within the scope of Annex 6 Part I, performed by aircraft, chiefly in agriculture, construction, photography and surveying.

In 1987, an ICAO document outlining model regulations[143] provided a modified definition, which specifically included aerial ambulance operations:

> An aerial work operation shall be a specialized aviation operation, other than an air transport operation, in which an aircraft is flown by the operator or owner of the aircraft so as to provide a service for purposes such as agriculture, construction, photography, surveying, observation and patrol, aerial ambulance and rescue.

However, since 1990, Annex 6 provided the following definitions:

> ***Aerial work.*** An aircraft operation in which an aircraft is used for specialized services such as agriculture, construction, photography, surveying, observation and patrol, search and rescue, aerial advertisement, etc.
>
> ***Commercial air transport operation.*** An aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire.
>
> ***General aviation operation.*** An aircraft operation other than a commercial air transport operation or an aerial work operation.

ICAO advised the ATSB that air ambulance or medical transport operations would normally be classified as a commercial air transport operation. However, if an air ambulance operation was conducted by a charity or missionary organisation, and that organisation did not receive payment for the services, then the operation would be classified as general aviation. It would not be considered aerial work as the definition of aerial work did not include the transportation of people.

Australian regulatory requirements

Under Australian civil aviation regulations since 1947, there were four separate classes of operations:

- regular public transport (RPT)
- charter
- aerial work and

[143] ICAO, Manual of Model Regulations for National Control of Flight Operations and Continuing Airworthiness of Aircraft, Second Edition 1987 (ICAO Doc 9388-AN/918).

- private.

RPT and charter applied to the carriage of both passengers and freight. Civil Aviation Regulation (CAR) 206 defined aerial work using a list of specific examples, which included 'ambulance functions'.[144]

Different regulatory requirements applied to each class of operation, with RPT operations having the highest level of minimum standards and regulatory oversight, and private operations having the lowest level of minimum standards and regulatory oversight. Within each class, there were variations in the standards and oversight associated with a range of factors, such as aircraft size, aircraft complexity and number of passengers.

In 1996, CASA commenced a complete review of the safety requirements outlined in the CARs and CAOs, with the revised legislation to be called the Civil Aviation Safety Regulations (CASRs). In 1997, CASA published a policy on the classification of operations to provide a framework for developing the new regulations. The policy included three classes of operations:

- passenger transport (amalgamating RPT and charter operations that carried passengers)
- aerial work (including a wide range of operations in which only essential crew are carried, including the transport of freight)
- general aviation.

A synopsis attached to the policy stated passengers in passenger transport activities have some knowledge of but little control over risk factors, and personnel on aerial work activities are knowledgeable of or informed of risks, usually on the basis of their employment. The synopsis specifically included 'aerial ambulance operations' in the passenger transport class of operation.

Following the publication of the 1997 policy, some air ambulance operators expressed concern to CASA regarding the implications of classifying ambulance operations as a passenger transport activity.

In February 2001, the CASA Board approved some amendments to the classification of operations policy. The revised policy included 'emergency medical services and aerial ambulance' under aerial work. In March 2003, CASA issued a notice of proposed rule making (NPRM) to change the definition of aerial work in CAR 206.[145] The proposed definition included 'medical services' as a type of aerial work.

In November 2004, CASA issued a regulatory policy titled 'CASA's Industry Sector Priorities'. The policy outlined a hierarchy of priorities for devoting its resources. The initial hierarchy included 'humanitarian aerial work', with an air ambulance operator as an example, as part of 'passenger transport - small aircraft', and at a higher priority level than other types of aerial work.

Subsequent versions of this regulatory policy, published in April 2007 and April 2009, were titled 'CASA's Industry Sector Priorities and Classification of Civil Aviation Activities'. These documents outlined in more detail the general principles associated with CASA's hierarchy of priorities and the classification of aviation activities. The policy differentiated between:

- passengers, who are not expected or assumed to have knowledge of the risks that are exposed to or have little or no control of those risks
- task specialists, who have assigned in-flight duties related to a specialised use of an aircraft and are informed of and accept the associated risks
- participants, who voluntarily engage in an aviation activity, are informed of the risks and have explicitly accepted the risks of their involvement.

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[144] CAR 206 was introduced in 1988. However, ambulance functions were also defined as aerial work in legislation prior to the introduction of the CARs.

[145] NPRM 0304OS, March 2003, Air Service Operations, Part A: Proposed amendment to regulation 206 (1), and consequential amendments to regulations CAR 2(1) and CAR 2(7), of the Civil Aviation Regulations 1998.

The resulting classification of operations differentiated between passenger transport (involving passengers) and aerial work (usually involving the carriage of task specialists). The 2007 and 2009 versions of the policy did not indicate how ambulance flights would be classified. They also did not indicate how a patient or a support person for a patient carried on an ambulance flight would be classified (that is, as a passenger or other type of occupant).

Since 1999, CASA issued a number of discussion papers and NPRMs to change various aspects of the CARs. However, as of November 2009, none of the proposed changes in these documents involved reclassifying air ambulance operations. Consequently, such operations remained classified as aerial work for the purpose of regulatory requirements.

Comparisons with other countries

On 17 October 2003, a Bell 407 helicopter was being operated on flight from Mackay to Hamilton Island, Queensland to pick up a patient, who was not critically ill or injured. The helicopter impacted the sea in dark night conditions, and all three crew members on board were fatally injured. In its investigation report, the ATSB stated:

> A review of aviation regulations in other countries indicated that they classified helicopter EMS [emergency medical service] operations as Air Transport, Public Transport or commercial flights and all receive increased regulatory scrutiny beyond what is currently required by CASA for helicopter EMS operators in Australia.
>
> Current CASA policy includes a plan to harmonise aviation regulations in Australia with the US FAA Federal Aviation Regulations. Under current Australian regulations, helicopter EMS flights, including those in which a patient is carried aboard the helicopter, are classified as Aerial Work operations. As a result, EMS helicopter operations are subject to a lesser degree of regulatory control and oversight than similar Charter operations.

Although the focus of this review was on helicopter operations, the same basic situation applied to fixed-wing air ambulance operations.

In its 2004 response to the ATSB’s draft report on the Bell 407 accident, CASA stated:

> CASA acknowledges that there are differences between Australian EMS requirements and those in northern hemisphere countries.
>
> However, adopting the same conditions in Australia may unnecessarily stymie EMS operations and/or drive up costs when environmental conditions in Australia do not mitigate such action. CASA sees no merit in changing the operating category from aerial work to charter or public transport. Nevertheless, an evaluation of specific EMS compliance provisions is supported. In this context, the promulgation of a specific instruction for EMS may be appropriate, similar to the approach taken for marine pilot transfers.

In its final investigation report, the ATSB issued the following recommendation:[146]

> ATSB Recommendation R20050002
>
> The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review its operator’s classification and/or its minimum safety standards required for helicopter Emergency Medical Services operations. This review should consider increasing; (1) the minimum pilot qualifications, experience and recency requirements, (2) operational procedures and (3) minimum equipment for conduct of such operations at night.

CASA subsequently reviewed several aspects of EMS operations, but there was no change to the classification of these operations.

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[146] In 2001, the ATSB also issued recommendation R20010195 to CASA to ‘consider proposing an increase in the operations' classification, and/or the minimum safety standards required, for organisations that transport their own employees and similar personnel... on a regular basis’.

In July 2013, CASA issued an NPRM to change the requirements for aeroplane and helicopter ambulance flights.[147] In the NPRM, CASA stated:

> Leading aviation nations, such as the UK, Europe, Canada, New Zealand and the USA (for the USA, specifically when the patient is on board the aircraft), recognise that MT [medical transport] flights, including:
>
> - patient inter-hospital retrieval
> - international patient repatriation
> - emergency medical service (EMS) operations,
>
> are conducted as air transport operations under the authority of an AOC issued by the operator's State. It is widely understood that this approach to classification and level of regulation has many advantages for the overall context of these flights, particularly from operational and safety systems perspectives.
>
> These nations have applied definitions and applicability of commercial air transport (CAT) Standards and Recommended Practices (SARPs) – as outlined in Annex 6, Parts I and III to the Chicago Convention – to their operations. In Annex 6 to the Chicago Convention, the International Civil Aviation Organization (ICAO) defines commercial air transport as:
>
> > ***commercial air transport operation*** (is) an aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire.
>
> Clearly, the abovementioned countries have interpreted this to mean that the transport of passengers for MT flights is an AT operation, and have written their legislation for these operations accordingly. CASA is of the view that such an interpretation confers many safety advantages to MT flights, chiefly that the full range of organisational, equipment, flight crew and safety system standards confirmed by the issue of an AOC are applicable to such operations…
>
> Amongst leading aviation nations, Australia is unique in classifying MT flights as aerial work under the prescribed purpose of 'ambulance functions', outlined in subregulation 206 (1) (a) of CAR. This classification subjects Australia's MT operations to a different standard of regulation than would be the case under the ICAO AT standards and those of most other leading ICAO Member States.

Further details of CASA's changes to the regulation of air ambulance flights since November 2009 are discussed in *Safety issues and actions*.

Operator information

Overview of operations

The operator, Pel-Air Aviation Pty Limited (Pel-Air Aviation), operated under that name from October 2006. In June 2009, CASA reissued its Air Operator's Certificate (AOC) for 3 years. The AOC authorised operations as outlined in Table 20.

[147] NPRM 1304OS, July 2013, Regulations of aeroplane and helicopter 'ambulance function' flights as air transport operations.

Table 20: Types of operations permitted by the operator's AOC

Type of operation	Details and conditions	Authorised aircraft types
Regular public transport	Freight only Several specified ports in Australia as well as Auckland and Port Moresby	IAI 1124/1124A (Westwind)
Charter	Passenger and freight (both domestic and international)	Saab 340A, 340B Fairchild SA227-AC, -AT, -DC (Metro) Embraer EMB-120 ER, RT (Brasilia) IAI 1124/1124A (Westwind) Gates Learjet 35A, 36, 36A
Aerial work	Ambulance functions and target towing (both domestic and international)	IAI 1124/1124A (Westwind) Gates Learjet 35/36

The operator organised its flight operations into three basic fleets:

- civil jet (or Westwind) operations
- military jet operations
- turboprop operations.

Table 21 describes the key characteristics of each of the three fleets at the time of the accident.

Table 21: Summary of the operator's flight operations' activities

Fleet	Description
Westwind operations	Up to 7 Westwind aircraft Main bases in Sydney and Darwin, small bases in Perth and Cairns Air ambulance and ad hoc charter operations, including most of the passenger charter operations the operator conducted for the Australian Defence Force (ADF) 16 flight crew
Military jet operations	4 Learjets and some Westwind aircraft (as required) Base in Nowra Primarily tactical mission simulation, with some passenger charter operations for the ADF 11 flight crew
Turboprop operations	5 Saab 340 and 6 Metro aircraft (4 Metro 23 and 2 Metro III) Bases in Adelaide, Sydney, Brisbane, Mackay, Townsville Regular freight operations and passenger charter operations (primarily fly-in fly-out support to mining operations) 32 flight crew

The Saab 340 was the largest aircraft used by the operator, with capacity for 34 passengers. The EMB-120 was a similar size to the Saab 340, but the operator only used the EMB-120 for freight operations. It ceased using the EMB-120 in April 2009. The Metro 23 had capacity for 19 passengers and the Metro III was only used for freight operations. The Westwind had capacity for 10 passengers but was typically operated with a capacity of less than 10 passengers (see also *Enhanced ground proximity warning system*).

At the time of the accident, the operator had nine Westwind aircraft on the civil aircraft register. This included seven 1124s and two 1124As (including VH-NGA). Seven of the 1124/1124A aircraft were regularly used by the operator's Westwind fleet.

History of the operator's organisation and activities

The operator commenced operations in 1984, over the years conducting a wide variety of operations under various trading names. In the period prior to October 2006, it conducted operations under two separate AOCs:

- Doskite Pty Limited (Doskite) trading as Pel Air (conducting freight, air ambulance and passenger operations in Westwind aircraft and military support activities in Westwind and Learjet aircraft)
- Pel-Air Express (conducting freight operations in turboprop aircraft).

Both operators were owned by Pel-Air Aviation and had the same directors and a similar senior management team, although each had a different chief pilot. The two operators shared a common operations manual (OM).

In November 2005, Regional Express Holdings Limited (REX), a large low-capacity passenger transport operator using Saab 340 aircraft, purchased a 50 per cent share of Pel-Air Aviation. It purchased the remaining 50 per cent during the first half of 2007. The purchase resulted in some board and senior management changes.

In early 2006, the operator advised CASA that it wanted to merge its two AOCs into one entity and add the Saab 340 aircraft to its operations. Following a CASA approval process, the merged AOC was issued to Pel-Air Aviation in October 2006. The jet AOC chief pilot became the chief pilot of the new entity, and the jet AOC head of training and checking (HOTC) became the HOTC of the new entity. In 2008, the operator selected a new chief pilot, who was approved by CASA in November 2008.

Table 22 summarises changes to the operator's organisational structure and activities during 2005–2009, focussing on aspects relevant to the operator's Westwind operations. Further details of some events are provided in subsequent sections.

Table 22: Overview of changes in the operator's organisation and activities during 2002–2009

Date	Event
January 2002	CASA amended the operator's AOC to permit air ambulance operations in Westwind aircraft (as aerial work).
April 2002	The operator (jet AOC) commenced air ambulance operations in conjunction with CareFlight.
May 2005	To reduce the chief pilot's workload, the operator (jet AOC) appointed a senior Westwind check pilot as HOTC. CASA approved the candidate as HOTC and also as capable of acting as chief pilot if the chief pilot was absent.
August 2005	The EMB-120 was added to the operator's turboprop AOC.
November 2005	The parent airline purchased 50 per cent stake in Pel-Air, resulting in some board and senior management changes.
October 2006	The jet AOC and turboprop AOC were merged, with the new AOC issued to Pel-Air Aviation. The jet AOC chief pilot was appointed as the new chief pilot, and the jet AOC HOTC was appointed as the HOTC. The Metro 23 was added to the AOC.
February 2007	Operator commenced Westwind air ambulance operations from Darwin base.
June 2007	Operator became a wholly-owned subsidiary of the parent airline, resulting in some board and senior management changes.
March 2008	CASA issued a safety alert to the operator after an audit found the operator had not provided annual FRMS training to flight crew as required by its OM. The operator conducted a detailed review of the circumstances leading to the safety alert. The review included recommendations that the chief pilot's role be more focussed on regulatory functions, and that a new person be assigned the role of chief pilot.
June 2008	Operator commenced Westwind air ambulance operations from Perth base.
August 2008	HOTC resigned; chief pilot resumed the role of HOTC. Two new Westwind check pilots appointed, with one subsequently leaving the operator in October 2008. Compliance manager resigned, and the parent airline took over the compliance and internal auditing function.
November 2008	Parent airline took over the safety management function. New chief pilot appointed. Previous chief pilot appointed as Westwind standards manager and General Manager Flying Operations (Medivac and Charter).
December 2008	Operator commenced Saab 340 operations.
March 2009	Operator's safety management group (SMG) commenced monthly safety management meetings.
April 2009	End of scheduled Westwind freight operations. EMB-120 operations ceased.
May 2009	Operator commenced Westwind air ambulance operations from Cairns base.

During the 1990s and most of the 2000s, the operator's Westwind flights were primarily night freight operations, particularly between Darwin, Alice Springs and Melbourne. CASA audit reports in 2002–2004 stated the operator's freight flights at that time were scheduled flights but not RPT.[148] The scheduled freight operations started decreasing in 2008 and ceased in April 2009. From that time, the Westwind fleet primarily conducted air ambulance tasks as well as some ad hoc charter flights.

The operator's turboprop operations were historically all night freight operations, primarily in Metro aircraft. These operations started decreasing during 2007–2008, and regular freight operations in

[148] The CASA audit reports stated the operator wanted to keep the RPT approval on its AOC to satisfy overseas authorities who may insist on such an approval to permit operations. The operator conducted RPT freight activities between Sydney and Auckland prior to 2002.

Metro III aircraft ceased in April 2009. CASA approved the addition of the Saab 340 on to the operator's AOC in November 2008, and during 2009 the operator commenced passenger charter operations in Saab 340 and Metro 23 aircraft, primarily fly-in fly-out support for mining operations.

History of the operator's air ambulance activities

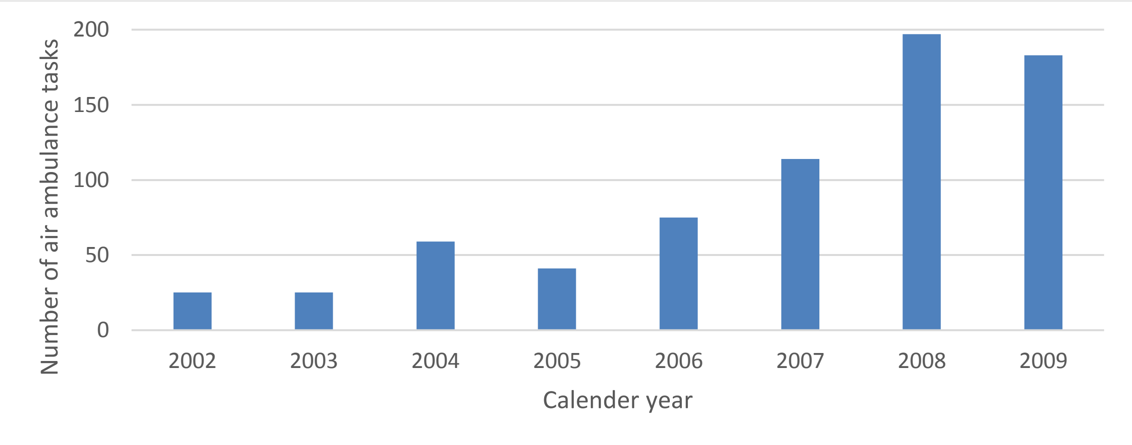
The Westwind standards manager stated the operator commenced air ambulance operations in 2000 as part of a contract to provide transport services out of East Timor.[149] These air ambulance flights were conducted as a passenger charter operation.

In 2001, the operator commenced discussions with CareFlight (an air ambulance provider) to conduct international air ambulance operations using Westwind aircraft. A formal agreement was signed in May 2002. Under the agreement, the air ambulance provider used the operator as its preferred operator to undertake air ambulance or medical retrieval tasks. It also supplied the medical personnel for such operations.

Initially, the air ambulance provider was primarily interested in transporting patients from Noumea, New Caledonia to Australia. The Westwind standards manager reported that, prior to conducting air ambulance operations to New Caledonia, the French aviation regulator (Direction Générale de l'Aviation Civile or DGAC) required the operator to have air ambulance operations listed as an approved type of operation on its Australian AOC. In January 2002, the operator applied to CASA to have 'aerial work – ambulance functions' added to its AOC, and CASA approved the application (see *Overview of AOC assessment processes*).

The operator commenced air ambulance work with the air ambulance provider in April 2002. Initially these activities were based out of Sydney, and primarily involved trips to Noumea. The number of trips and range of destinations increased over time. The operator and the air ambulance provider opened new bases for air ambulance operations in Darwin in February 2007, Perth in June 2008 and Cairns in May 2009. Figure 33 shows the number of air ambulance trips during 2005–2009. Many trips involved two flights, and some involved several flights.

Figure 33: Number of air ambulance tasks conducted by the operator during 2002–2009



Source: ATSB based on data provided by CareFlight and Pel-Air Aviation. Note: Data for 2005–2009 was obtained from the air ambulance provider. Data for 2002–2004 was obtained from reviewing the operator's flight records. The data from the operator's flight records for 2005–2006 gave similar results to those provided by the air ambulance provider.

The air ambulance tasks primarily involved transporting a patient to a hospital in a major city, usually in Australia, but occasionally in New Zealand or another country. Most of the retrievals were from international locations in the Oceanic/South Pacific region, as well as Norfolk Island, Christmas Island, Indonesia, Papua New Guinea and Timor-Leste. Some of the tasks were also between Australian mainland locations, particularly from Darwin to Adelaide. Much (but not all) of the increase in the number of trips during 2007–2009 was associated with trips from Darwin to

[149] East Timor was renamed Timor-Leste in 2002.

Adelaide and Darwin to Bali. Further details of the operator's flights to remote aerodromes are provided in *Operator's Westwind operations to remote aerodromes*.

For some locations, CareFlight was the sole air ambulance provider. However, for many tasks it would compete with other air ambulance providers to conduct the task for a medical insurance company. In some cases where the operator was not able to conduct a task, the air ambulance provider used another Australian aircraft operator.

Flight operations management personnel

The chief pilot as of November 2009 was also the head of training and checking (HOTC). He commenced work in those positions in November 2008. His previous experience was with Metro and Saab 340 aircraft. He had a copilot endorsement on the Westwind but limited experience on that aircraft type and he did not have endorsements for the Learjet and EMB-120. Accordingly, his chief pilot instrument issued by CASA stated he did not need to hold an endorsement on the Westwind, Learjet or EMB-120 as long as a specified person continued to be employed by the operator and acted as 'senior pilot' for each of these aircraft types.

The senior pilot specified for Westwind and Learjet aircraft was the operator's former chief pilot. At the time of the accident, he had the roles of Westwind standards manager and General Manager Flying Operations (Medivac and Charter). He also managed and supported many aspects of the operator's Westwind air ambulance and charter operations. The Westwind standards manager was previously the chief pilot of the operator's jet AOC from June 2000 to October 2006, and the chief pilot of the operator from October 2006 until November 2008. He had over 16,000 hours experience in command of multi-engine aircraft, the majority of which was on Westwind aircraft.

The Westwind operations manager provided operational support for the Westwind fleet. Her tasks included taking bookings and providing quotes for tasks and managing the Westwind fleet's flight crew roster. Her main duties after a task was approved included obtaining authorisations for the crew to land at relevant airports, pre-booking fuel, booking accommodation and monitoring the flight crew's fatigue scores (see *Fatigue management*). As an example, for the 17–18 November 2009 task, the operations manager arranged permission for the aircraft to land at Norfolk Island and Apia, arranged for refuelling at Norfolk Island and Apia and booked accommodation at the hotel in Apia. She also kept in contact with flight crew and monitored the progress of each task. She was not a pilot and had no role monitoring the conduct or quality of flight operations.

Further discussion of the roles of chief pilot, standards manager and other management personnel is provided in *Roles and responsibilities*.

Operations manual

Civil Aviation Regulation (CAR) 215 required an operator to provide an OM for the use and guidance of its personnel. The OM was required to contain information, procedures and instructions for the flight operations of all types of aircraft operated by the operator to ensure their safe conduct. In accordance with the CARs, the operator's personnel were required to comply with the instructions in the operations manual.

The operator's flight operations policies and procedures were promulgated in its OM. The documented purpose of this manual was to enable management's operational control and to enable compliance with current regulatory requirements for its AOC operations.

The OM consisted of several parts:

- part A – policy and organisation (which outlined the roles and responsibilities of personnel and provided flight operations' policies)
- part B – standard operating procedures (which outlined generic flight crew procedures applicable to all aircraft types as well as specific procedures relevant to each type)
- part C – supplemental operations (which provided additional procedures for specific types of operations, including a section on air ambulance operations)

- part D – check and training (which provided policies and procedures regarding flight crew training and checking)
- part E – defence air support operations
- part F – dangerous goods
- part G – fatigue risk management system (which provided policies and procedures regarding the management of flight and duty times, rostering and fatigue management).

All of the operator's flight crew were required to acknowledge that they had read, understood and agreed to comply with the OM requirements.

Pre-flight fuel planning

General requirements

Civil Aviation Regulation (CAR) 234 (Fuel requirements) provided the primary requirements for pre-flight fuel planning for Australian pilots and operators. It stated:

> (1) The pilot in command of an aircraft must not commence a flight within Australian territory, or to or from Australian territory, if he or she has not taken reasonable steps to ensure that the aircraft carries sufficient fuel and oil to enable the proposed flight to be undertaken in safety.
>
> (2) An operator of an aircraft must take reasonable steps to ensure that an aircraft does not commence a flight as part of the operator's operations if the aircraft is not carrying sufficient fuel and oil to enable the proposed flight to be undertaken in safety.
>
> (3) For the purposes of these regulations, in determining whether fuel and oil carried on an aircraft in respect of a particular flight was sufficient within the meaning of subregulations (1) and (2), a court must, in addition to any other matters, take into account the following matters:
>
> (a) the distance to be travelled by the aircraft on the flight to reach the proposed destination;
>
> (b) the meteorological conditions in which the aircraft is, or may be required, to fly;
>
> (c) the possibility of:
>
> (i) a forced diversion to an alternative aerodrome; and
>
> (ii) a delay pending landing clearance; and
>
> (iii) air traffic control re-routing the flight after commencement of the flight; and
>
> (iv) a loss of pressurisation in the aircraft; and
>
> (v) where the aircraft is a multi-engined aircraft — an engine failure;
>
> (d) any guidelines issued from time to time by CASA for the purposes of this regulation.

In addition, CAR 220 (Fuel instructions and records) stated:

> (1) An operator shall include in the operator's operations manual specific instructions for the computation of the quantities of fuel to be carried on each route, having regard to all the circumstances of the operations, including the possibility of failure of an engine en route.

Civil Aviation Advisory Publication (CAAP) 234-1 (Guidelines for Aircraft Fuel Requirements) provided guidance on the requirements in CARs 220 and 234. The CAAP stated the amount of fuel on board at any particular point in a flight should be sufficient to:

- enable the aircraft to fly from that point to a height of 1,500 ft above the destination aerodrome, conduct an approach and land
- provide for diversion to an alternate aerodrome (if required)
- provide for a variable fuel reserve
- provide for a fixed fuel reserve
- provide additional fuel for emergencies such as an engine failure or loss of pressurisation.

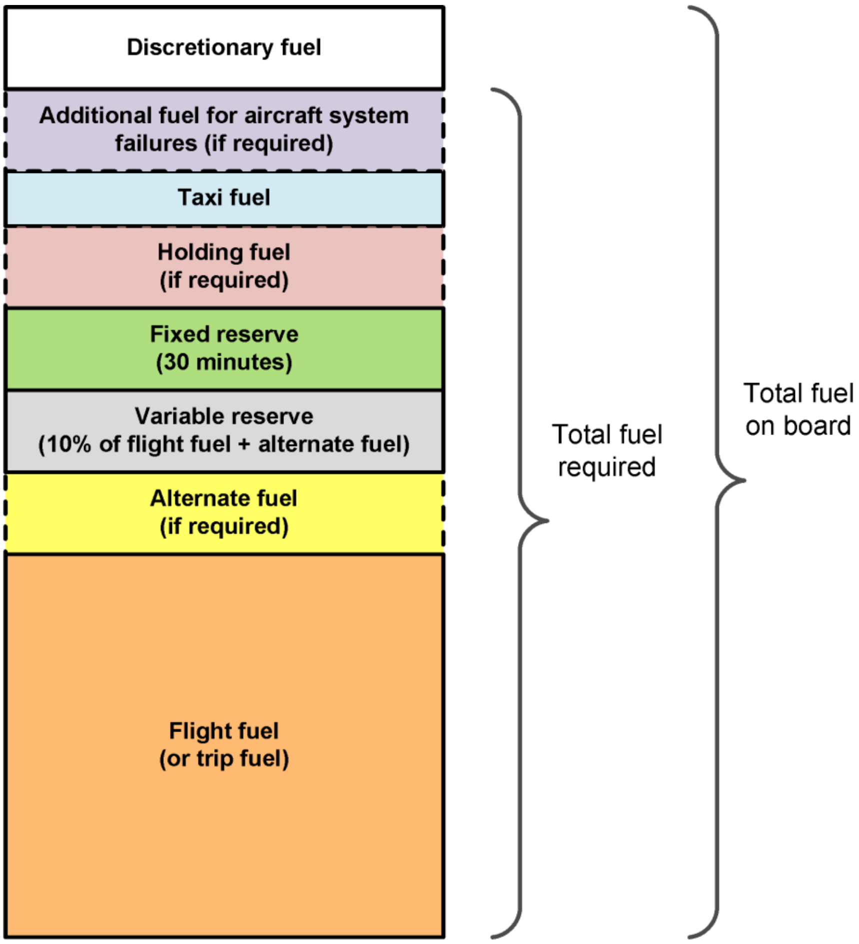
It also stated allowance should always be made for forecast weather conditions en route, planned air traffic control routing, and any delays associated with traffic holding for the relevant aerodrome(s).

The operator's OM required that, prior to departure for a flight, a captain had to ensure sufficient fuel was carried for the intended flight as per the operator's fuel policy. Part A section 9.11.1 (Company Fuel Policy) included:

> The PIC [pilot in command or captain]… shall calculate the amount of fuel to be carried by using the consumption rate for the type of aircraft as specified in Part B. Sufficient fuel shall be carried for:
>
> - Flight fuel from the departure aerodrome to the destination aerodrome; and
> - Alternate fuel to an alternate aerodrome, if required; and
> - The provision of variable reserve fuel; and
> - The provision of fixed reserve fuel; and
> - Additional fuel for weather, traffic, OEI [one engine inoperative] or loss of pressurisation or other specified reasons; and
> - Taxi fuel.

In summary, the total fuel required for a flight involves calculating several elements, as indicated in Figure 34.

Figure 34: Elements required when calculating the total fuel required for a flight



Source: Adapted from ICAO Document 9976, *Flight planning and fuel management (FPFM) Manual*, 2015 (First edition). Modified to suit the Australian requirements in effect during 2009.

The remainder of this section discusses the elements in Figure 34. It then discusses fuel planning aspects related to isolated aerodromes and remote islands, and other aspects of fuel planning and flight planning. The last section discusses fuel planning calculations related to the accident flight.

Flight fuel

Operator's methods

The OM defined flight fuel (also known as trip fuel) as:

> Fuel from departure aerodrome to planned destination aerodrome, including provision for an approach and landing.

The manual outlined three different methods for calculating the flight fuel for a Westwind:

- an hour-by-hour method
- 23 lb/minute method
- the aircraft manufacturer's 1124 or 1124A Operational Planning Manual (OPM).

The operator's OM described the hour-by-hour method as:

1st hour	1700 lb
2nd hour	1400 lb
3rd hour	1300 lb
4th hour	1200 lb
5th hour	1100 lb

> For temperatures above ISA,[150] add 100 lbs fuel on to first hour for every 5° temp is above ISA.

In terms of the 23 lb/minute method, the OM stated:

> Through Company experience in Westwind operations, it has been found that an alternative method for fuel calculations is:
>
> a) Pre-flight Planning
>
> Allow 23 lbs/minute plus 400 lbs for the climb;
>
> eg. Planned flight time = 100 mins, so 100 x 23 + 400 = 2700 lbs of fuel can be expected to be burned on this sector.
>
> b) In-flight Re-planning
>
> Allow 23 lbs/minute in stable cruise.

The aircraft manufacturer's OPM included detailed information regarding fuel consumption for a variety of situations, including climb, long-range cruise, constant speed cruise, single-engine (long-range) cruise, descent and holding. It also included fuel planning charts to provide a total estimate of the flight fuel for a flight. Using the planning charts, a pilot could estimate the flight fuel required based on the cruising flight level, distance, average Mach number (in cruise), wind component, temperature and take-off weight.

Pilots reported they were provided with a copy of the 1124 OPM. In addition, a copy of the relevant OPM was located on each aircraft. The operator advised VH-NGA had a copy of the 1124A OPM on board.

The OM did not outline any specific situations where any of the three methods was preferred for calculating the flight fuel. Some of the operator's Westwind pilots (including the captain of the accident flight) reported they generally used the 23 lb/minute method, and some pilots reported they generally used the hour-by-hour method. The Westwind standards manager reported that he

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150 International Standard Atmosphere (ISA): hypothetical meteorological conditions that provide standard temperatures and pressures at specified altitudes. ISA conditions are used as a datum for calculating aircraft performance data.

used a flight planning software tool that incorporated performance data from the 1124 OPM. Other pilots reported that they incorporated the operator's OM methods into a flight planning software tool.

None of the pilots reported they used the OPM planning charts or other OPM data when fuel planning, except perhaps for unique, challenging situations. Pilots stated they would generally treat the 1124 and 1124A the same for fuel planning purposes, even though the 1124A was more fuel efficient that the 1124.

The 1124 OPM's planning charts included a correction (addition) for climbs conducted in hot conditions. For example, for flights at FL 350, 370 and 390, for an aircraft weight of 21,800 lb and a temperature of ISA+10°C, an addition of 240 lb was required to the planning chart figure. For ISA+20°C, an addition of 840 lb was required.[151] These additions for a hot day climb were simplistic and very conservative, as they did not take into account the additional distance flown during the climb phase on a hot day.

The 1124A OPM did not include any additions for hot day climbs. The aircraft manufacturer reported this was an unintended omission when the 1124A OPM was prepared. Given that manual was published in 1980, it is unclear why this omission had not been previously identified.

If the same approach was taken to develop the additions for a hot day climb for the 1124A OPM as was included in the 1124 OPM, it would result in lower figures due to the improved performance of the 1124A. For example, for flights at FL 350, for an aircraft weight of 21,800 lb and a temperature of ISA+10°C, the addition would be 140 lb. For ISA+20°C, the addition would be 420 lb.

An analysis by the ATSB of the 1124A OPM fuel data indicated the fuel burn-offs for the hot day climbs are about 15–90 lb greater than climbs conducted in ISA conditions, after accounting for the fuel consumed in cruise for the flights in ISA conditions to reach the same distance as the hot day top of climb points.[152] The higher amounts occurred at higher flight levels for ISA+20°C conditions. Given these conditions would be rare at such altitudes, and the overall amounts were small, the absence of the hot day climb figures in the 1124A OPM was not considered to be a significant omission.

The captain did not use the OPM planning charts during his fuel planning on the day of the accident, and the available evidence indicates the operator's flight crew did not regularly use the 1124A planning charts when conducting fuel planning tasks. Therefore, the omission of the hot day climb fuel allowance from the 1124A planning charts had no influence on the circumstances of the accident.

Selection of route

In a section on air ambulance flights, the OM stated:

> All flights are to be planned by the shortest and/or most expeditious route, having regard to:
>
> a) Special patient requirements example: sea level cabin [pressure];
>
> b) Minimum flight time;
>
> c) Operational requirements;
>
> d) Weather (patients comfort);
>
> e) Diplomatic requirements.

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151 These figures reduced for lower flight levels and lower weights. For example, for FL 310, an aircraft weight of 21,800 lb and a temperature of ISA+10°C, the addition was 160 lb. For FL 350, an aircraft weight of 20,000 lb and a temperature of ISA+10°C, the addition was 160 lb.

152 The additional fuel was dependant on aircraft weight, temperature and top of climb flight level. The additional fuel was estimated to be 13 lb at 20,000 lb gross weight to FL 290 in ISA+10°C and 88 lb at 20,000 lb gross weight to FL 370 in ISA+20°C. The figures for heavier aircraft gross weights were similar to these figures.

The Westwind operations manager reported that, when quoting for a task, she used a spreadsheet prepared by the Westwind standards manager to provide approximate flight times. If the flight was longer than 1,700 NM, she consulted with the standards manager before providing a quote.

The operations manager also advised that for the more common long-distance flights, the operator generally used the same refuelling stop. For example, for flights from Sydney to Samoa or Fiji, the normal refuelling stop was Norfolk Island. However, the captain of a flight was responsible for flight planning, and they were able to flight plan using another route if they had an operational reason for doing so. As noted in appendix O, some of the operator's flights from Apia back to Sydney were conducted via Auckland or Noumea rather than Norfolk Island.

Selection of flight level

As indicated above, the 23 lb/minute and hour-by-hour methods for calculating flight fuel assumed flights would follow a standard flight profile of operating at about FL 350 or above. Pilots reported they generally planned to operate at about FL 350.

The aircraft's ability to climb was affected by factors such as aircraft weight and temperature. In almost all situations, a Westwind would be able to reach FL 350. However, at certain weights and temperatures, the aircraft would not be able to reach FL 390.

In some cases, the operator's pilots were required to flight plan at lower flight levels. For example:

- a patient needing to be transported with a sea-level cabin pressure (restricting the highest altitude to about FL 230–240)
- air traffic control restrictions, such as restrictions accessing RVSM airspace from FL 290-410.

The OM did not provide any specific figures for calculating flight fuel at any cruise level below FL 290.

Calculation of flight time

To apply either the 23 lb/minute or the hour-by-hour method, a pilot first needed to calculate the flight time. The OM provided the following information for the Westwind:

> The following table is a guide only to planning. Refer to A/C OPS Planning Manual for precise information.

Block Speed (over 400 miles)	380 Kts
Block Speed (200 – 400 miles)	360 Kts
Range (full fuel – Nil wind)	2250 nm
Climb to cruise FL350	28 min/162 nm/1050 lbs
Initial cruise altitude (at gross)	FL350 @ ISA
Cruise speed (10 000 Kg)	M.72/400 – 420 Kts
Long range cruise (10 000 Kg)	M.70/400 Kts

The OM also provided additional information on cruise speeds:

> Normal cruise speed for flights up to 2 hrs is M.72. As soon as M.72 is achieved, climb 2000 feet to the next available level at M.70, allow the aircraft to accelerate to M.72 again and so on.
>
> Constant Mach cruise may be used instead of the above. In this case, maintain speed between M.70 and M.72 (as selected) and reduce power [thrust] to maintain that speed as weight decreases. When ITT has decreased to 830°C, increase power [thrust] to 849° and climb 2000 feet to the next available level.
>
> If employing constant Mach cruise technique, use M.72 or M.70 for normal and long range cruise respectively. For more accurate information, refer to the Operational Planning Manual.

The Westwind standards manager reported the block speed[153] of 380 kt for longer flights was based on the operator's recommended technique and speeds for climb, cruise and descent. However, it was acceptable for pilots to use a higher cruise speed during flight, as long as they planned the flight accordingly.

When asked in 2015–2016, some pilots said they used the OM recommended block speed of 380 kt for flight planning and some pilots reported using 380–400 kt. Other pilots could not recall what speed they used.

The operator produced standard flight planning data for its regularly-used freight routes. The data in one of these plans indicated a block speed of about 380–390 kt.

The captain of the accident flight reported he used a block speed of 420 kt for longer flights in a 1124A. He said the 1124A could cruise up to 430–435 kt TAS, about 15 kt faster than the 1124. He also believed the climb and descent phases had minimal influence on the overall block speed for a long flight. A review of the OPMs for the 1124 and the 1124A indicated that, for the same fuel burn off under the same conditions, a 1124A would cruise at about 6–17 kt faster than a 1124 depending on aircraft weight and flight level.

As noted in *Outbound flights*, the captain's submitted flight plan times for the two outbound flights on 17 November 2009 were slightly shorter than the actual flight times. The captain also reported his submitted flight plan times would normally be rounded to the nearest 15 minutes. Using a block speed of 420 kt and the average estimated wind for each of the two outbound flights (45 kt), the estimated flight times were consistent with the captain's submitted flight times.

A block speed of 420 kt (including the climb and descent) was higher than would be used in normal operations for a 1124A. More specifically:

- Based on the 1124A OPM, a block speed of 420 kt for a flight was only possible in a restricted set of circumstances. For example, it could be achieved for flights longer than 1,000 NM in nil wind conditions at FL 350 using a constant cruise speed of Mach 0.74 in ISA+10°C. This Mach number equated to using a cruise TAS of about 436 kt. This cruise speed could not be achieved at aircraft weights above 19,000 lb at FL 350 in ISA+10°C conditions.
- On the outbound flight on 17 November 2009 from Sydney to Norfolk Island, the average cruise TAS was about 420 kt and the average TAS (including climb and descent) was 380 kt.
- On the outbound flight on 17 November 2009 from Norfolk Island to Apia, the average cruise TAS was about 420 kt and the average TAS (including climb and descent) was about 400 kt.
- For the accident flight on 18 November 2009 from Apia to Norfolk Island, the average cruise TAS was about 410 kt and the average TAS (including climb and descent) was about 390 kt.

Approach fuel

Extra track miles can be involved when conducting an instrument approach to an aerodrome. The OPM planning charts were based on climb, cruise and descent components, and worked examples did not include a fuel allowance for an instrument approach.

The OM did not include a specific amount for an instrument approach for a Westwind. The operator's fuel planning methods were based on continuing at the cruise level until reaching the destination aerodrome. They therefore did not allow for the significantly reduced fuel flow during the descent phase. In general, the reduction in fuel flow during the descent was greater than the fuel used during a standard instrument approach.

Westwind pilots, including the captain, reported they generally did not include an amount for approach fuel when fuel planning.

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153 Block speed is the average TAS for a flight in nil wind conditions, and includes the take-off, climb, cruise, descent and landing. It is also known as the block planning speed or flight planning TAS.

For an instrument approach requiring an extra 5 minutes flying, the ATSB estimated that the approach fuel would be about 100 lb. To allow for a missed approach would require an additional 200 lb.

Comparison of the fuel planning methods

The Westwind standards manager and other pilots reported that from their experience the flight fuel consumption figures specified in the manufacturer's OPM and the operator's OM were accurate.

The operator's 23 lb/minute method and the hour-by-hour method for ISA+10°C[154] conditions produced similar flight fuel figures. For flights less than 3.30 hours, the hour-by-hour method produced slightly higher figures, and for flights longer than 3.30 hours the 23 lb/minute method produced slightly higher figures. For a flight time of 3.50 hours, the 23 lb/minute method was 30 lb more than the hour-by-hour method, and for a flight time of 4.00 hours it was 120 lb more.

The operator's 23 lb/minute method and the hour-by-hour method were derived from the 1124 OPM. A review of the different methods identified that the operator's methods provided reasonable approximations of the 1124 OPM planning figures for the operator's normal operating conditions. For example, for flights of 1,200–1,500 NM at the maximum take-off weight for a 1124 (22,850 lb) and in ISA+10°C conditions, at FL 350 and constant speed cruise of Mach 0.72 in nil wind, the 23 lb/minute method resulted in a flight fuel figure about 290 lb less than the OPM figures for FL 350. The hour-by-hour method resulted in a figure of about 330 lb less than the OPM. The OPM figures included 320 lb addition for a hot day climb, which as noted in *Operator's methods* was very conservative.

For the same distance, aircraft weight and conditions as noted above, the 1124A required less fuel that a 1124. For example, the OPM derived flight fuel required for a flight at FL 350 with constant speed cruise of Mach 0.72 in ISA conditions was about 500 lb less for a 1124A compared to a 1124. This comparison included the OPM addition for a hot day climb for the 1124 but not the 1124A, so if this addition was removed the flight fuel required 200 lb less for the 1124A.

Various factors could influence the fuel consumed during a flight. Based on the 1124A OPM for flights of 1,200 to 1,500 NM at the maximum take-off weight (23,500 lb) in ISA+10°C and nil wind conditions:

- flights at FL 350 required about 100 lb more fuel than flights at FL 370 (for the same speed of Mach 0.72)
- flights at Mach 0.72 required about 100 lb more fuel than flights at Mach 0.70 (for the same flight level).

If full fuel was carried in the 1124A at 23,500 lb take-off weight, the flight would burn an additional 200 lb of fuel compared to carrying full mains fuel at 22,000 lb take-off weight. This comparison was based on using the 1124A OPM for flights of 1,200–1,500 NM at Mach 0.72 in ISA+10°C, at FL 350–370, and nil wind conditions.

Comparisons of different fuel planning methods relevant to the accident flight are provided in *Fuel planning calculations related to the accident flight*.

Alternate fuel

Weather-related requirements for an alternate aerodrome

The AIP defined an alternate aerodrome as:

[154] ISA+10°C conditions were used for most comparisons as such conditions are common in Australia and the Oceanic/South Pacific region.

> An aerodrome to which an aircraft may proceed when it becomes either impossible or inadvisable to proceed to or to land at the aerodrome of intended landing.[155]

As noted above, CAR 234(3) specifically required the possibility of a forced diversion be considered when determining the amount of fuel required for a flight.

In terms of weather-related requirements for nominating an alternate aerodrome when flight planning, CAR 239 (Planning of flight by pilot in command) paragraph (2) stated:

> When meteorological conditions at the aerodromes of intended landing are forecast to be less than the minima specified by CASA, the pilot in command shall make provision for an alternative course of action and shall arrange for the aircraft to carry the necessary additional fuel.

In addition, the Australian AIP (ENR 1.1 General Rules, section 73) outlined more specific requirements regarding alternate aerodromes. In terms of forecast weather conditions, paragraph 73.2.12 stated:

> Except when operating an aircraft under the VFR by day within 50 NM of the point of departure, the pilot in command must provide for a suitable alternate aerodrome when arrival at the intended destination will be during the currency of, or up to 30 minutes prior to the forecast commencement of any of, the following weather conditions:
>
> a. cloud - more than SCT [scattered] below the alternate minimum...;[156] or
>
> b. visibility - less than the alternate minimum; or
>
> c. visibility – greater than the alternate minimum, but the forecast is endorsed with a percentage probability of fog, mist, dust or any other phenomenon restricting visibility below the alternate minimum; or
>
> d. wind - a crosswind or downwind component more than the maximum for the aircraft.

If the conditions were forecast to improve by a specific time, or be temporary in nature, then provision for sufficient holding fuel could be used instead of the nomination of an alternate aerodrome.[157]

The alternate minima in Australia were generally determined by adding 500 ft to the minimum descent altitude (MDA) and 2 km to the minimum visibility for a circling approach procedure.[158] Accordingly, the published alternate minima for Norfolk Island applicable to a Westwind were:

- ceiling of 1,269 ft above the aerodrome elevation (based on a forecast QNH)
- visibility of 6,000 m.

In other words, according to the AIP, if the reported base of broken or overcast cloud in the TAF was below 1,269 ft, then Westwind pilots were required to plan for an alternate aerodrome.

The operator’s OM stated that, for international operations under the IFR:

> The alternate minima shall be the greater of:
>
> - The values approved by the country operating aerodromes, or

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155 CAAP 234-1 provided a similar definition, stating it was ‘… an aerodrome specified in the flight plan to which a flight may proceed when it becomes inadvisable to land at, or continue toward, the aerodrome of intended landing’.

156 Forecast amounts of cloud below the alternate minima were cumulative. For example, few cloud at one height below the minima and scattered at another height below the minima was equivalent to broken cloud below the minima.

157 Any additional holding fuel also included provision of an additional 30-minute buffer, except when using a trend type forecast.

158 The Manual of Standards (MOS) for (Australian) CASR Part 173 (Standards applicable to instrument approach procedure design) outlined requirements for the specification of alternate minima. For some airports, ‘special alternate minima’ were available for aircraft fitted with dual ILS/VOR navigation capability. Special alternate minima were lower (or less conservative) than the general alternate minima developed based on the circling minima. Typically special alternate minima were available at major airports with an ILS, such as Sydney or Darwin. The operator’s Westwind aircraft were adequately equipped to use special alternate minima where they were available.

- The most restrictive circling minima when more than one circling minima is published, plus 500 feet and 2 km.

The OM did not define 'international operations'. The Westwind standards manager advised the term would generally apply to any flight to or from an international aerodrome. Regardless, in the case of Norfolk Island both options in the OM procedure led to the same result, as the second dot point was effectively the same as the rule for developing the general alternate minima in Australia.

In many countries the alternate minima for each aerodrome are not specified on approach charts or aerodrome charts. Rather, regulations outlined how to calculate the alternate minima based on the landing minima (see appendix K). As far as could be determined, the operator had no formal method of determining these alternate minima and ensuring flight crews knew these alternate minima.[159]

Other requirements for an alternate aerodrome

In addition to weather-related requirements for an alternate:

- The AIP specified requirements for planning for an alternate aerodrome depending on the availability of radio navigation aids and runway lighting.
- The AIP required an alternate aerodrome when the aerodrome forecast was not available or was 'provisional'.
- CAO 82.0 (Air operator's certificates – Applications for certificates and general requirements) required that passenger-carrying charter flights to remote islands have sufficient fuel to conduct a missed approach at the destination aerodrome and divert to an alternate aerodrome, regardless of the forecast weather conditions (see *Australian requirements for remote islands*).

None of these requirements affected the planning of the 18 November 2009 flight to Norfolk Island.

The operator's OM contained no explicit requirements for the carriage of alternate fuel (in addition to those specified in the AIP). However, the OM contained a section titled 'In-Flight Fuel Checks' (see also *In-flight fuel checks*). This section stated flights could not proceed to the destination aerodrome unless there was sufficient fuel to divert to an alternate aerodrome or 'provided that two separate runways are available' at the destination aerodrome (and the expected weather conditions at the destination aerodrome were suitable). This policy implicitly required that, regardless of the weather conditions, flight crews needed to have sufficient fuel for an alternate aerodrome unless the destination aerodrome had two separate runways available (or there was another aerodrome with a runway available close to the destination aerodrome).

The context of this policy in the OM indicated it may have only applied to international operations.[160] There was no indication in the manual of the required characteristics of the two runways. The Westwind standards manager advised that his interpretation of this procedure was that it only applied if an alternate aerodrome was formally required. In addition, he indicated opposite ends of the same runway could be interpreted as two separate runways. As noted in *Runways*, Norfolk Island had two separate runways, one of which may only have been suitable for 1124/1124A operations in an emergency (depending on the weather conditions).

Westwind pilots stated the operator had no specific, formal requirements regarding the carriage of alternate fuel for any specific type of operation or aerodrome. However, several pilots reported that for some destination aerodromes (such as Norfolk Island) they always ensured they had

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159 Australian operators conducting scheduled operations to other countries could have their procedures approved by those countries. However, there was no indication the operator of VH-NGA had received approval from other countries to use different alternate minima.

160 Some countries included a requirement that an alternate aerodrome needed to be nominated if the destination aerodrome did not have two separate runways (see appendix K). There was no such requirement for Australian operations. Separate runways are usually defined as separate landing surfaces that may overlay or cross each other.

sufficient fuel to arrive at the destination aerodrome, conduct a missed approach and then divert to an alternate aerodrome (see also *Operator requirements for flights to remote aerodromes*).

Fuel for an alternate aerodrome

CAAP 234-1 stated that, when an alternate aerodrome was required, the amount of fuel on board at any particular point in the flight should be sufficient to:

- enable the aircraft to fly from that point to a height of 1,500 ft above the destination aerodrome and conduct an approach to that aerodrome
- conduct a missed approach, fly to the alternate aerodrome and conduct an approach and land at that aerodrome
- provide for a variable fuel reserve
- provide for a fixed fuel reserve
- provide for holding fuel to account for any notified traffic delays at the destination and/or alternate aerodrome.

Consistent with the CAAP guidance, the operator's OM defined 'alternate fuel' as

> … sufficient fuel for a missed approach from the instrument minima at the planned destination aerodrome, to fly to the alternate aerodrome, to make an approach at the alternate aerodrome and to land at the alternate aerodrome.

The OM did not specify how much fuel to use for the climb to cruise level following a missed approach. The OM's description of the 23 lb/minute method indicated 400 lb should be added to the cruise fuel burn off for the initial route segment to allow for the higher fuel flow during the take-off and climb. A review of OPM figures indicated an addition of at least 340 lb for a climb to FL 350 would be appropriate for low aircraft weights, such as during a missed approach after a relatively long flight.

Variable reserve

Fuel planning requires the use of fuel reserves to compensate for a range of unforeseen factors. This involves a variable reserve and a fixed reserve.

CAAP 234-1 defined the variable reserve as:

> ***…***an amount of fuel on board an aircraft that is sufficient to provide for unexpected fuel consumption caused by factors other than a loss of pressurisation or an engine failure…

The variable reserve is meant to allow for contingencies that are not anticipated during flight planning, such as unforecast weather conditions, aircraft performance variations, minor deviations from the planned flight level, unplanned manoeuvring off the planned track and other unexpected delays prior to or after departure.

The CAAP stated that, for turbine-engine aircraft being operated on RPT or charter flights, the variable reserve should be 10 per cent of the flight fuel and alternate fuel (if required). No amount was specified for aerial work or private flights.

The operator's OM stated that (for RPT, charter and aerial work flights):

> **Variable Reserve Fuel** – 10% of the trip [flight] fuel including trip fuel to an alternate if required. In the event of in-flight re-planning, contingency fuel shall be 10% of the trip fuel for the remainder of the flight.

Westwind pilots reported they added 10 per cent of the flight fuel for the variable reserve. This was confirmed by reviewing samples of fuel plans provided to the ATSB or contained in CASA files.

Fixed reserve

CAAP 234-1 defined the fixed reserve as:

> ***…***an amount of fuel, expressed as a period of time holding at 1 500 feet above an aerodrome at standard atmospheric conditions, that may be used for unplanned manoeuvring in the vicinity of the

> aerodrome at which it is proposed to land, and that would normally be retained in the aircraft until the final landing...

Similarly, the OM stated:

> **Fixed Reserve Fuel** – Fuel to fly for 30 minutes at holding speed, for the planned weight, at 1500 ft above either the destination or the alternate aerodrome elevation at ISA.

The OM did not specify a figure for the fixed reserve for the Westwind. It did specify fixed reserve figures for the operator's other aircraft types.

Based on the OPM at ISA, the fixed reserve at the maximum landing weight (19,000 lb) is about 600 lb for a 1124 and about 560 lb for a 1124A. The fixed reserve at normal landing weights (about 16,000 lb) is about 510 lb for the 1124 and about 490 lb for the 1124A.

Westwind pilots generally reported they added 600 lb for the fixed reserve for both 1124 and 1124A flights. Sample fuel plans provided to the ATSB or contained in CASA files had values of 500 lb, 550 lb or 600 lb. The flight plans provided by the Westwind standards manager included a combined figure for the fixed reserve and 1 hour's holding fuel, based on the 1124 OPM, of about 1,400 lb.

In his initial interviews with the operator following the accident, the captain of the accident flight reported that for longer flights (more than 3.50 hours) he used 1,500 lb as the figure for both the variable and fixed reserve, and for shorter flights (less than 3.50 hours) he used 1,200 lb.

In general, the use of 1,500 lb for fuel reserves for flights over 3.50 hours was conservative (that is, it added more fuel than using 10 per cent for the variable reserve and 600 lb for the fixed reserve). More specifically:

- For a 3.75-hour flight the captain's method resulted in 340 lb more fuel reserves than using the standard method.
- For a 4.00-hour flight the captain's method resulted in 300 lb more fuel reserves than using the standard method.
- For a 4.25-hour flight the captain's method resulted in 280 lb more fuel reserves than using the standard method.

In his subsequent interviews with the ATSB, the captain reported he used the operator's normal method for calculating the fuel reserves when planning the 18 November 2009 flight (that is, 10 per cent for the variable reserve and 600 lb for the fixed reserve).

Holding fuel

CAAP 234-1 defined holding fuel as:

> … an amount of fuel that will allow an aircraft to fly for a specified period of time, being an amount that is calculated at the holding rate established for the aircraft at a level not greater than flight level 200 and at a temperature not less than forecast.

The AIP (ENR 1.1 General Rules, section 73) stated holding fuel was required to be carried when weather conditions were forecast to be intermittently or temporarily below the alternate minima, or to allow for traffic delays at some major aerodromes. None of these circumstances applied when the captain planned the flight from Apia to Norfolk Island on 18 November 2009.

Based on the OPM in ISA+10°C conditions, the holding fuel flow at the maximum landing weight at FL 200 is about 1,100 lb/hour for the 1124 and about 970 lb/hour for the 1124A. The holding fuel flow at more typical landing weights (16,000 lb) at FL 200 is about 900 lb/hour for the 1124 and about 830 lb/hour for the 1124A.

Westwind pilots reported that they would include holding fuel if required. As noted above, sample flight plans provided by the Westwind standards manager indicated he always included 1 hour of holding fuel.

Taxi fuel

The OM did not specify a figure for taxi fuel for the Westwind. It did specify taxi fuel figures for the operator's turboprop aircraft (such as 100 lb for the Metro).

The 1124/1124A OPMs did not specify a figure for taxi fuel, although worked examples included 150 lb for taxiing out. This figure corresponded to the difference between the aircraft's maximum ramp gross weight (23,650 lb) and the aircraft's maximum take-off weight (23,500 lb).

The Westwind standards manager reported that he used 150 lb for pre-flight taxi fuel, and this was confirmed in sample flight plans he provided to the ATSB. Some of the other pilots reported including a figure for taxi fuel, though they could not recall the amount they used. Sample fuel plans provided to the ATSB or contained on CASA files used values of 50, 100 or 150 lb, with the latter being most common. The captain of the accident flight reported he generally did not include a figure for taxi fuel.

The ATSB estimated that for 5 minutes taxi time, the fuel burn off would be about 50 lb. Therefore a figure of 100–150 lb would generally be appropriate to allow for the fuel used during the taxi phase.

Additional fuel for aircraft system failures

General fuel planning requirements for aircraft system failures

As noted above, CAR 234(3) specifically required that contingencies such as a loss of pressurisation or engine failure be considered when determining the amount of fuel required for a flight. CAR 220 also required the operator to provide specific instructions for situations such as an engine failure.

CAAP 234-1 provided additional guidance for these abnormal situations. For a loss of pressurisation, the CAAP stated that, at any time after take-off, the fuel on board should be sufficient to:

- enable the aircraft to fly to a height of 1,500 ft above a suitable aerodrome, conduct an approach and land
- provide for a fixed reserve (30 minutes for turbine-engine aircraft).

For an engine failure or one-engine inoperative (OEI) situation, the CAAP stated that, at any time after take-off, the fuel on board should be sufficient to:

- enable the aircraft to fly to a height of 1,500 ft above a suitable aerodrome, conduct an approach and land
- provide for a variable reserve (10 per cent of the flight fuel for turbine-engine aircraft)
- provide for a fixed reserve of 10 minutes.

The operator's OM required additional fuel to be carried to allow for loss of pressurisation and OEI situations. More specifically, it required fuel for:

> Flight to the critical point (CP) [see below] and then to a suitable aerodrome based on 'one engine inoperative' (OEI) with contingency fuel of 10% and 30 minutes final reserve fuel; or
>
> Flight to the CP and then to a suitable aerodrome based on two engine depressurised cruise with contingency fuel of 10% and final reserve fuel of 30 minutes…

The operator's use of a 10 per cent variable reserve and 30 minutes fixed reserve when calculating the additional fuel required for these abnormal situations was conservative, as it required more fuel than the CAAP guidance.

For the Westwind 1124/1124A, a depressurised configuration is more critical (requires more fuel) than an OEI configuration. Therefore, for the purposes of determining the minimum total fuel required to allow for system failures, the depressurisation calculation was the most important.

The calculation of the additional fuel required to allow for system failures involved a separate calculation of the total fuel required for a flight. In other words, for applicable flights, a pilot was required to calculate two total fuel figures:

- the total fuel required for a normal operation (that is, flight fuel, alternate fuel, variable reserve, fixed reserve, holding fuel and taxi fuel)
- the total fuel required to allow for a depressurisation (that is, flight fuel to the CP, variable reserve to the CP, additional fuel from the CP to the destination or alternate aerodrome, applicable variable reserve from the CP to the destination or alternate aerodrome, fixed reserve and taxi fuel).

The minimum total fuel required prior to departure was the larger of these two totals. In other words, the additional fuel required to allow for aircraft system failures was the difference between the total fuel required for the depressurised situation minus the total fuel required for a normal (or non-depressurised) operation. If the total fuel for a normal operation was larger, no additional fuel was required.

Critical points

A critical point (CP), sometimes known as the equi-time point (ETP), is the point in the flight where it will take the same time to:

- continue to the destination aerodrome, and
- either return to the departure aerodrome or divert to a suitable alternate aerodrome.

A CP is normally associated with system failures or emergency situations when a flight crew needs to land as soon as possible. However, it also has a role in determining minimum fuel requirements when flight planning, as the crew need to ensure there is sufficient fuel at all stages of the flight to be able to reach a suitable aerodrome. Some of these situations, such as a loss of pressurisation, will result in a higher than normal fuel burn off.

The operator’s OM required that:

> The PIC shall calculate a critical point on appropriate flights over water greater than 200 miles [NM] from land and on all other flights where the availability of an adequate aerodrome is critical.[161] The PIC shall determine the most critical case between normal operations; operations with one engine out and all engines depressurised operations.
>
> The PIC shall calculate the CP before flight and shall update the CP at top of climb.

Guidance for calculating a critical point

CASA did not provide any formal guidance material on calculating a CP or a point of no return (PNR). It stated CPs and PNRs are both assessed in theory examinations that flight crew are required to pass in order to obtain a CPL and an ATPL, and there are multiple methods available to conduct such calculations (see also *Guidance for calculating a PNR*).

Part B of the operator’s OM provided some guidance on calculating a CP before flight, using a simple formula and a navigation computer.[162] In both cases, this guidance was based on a scenario where the two aerodromes being considered were on the planned track between the departure aerodrome and the destination aerodrome. The guidance did not cover a situation involving a potential diversion to an off-track alternate aerodrome.

For an OEI situation, Part A of the OM stated 300 kt was to be used for flight planning. It also required that the fuel required from the CP to the suitable aerodrome be calculated using the appropriate OEI consumption rate for the aircraft type as specified in the OPM, using the estimated mid-zone weight for the sector.

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[161] Part B of the operations manual also stated a CP was required ‘… to be calculated for all flights over water greater than 200 nm from land and on flights where no intermediate aerodromes are available’.

[162] An aviation navigation computer is a logarithmic, circular slide rule.

For a loss of pressurisation situation, the OM stated fuel calculations should be based on depressurised, long-range performance. The manual also stated:

- For a gradual loss of pressurisation, crews should descend to an altitude that would result in the cabin pressure remaining at or below 10,000 ft.
- For a sudden depressurisation, crews must instantly initiate descent to an altitude of FL 140 or below.

The OM did not provide any figures to use for speed or fuel flow from the CP for the remainder of the flight for a loss of pressurisation. Therefore, pilots were required to derive figures from the OPM.

A review of the 1124A OPM indicated that using long-range cruise settings at FL 140 in ISA+10°C conditions at an aircraft weight of 17,000 lb would result in a TAS of 272 kt and a fuel burn off of about 20 lb/minute.

Flight crew practices for calculating critical point and additional fuel

Some Westwind pilots reported they did CP calculations prior to flight to ensure they had sufficient fuel to comply with the OM requirements. Other pilots reported they did not conduct specific CP calculations during flight planning. Instead, they carried a substantial amount of discretionary fuel, which allowed for aircraft system failures such as a loss of pressurisation.

In his initial interviews with the operator and the ATSB in November and early December 2009, the captain did not discuss additional fuel for a depressurisation when explaining his process for fuel planning and his calculations of the total fuel required for the flight. He subsequently reported that his normal practice was to allow for an amount of fuel that would cover a depressurised situation, rather than calculate a CP and the additional fuel required. He could not recall how he made his assessment of the additional fuel for the accident flight.

The captain also stated the operator had not provided him with any specific fuel burn off figures to use for depressurised operations. However, he had derived some figures from the 1124 OPM. These figures involved the use of a TAS of about 340 kt and a fuel burn off of about 33 lb/minute at FL 140 for a depressurised aircraft. The ATSB found that such figures provided a similar result to using long-range cruise settings.

Discretionary fuel

Discretionary fuel refers to the extra fuel carried at the discretion of a captain in addition to the minimum amount required for the flight.

The operator’s Westwind pilots reported they generally took significantly more fuel than the minimum amount required. They said they usually departed with full fuel (full main and full tip tanks) for long-distance flights. Occasionally, if they had aircraft weight limitations, they refuelled to a more specific amount. Such weight limitations were more commonly associated with freight flights, and rarely associated with long-distance air ambulance flights.

Sample flight plans provided by the Westwind standards manager and flight plans identified in CASA files all included a substantial amount of discretionary fuel. A review of flights records for long-distance air ambulance flights also indicated flight crews generally departed with full fuel, which generally included a substantial amount of discretionary fuel (see *Review of the operator’s previous air ambulance flights* and appendix M).

The captain noted his use of 1,500 lb for the fuel reserves for flights over 3.50 hours provided a more conservative amount for the fuel reserves than using the operator’s prescribed method of 10 per cent variable reserve and 600 lb fixed reserve. In addition, the captain reported:

- He would normally round up his fuel planning calculations, such as flight time, to higher values to be more conservative.

- He considered full main tanks on the 1124 and 1124A to be nominally 7,200 lb, and full fuel to be 8,700 lb. If he calculated his total fuel required to be less than 7,200 lb, he refuelled to full main tanks. If the total fuel required was more than 7,200 lb, he almost always refuelled to full fuel. He would occasionally refuel to an amount between 7,200 lb and 8,700 lb if for some reason he needed a specific fuel amount.

International standards for isolated aerodromes

Standards for international commercial air transport operations

As discussed in Classification of operations, ICAO Annex 6 (Operation of Aircraft) specified SARPS for the operation of aircraft. Under Australian requirements, air ambulance operations were classified as aerial work. Annex 6 did not specify any requirements for international aerial work operations.

Annex 6 Part I applied to operators conducting international commercial air transport operations in aeroplanes.[163] Part I stated:[164]

> 4.3.4.3 *Destination alternate aerodromes*
>
> For a flight to be conducted in accordance with the instrument flight rules, at least one destination alternate aerodrome shall be selected and specified in the operational and ATS flight plans, unless:
>
> a) the duration of the flight and the meteorological conditions prevailing are such that there is reasonable certainty that, at the estimated time of arrival at the aerodrome of intended landing, and for a reasonable period before and after such time, the approach and landing may be made under visual meteorological conditions [VMC]; or
>
> b) the aerodrome of intended landing is isolated and there is no suitable destination alternate aerodrome.

In other words, Annex 6 defined an ‘isolated’ aerodrome as a destination aerodrome for which there was no suitable alternate aerodrome available.

In terms of fuel planning requirements for aircraft equipped with turbojet engines operating a commercial air transport flight, if a destination alternate aerodrome was required then the flight was required to carry alternate fuel. If the flight was to an isolated aerodrome, the flight was required to have sufficient fuel to:

> … fly to the aerodrome to which the flight is planned and thereafter for a period of two hours at normal cruise consumption.

This 2-hour requirement included the fixed reserve. In effect, this meant that the flight needed to be planned so that the aircraft arrived at the (isolated) destination aerodrome with sufficient fuel for at least 90 minutes holding at 1,500 ft as well as the fixed reserve of 30 minutes.[165]

Depending on the en route wind and temperature conditions, Norfolk Island could be an isolated aerodrome for a flight from Apia to Norfolk Island in a Westwind 1124 or 1124A. That is, even if an aircraft departed with full fuel, this fuel load would not be sufficient to allow for the required taxi fuel, flight fuel, alternate fuel and fuel reserves to conduct a flight to Norfolk Island, conduct a missed approach and then divert to an alternate aerodrome (see *Estimated fuel on board for the accident flight and other scenarios*). For the flight on 18 November 2009, Norfolk Island was an

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[163] The 4th edition of Part 1 (1983) stated it was applicable to the operation of aeroplanes in scheduled and unscheduled international air services. The 5th edition (1990) stated it was applicable to the operation of aeroplanes by operators authorised to conduct international commercial air transport operations.

[164] Material from Annex 6 Part I in this section is from the 8th edition (2001). The same wording was in the seventh edition (1998), and the requirements were similar in earlier editions.

[165] ICAO (2015), Document 9976, *Flight planning and fuel management (FPFM) Manual*, 1st edition.

isolated aerodrome. For a Westwind 1124, 2 hours holding at 1,500 ft equated to about 2,200 lb. For a 1124A, 2 hours holding at 1,500 ft equated to about 2,100 lb.[166]

Standards for international general aviation operators

Annex 6 Part II[167] applied to international general aviation operations using aeroplanes. Paragraph 4.7 was effectively the same as paragraph 4.3.4.3 of Part I (see above). That is, flight planning did not require an alternate aerodrome if it was reasonably certain the weather conditions at the destination aerodrome would be VMC, or the destination aerodrome was an isolated aerodrome.

In addition, Part II outlined more specific weather-related requirements. It stated an IFR flight without an alternate aerodrome could not be commenced unless the destination aerodrome had an instrument approach procedure and the forecast weather conditions (from 2 hours before to 2 hours after the intended time of landing) were:

- a cloud base of at least 1,000 ft higher than the minimum for the instrument approach
- visibility of at least 5.5 km, or 4 km more than the minimum for the instrument approach.

These requirements were generally more conservative than the alternate minima specified for Australian aerodromes, particularly for aerodromes without a precision approach such as Norfolk Island or Christmas Island.

For example, in the case of Norfolk Island, if planning for a runway 29 VOR approach, the Annex 6 Part II criteria for a flight to be conducted without an alternate aerodrome (such as a flight to an isolated aerodrome) would be a cloud base of 1,584 ft and a visibility of 7,300 m.[168] The published alternate minima for Norfolk Island were a ceiling of 1,269 ft and a visibility of 6,000 m. The forecast conditions when the flight from Apia to Norfolk Island on 18 November 2009 was planned were better than either set of criteria (that is, the TAF forecast scattered cloud at 2,000 ft and a visibility of at least 10,000 m).

Application of the international standards in other countries

Appendix K provides a review of the regulatory requirements for alternate aerodromes and isolated aerodromes for passenger-carrying IFR flights in New Zealand, US, Canada and Europe. Each country or group of countries has its own regulatory requirements, and focussing on specific aspects may not give a full picture of the relative standards that apply in each case. However, in general terms:

- Europe effectively applied the ICAO Annex 6 Part I requirements for isolated aerodromes to all commercial air transport operations (that is, no weather-related criteria were specified, but all operations needed sufficient fuel for at least 2 hours holding, including the fixed reserve).
- The US and Canada required airline operations to some types of isolated aerodromes have sufficient fuel to arrive at the destination aerodrome and then fly for 2 hours. This requirement only applied if an alternate aerodrome was not required due to weather-related requirements.
- For operations to non-isolated aerodromes in Europe, and all aerodromes in the other countries, weather-related requirements were specified for when an alternate aerodrome was required. These weather-related requirements generally included a more conservative ceiling than specified in Australia.

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166 These figures assume ISA+10°C and an aircraft weight of 17,000 lb. Ninety minutes fuel burn at long-range cruise settings at 1,500 ft plus 30 minutes fixed reserve results in a higher fuel burn, whereas 90 minutes holding at FL 200 plus 30 minutes fixed reserve results in a lower fuel burn.

167 Material from Annex 6 Part II in this section is from the 6th edition (1998). The same wording was in the 5th edition (1995). Prior to 1995, there was no requirement to nominate an alternate aerodrome, but if an alternate aerodrome was not declared the requirements regarding the decision criteria still applied.

168 This calculation is based on using the landing minima for the VOR approach to runway 29, which would have been the approach most likely to be used based on the aerodrome forecast. It also assumed the use of a forecast QNH.

- For operations in Canada, operations to non-isolated aerodromes in Europe and international airline operations to and from New Zealand, a flight could not be conducted without an alternate aerodrome unless the destination aerodrome had two separate runways.[169]

Application of the international standards in Australia

As of 2009, the Annex 6 Part I and Part II SARPS for isolated aerodromes were not specified in Australian regulatory requirements, although CASA had initiated a proposal to introduce the Part I requirements as part of its regulatory reform program in 2002.[170] In terms of why the Annex 6 Part I requirements for isolated aerodromes had not previously been introduced into Australia, CASA advised:

> The differences at that time between the Australian rules for alternates and fuel and those contained in ICAO Annex 6 (and other NAAs [national aviation authorities]) have been on the basis of the acknowledgement of two fundamental differences.
>
> Firstly, Australia did not have the aviation supporting infrastructure that was available in Europe and North America. The distances between Australian aerodromes necessitated a difference from the rules applicable in states where aerodromes are far more prevalent and generally with much shorter distances between them.
>
> Secondly, the benign aviation weather found in Australia does not impose the kind of impacts found in Europe and North America in winter that routinely close airports for long periods of time, such as snow and ice. Additionally, the weather reporting facilities for many remote areas was limited and as such the reliability of obtaining accurate weather information required a different approach be taken by the regulator.
>
> For the reasons above, the Australian methodology has been to require an alternate (destination alternate) be nominated only if the anticipated conditions (cloud, visibility, wind or presence of thunderstorms) are below a threshold value or if aerodrome lighting is uncertain. For many years Australia had adopted the policy of requiring the alternate weather minima to be applied to the destination weather in order to determine if a destination alternate was required.
>
> Having set the requirement for a destination alternate to be nominated under certain conditions, the [Australian] alternate related fuel carriage requirements then follow accordingly.

In August 2009, CASA commenced a project to review the Australian requirements for fuel and alternates. The terms of reference noted the ATSB database had provided evidence that fuel quantity issues were becoming problematic, and it was proposed to strengthen CAAP 234, and to change CAR 234 in order to encourage industry to follow the contents of the CAAP. It also noted proposed amendments to ICAO Annex 6 for fuel and alternate requirements for commercial air transport operations ‘require CASA to explore this issue and identify any potential issues the proposed ICAO amendments may have within the Australian aviation operating environment’. Further details of actions taken as a result of this project are provided in *Safety issues and actions*.

Australian requirements for remote islands

Although Australia did not have any fuel planning requirements for isolated aerodromes, it did have requirements for ‘remote’ islands. CAO 82.0 (Air operator’s certificates – Applications for certificates and general requirements) included the following requirements for charter operations in paragraph 3A:

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169 In a 2002 discussion paper (DP), CASA indicated that after consultation with industry it had elected not to include a requirement for two runways when developing new regulations for air transport operations. It noted such a requirement did not exist in the US or in ICAO standards. DP 0207OS, March 2002, Air transport operations – small aeroplanes, Proposed Part 121B of the Civil Aviation Safety Regulations (CASRs).

170 NPRM 0211OS, April 2002, Air transport operations – large aeroplanes, Proposed Part 121A of the Civil Aviation Safety Regulations (CASRs). The definition of large aeroplanes included aircraft with a MTOW greater than 5,700 kg (which included the Westwind 1124). The same requirements were not proposed for air transport operations in smaller aircraft (see NPRM 0307OS, July 2003, Air transport operations – small aeroplanes, Proposed Part 121B of the Civil Aviation Safety Regulations (CASRs)).

> Each certificate authorising charter operations for the carriage of passengers is subject to the condition that an aeroplane operated under the certificate is to carry passengers on a flight to a remote island only if:
>
> (a) the aeroplane has more than 1 engine; and
>
> (b) the total amount of fuel carried by the aeroplane at the start of the flight is not less than the minimum safe fuel for the aeroplane for that flight; and
>
> (c) the alternate aerodrome for the aeroplane for that flight is not an aerodrome located on a remote island.

The CAO defined a 'remote island' as Norfolk Island, Christmas Island and Lord Howe Island. It defined 'minimum safe fuel' as:

> 2.3 The minimum safe fuel for an aircraft undertaking a flight to a remote island is:
>
> (a) the minimum amount of fuel that the aeroplane should carry on that flight, according to the operations manual of the aeroplane's operator, revised (if applicable) as directed by CASA to ensure that an adequate amount of fuel is carried on such flights; or
>
> (b) if the operations manual does not make provision for the calculation of that amount or has not been revised as directed by CASA — whichever of the amounts of fuel mentioned in paragraph 2.4 is the greater.
>
> 2.4 For the purposes of subparagraph 2.3 (b), the amounts of fuel are:
>
> (a) the minimum amount of fuel that will, whatever the weather conditions, enable the aeroplane to fly, with all its engines operating, to the remote island and then from the remote island to the aerodrome that is, for that flight, the alternate aerodrome for the aircraft, together with any reserve fuel requirements for the aircraft; and
>
> (b) The minimum of fuel that would, if the failure of an engine or a loss of pressurisation were to occur during the flight, enable the aeroplane:
>
> (i) to fly to its destination aerodrome or to its alternate aerodrome for the flight; and
>
> (ii) to fly for 15 minutes at holding speed at 1 500 feet above that aerodrome under standard temperature conditions, and
>
> (iii) to land at that aerodrome…

In other words, CAO 82.0 required a passenger-carrying charter flight to a designated remote island to carry sufficient fuel to comply with specific requirements in the operator's OM for such flights. If there were no specific requirements in the OM for such flights, then the flight required sufficient fuel to conduct an approach at the destination aerodrome and then divert to an alternate aerodrome.

The CAO 82.0 remote island requirement did not apply to air ambulance operations as such operations in Australia were classified as aerial work (see *Classification of operations*).

The CAO 82.0 requirement also did not apply to RPT operations. CASA advised RPT operations were not included as, at the time the requirement was introduced (August 1999), it was already a condition on an RPT operator's AOC that CASA approved both the route over which an RPT operation was flown and the fuel policy of the operator. Therefore, for RPT operations, CASA already had a means in place to regulate the carriage of adequate fuel for remote islands. CASA also advised that, after 1999, it issued approvals for an operator to conduct operations within a defined area rather than for specified routes. With this change from route approvals to area approvals for some RPT operators, relevant conditions on the AOC holder were applied by CASA on a case-by-case basis by the relevant regional office. However, subsection 3A of CAO 82.0 was not modified to require the nomination of alternate aerodromes for RPT operations to remote islands.[171]

When the CAO 82.0 requirements were initially introduced (August 1999), operators of passenger-carrying charter flights needed a specific approval from CASA to conduct each flight to a remote island. The CAO 82.0 requirements were subsequently modified in December 2000 to remove this requirement. Appendix L provides further information on the history of Australian fuel requirements for remote islands.

Operator's Westwind operations to remote aerodromes

Overview of the operator's Westwind flights to remote aerodromes

For the purposes of this report, the ATSB defined a 'remote aerodrome' for Westwind 1124/1124A aircraft as a destination aerodrome where no suitable alternate aerodrome for a safe landing was available within 240 NM.[172] This definition includes the Australian remote islands specified in CAO 82.0, as well as several international destination aerodromes that the operator used. It also effectively included flights to isolated aerodromes.

From 1 January 2002 until 17 November 2009, the operator's Westwind aircraft conducted 185 flights to remote aerodromes.[173] Other information about the flights included:

- There were 76 flights to Norfolk Island, 52 flights to Christmas Island, 4 flights to the Cocos Islands and 53 flights to remote aerodromes in other countries, mostly in the Oceanic/South Pacific region. The most commonly-used international remote aerodrome was Honiara, Solomon Islands (26 flights).
- Most (107) of the 185 flights were air ambulance flights. The remainder were a mixture of passenger charter, freight charter and aerial work flights.
- The number of flights to remote aerodromes each year was relatively constant during 2004–2009, averaging about 25 flights per year.
- Eighty-five (46 per cent) of the 185 flights landed at night.

In terms of the 76 flights to Norfolk Island:

- Most (61) of the flights were air ambulance flights and at least 8 were freight flights. Only a small proportion of the flights to Norfolk Island were passenger-carrying charter flights. However, the exact number could not be determined.
- About half (39) of the flights landed at night.
- Most of the flights departed from Sydney (57). Norfolk Island was also regularly used as a refuelling stop for flights between Sydney and Fiji, Samoa and American Samoa during 2004–2009.

Appendix N provides more detailed information about the operator's Westwind flights to remote aerodromes from 1 January 2002 to 17 November 2009.

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[171] CASA proposed including a requirement for an alternate aerodrome to be specified for all flights to designated remote islands by RPT and passenger charter operations in large aeroplanes in NPRM 0211OS, April 2002, Air transport operations – large aeroplanes, Proposed Part 121A of the Civil Aviation Safety Regulations (CASRs)). Similar requirements were also proposed for RPT and passenger charter operations in small aeroplanes in NPRM 0307OS, July 2003, Air transport operations – Small aeroplanes, Proposed Part 121B of the Civil Aviation Safety Regulations (CASRs).

[172] The minimum distance of 240 NM was selected so that Christmas Island (266 NM to the nearest alternate aerodrome) was included.

[173] Only flights with a flight time of at least 1.75 hours and a flight distance of at least 600 NM were included (see appendix P for more details). The 185 flights included one air ambulance flight where the crew conducted a missed approach at Norfolk Island and then diverted to Auckland.

Operator requirements for flights to remote aerodromes

The operator's OM contained no specific fuel planning requirements for flights to remote islands or isolated aerodromes, either generally or for any specific destination. The OM did not refer to CAO 82.0's requirements for remote islands, and the OM made no distinction between passenger charter and aerial work flights in relation to fuel planning requirements.

There was no evidence on CASA files that the operator had revised its OM to cater for remote island operations after the introduction of CAO 82.0, or that CASA had provided specific directions to the operator to revise its policy for remote island operations. Therefore, in accordance with paragraph 2.3 of the CAO, all the operators passenger-carrying charter flights to remote islands had to comply with paragraph 2.4 (that is, such flights needed to carry alternate fuel).

When asked why the CAO 82.0 requirements regarding remote island operations were not included in the OM, the Westwind standards manager advised that almost all of the operator's flights to remote islands were air ambulance flights or freight flights, and it rarely conducted passenger-carrying charter flights to remote islands. He also noted his interpretation of CAO 82.0 was that it did not specifically require that a passenger-carrying charter flight to a remote island carried alternate fuel (see also *October 2009 flight*). Rather, it only required that such a flight could not nominate another remote island as an alternate aerodrome.

As already noted above, passenger-carrying charter operations to remote islands needed specific CASA approval between August 1999 and December 2000. A review of CASA files for the operator identified one instance of the operator requesting CASA approval to conduct a passenger carrying charter flight (with one passenger and freight) from Darwin to Christmas Island in August 2001. The application, from the Westwind standards manager (then the chief pilot), included fuel planning documentation showing that the flight would carry alternate fuel. CASA approved the flight.

The Westwind standards manager and Westwind pilots confirmed the operator had no formal requirements regarding minimum fuel, alternate fuel or holding fuel specifically associated with remote islands or isolated aerodromes. Most of the operator's Westwind pilots also reported that they treated air ambulance operations the same as charter operations.

The operator's Westwind pilots reported that for long-distance flights to Australian remote islands, and similar aerodromes internationally, they always departed with as much fuel as possible. This was almost always full fuel, particularly for air ambulance flights.

Some pilots also reported that for flights to Norfolk Island and/or Christmas Island they always ensured they had sufficient fuel to arrive at the destination aerodrome, conduct a missed approach and then divert to an alternate aerodrome. Others stated they simply took as much fuel as they could, which usually provided enough fuel for an alternate aerodrome. However, they would only ensure there was sufficient fuel for an alternate if the forecast weather conditions or other circumstances indicated it was required.

A review of flight records for the operator's flights to remote aerodromes indicated flight crews generally departed with full fuel or as much fuel as possible. Flights that departed with less than full fuel had a relatively-short duration and had sufficient fuel to divert to an alternate aerodrome or hold for a significant period of time at the destination aerodrome (see *Review of the operator's previous flights to remote aerodromes* and appendix N).

The ATSB reviewed the operations manuals of three other Australian air ambulance operators which had conducted operations to Australian remote islands as at the time of the November 2009 accident. Two of the operators had no specific fuel planning requirements for flights to remote islands or isolated aerodromes. The other operator included a reference to the CAO 82.0 requirements for passenger-carrying charter operations.

Suitable alternate aerodromes for flights to Norfolk Island

The nearest aerodromes to Norfolk Island that were suitable for the operator's Westwind operations were:

- La Tontouta Airport, Noumea, New Caledonia: 432 NM north of Norfolk Island[174]
- Auckland Airport, Auckland, New Zealand: 589 NM south-east of Norfolk Island
- Nadi International Airport, Nadi, Fiji: 854 NM north-east of Norfolk Island.

All of these airports had instrument approaches, including an ILS approach, suitable lighting and facilities. Noumea was the closest alternate aerodrome and would normally be considered as the most suitable. The operator commenced air ambulance operations to Noumea in April 2002, and it regularly conducted flights to Noumea until February 2009. The operator also regularly conducted flights to the other two airports.

In February 2009, the French DGAC conducted a ramp check at Noumea on VH-AJV, one of the operator's Westwind aircraft undertaking a freight charter flight.[175] Following the ramp check, the DGAC advised the operator in writing that the flight, and the operator's air ambulance flights, were commercial air transport operations as per the definition in ICAO Annex 6 Part I. The DGAC stated:

> In accordance with the standards of ICAO, Annex 6, part 1, chapter 6.15.4, "from January, 1st 2007, all turbine-engined aeroplanes of a maximum certified take-off mass in excess of 5700kg or authorized to carry more than nine passengers, shall be equipped with a ground proximity warning system which has a forward looking terrain avoidance function".
>
> In accordance with the standards of ICAO, Annex 6, part 1, chapter 6.18.2, "from January, 1st 2005, all turbine-engined aeroplanes of a maximum certified take-off mass in excess of 5700kg or authorized to carry more than nineteen passengers, shall be equipped with an airborne collision avoidance system (ACAS II)".

Accordingly, the DGAC stated VH-AJV was required to be equipped with an EGPWS and ACAS II in order to perform international commercial transportation flights. It requested the operator provide the DGAC with a corrective action plan for fitting the required equipment to its aircraft prior to conducting any further operations over French territory. Subsequently, the DGAC also noted all aircraft were required to be fitted with a 406 MHz ELT in accordance with ICAO standards.

The DGAC advised CASA of the problem. It also advised CASA that another Australian air ambulance operator had not met the Annex 6 Part 1 requirements during a ramp check in April 2009, as the relevant aircraft did not have an ACAS II.

In April 2009, the operator advised the DGAC that it had ceased all flights to Noumea until its aircraft operating there were fully compliant with the DGAC's requirements. It subsequently fitted VH-NGA with the required systems in August 2009. It then conducted air ambulance flights to Noumea on 23 September 2009 and 6 October 2009.

The DGAC required the operator to submit a formal application for a permit before further flights were conducted to Noumea. The operator advised the ATSB that it submitted the required paperwork to the DGAC on 3 November 2009 and also queried the progress of the regulator's processing of the documentation on 13 November.[176] It received a formal response permitting planned flights to Noumea in VH-NGA on 23 November 2009, 5 days after the accident.

On 17 November 2009, the captain nominated Noumea as the alternate aerodrome for the flight from Sydney to Norfolk Island. He also reported he was considering the use of both Nadi and

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174 La Tontouta Airport only had one runway. However, Noumea Magenta Airport was located 21 NM south-east of La Tontouta. Although not suitable for normal commercial operations for a Westwind 1124/1124A aircraft, it was suitable for use in an emergency.

175 The captain of the 19 February 2009 flight was also the captain of the 18 November 2009 accident flight.

176 The operator also advised CASA about its progress with satisfying the DGAC's requirements during early November 2009.

Noumea as an alternate aerodrome during the accident flight from Apia to Norfolk Island on 18 November.

Both the captain and the first officer reported they were not aware whether the ban on the operator's planned flights to Noumea had been addressed. Even though they thought they could not plan a flight direct to Noumea, they both reported they would use Noumea as an alternate aerodrome if required. Other Westwind pilots also reported that, although they knew they could not conduct a planned flight to Noumea without prior approval, they could and would use Noumea as an alternate aerodrome.

Capacity of a Westwind to carry alternate fuel on flights to Norfolk Island

The ability to carry sufficient fuel for an alternate obviously depends on many factors, such as the flight fuel to the destination aerodrome, distance to the alternate aerodrome, aircraft weight, flight level and weather conditions. The ATSB calculated the capacity of the Westwind 1124A aircraft to conduct a flight from Apia to Norfolk Island, conduct an instrument approach and then divert to Noumea using each of the fuel planning methods (and including the applicable fuel reserves). In summary:

- Using the 23 lb/minute method at 400 kt block speed (including 400 lb for the missed approach climb), the total fuel required exceeded full fuel (8,730 lb) with a 0-kt headwind component.
- Using the hour-by-hour method at 400 kt block speed with a temperature of ISA+10°C (including 400 lb for the missed approach climb), the total fuel required exceeded full fuel with a 0-kt headwind component.
- Using the 1124A OPM at Mach 0.72 and a temperature of ISA+10°C resulting in a 395 kt block speed, the total fuel required exceeded full fuel with a greater than 15-kt headwind component and assuming long-range cruise settings were used during the diversion.[177]

In other words, for the circumstances that existed when planning the flight from Apia to Norfolk Island on 18 November 2009, Norfolk Island met the ICAO definition of an isolated aerodrome for a Westwind aircraft. Nevertheless, as an air ambulance flight, there was no Australian regulatory requirement or operator requirement for the flight to be planned to carry any alternate or holding fuel.

Obtaining information for flight/fuel planning

CAR 239(1) stated:

> Before beginning a flight, the pilot in command shall study all available information appropriate to the intended operation, and, in the cases of flights away from the vicinity of an aerodrome and all I.F.R. flights, shall make a careful study of:
>
> a. current weather reports and forecasts for the route to be followed and at aerodromes to be used;
>
> b. the airways facilities available on the route to be followed and the condition of those facilities;
>
> c. the condition of aerodromes to be used and their suitability for the aircraft to be used; and
>
> d. the air traffic control rules and procedure appertaining to the particular flight;
>
> and the pilot shall plan the flight in relation to the information obtained.

AIP ENR 1.10 (Flight Planning, paragraph 1.1) also stated these requirements. In addition, it stated a PIC was required to review NOTAMs applicable to the flight.

177 The calculations also assumed the same wind component for the flight to Norfolk Island and the diversion to Noumea. The figures included 150 lb taxi fuel and 600 lb fixed reserve. For the calculation using the OPM, approach fuel at Norfolk Island and Noumea was included.

In relation to types of forecasts that were required, section 1.2 of ENR 1.10 stated a forecast '…must be either a flight forecast[178] or an area forecast[179] with an aerodrome forecast for the destination and, where required, the alternate aerodrome'.

The AIP also stated a PIC 'must ensure that the forecasts cover the period of the flight', and that aerodrome forecasts for the destination aerodrome (and alternate aerodrome if required) were valid for a period of not less than 30 minutes before and 60 minutes after the planned time of arrival. In addition, it stated that when a flight was delayed, so that meteorological and operational no longer covered the period of the flight, '…updates must be obtained as necessary, to allow the flight to be concluded safely'. The AIP also stated that when pre-flight briefing information was obtained more than 1 hour prior to the estimated time of departure, '…pilots should obtain an update before each departure to ensure the latest information available can be used for the flight'.

In terms of pre-flight responsibilities, the operator's OM stated:

> Pilot In Command Duties include;
>
> a) The PIC is to obtain enroute and terminal [aerodrome] forecasts and NOTAMS.
>
> b) Prepare a flight plan for routes where a standard flight plan is not available…
>
> First Officer Duties include;
>
> a) The F/O is to fuel the aircraft to the quantity and distribution as ordered by the PIC…

The operator's OM also stated that, prior to departure on each flight, captains had to:

> a) Make a careful study of weather details pertaining to the flight route, alternate routes and aerodromes to be used.
>
> b) Ensure that the weather details are current and valid for the period of operation.
>
> c) Where required, ensure the ATS flight plan is submitted and correct and the aircraft is able to comply with any ATC requirements.
>
> d) Ensure the aerodromes... to be used are suitable and serviceable for the aircraft being flown.
>
> e) Check the availability of airways routes, navigation aid and communication facilities for the route to be flown.

Westwind pilots confirmed that a captain was responsible for fuel planning and flight planning, and a first officer generally prepared the aircraft for flight.

Westwind pilots reported that, for flights from their home base, the captain obtained the weather and other relevant information and submitted a flight plan via the internet either before arriving at the airport or at the operator's facilities soon after they arrived at the airport. When away from home base, captains obtained the weather and other relevant information in a variety of ways. These included via the internet at the hotel or somewhere at the aerodrome, such as through the local ground handling agent, a local operator or the aerodrome operator. Alternatively they could get information from the operator faxed to the hotel or somewhere at the aerodrome.

Westwind captains reported they obtained current weather information prior to conducting a flight. This included TAFs for the destination aerodrome and relevant alternate aerodromes, winds and

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[178] CASA advised that although the term 'flight forecast' is not expressly defined in the AIP, there is no ambiguity about the expression and it describes a weather forecast specific to a flight route.

[179] Area forecasts (ARFORs) were issued in narrative form for aircraft operations at or below FL200. They comprised statements of the general synoptic situation and the expected meteorological conditions in a designated area. For flights above 10,000 ft, a range of forecasts were available, including significant weather (SIGWX) forecast charts, grid point wind and temperature (GPWT) forecasts, upper air charts (wind and temperature) and route sector winds and temperatures (RSWT). CASA advised the AIP requirement for an 'area forecast' would be met by obtaining relevant SIGWX charts and wind and temperature forecasts for the planned flight levels and altitudes to be used in an emergency.

temperatures for the flight-planned routes, grid point winds and temperatures (GPWT) forecasts and significant weather (SIGWX) forecast charts.

The captain of the accident flight reported that, in terms of wind and temperature information, he always obtained winds and temperatures for the flight-planned routes. He generally did not obtain GPWT forecasts, although he acknowledged that during his command training he had been advised to obtain these forecasts.

Captains reported they would normally submit all the flight plans for a trip prior to leaving their home base. They would then check details prior to the return flights and, if required, amend the submitted flight plans rather than having to submit plans. Some captains noted they would use this approach, even if the trip involved a significant rest period.

The National Aeronautical Information Processing System (NAIPS) could be used by pilots to produce a specific pre-flight information bulletin (SPFIB) for a maximum of 10 flight stages. That functionality enabled NAIPS to provide pre-flight information for each of those flight stages, including flights being planned several days in advance.[180] The SPFIB information would include the forecast winds for the nominated route/sectors, using the estimated time of departure provided by the person requesting the briefing.

The captain of the accident flight reported it was his normal practice for air ambulance tasks to obtain the relevant weather information and submit flight plans prior to departure for all the flights involved in a trip, including the return flights. However, on this occasion, due to there being a long break planned in the middle of the trip, he elected to wait to obtain information and plan the return flights in Apia.

The first officer of the accident flight said that, in her experience, the captain of the accident flight normally conducted thorough flight planning. She recalled a previous flight they had undertaken together to a remote aerodrome neither of them had been to before, and the captain made significant preparations prior to the flight. Some other pilots who flew with the captain reported they did not notice any significant differences between the captain of the accident flight and other captains in terms of their flight planning. However, some pilots stated the captain appeared to conduct flight planning tasks in a less thorough manner than some of the other captains employed by the operator.

Operational support for flight/fuel planning

Assistance with obtaining information and completing flight plans

Most captains reported they rarely encountered difficulties in getting updated weather or NOTAM information when flight planning. However, occasionally there would be difficulties such as no internet access at a hotel. When they encountered such difficulties, they would always be able to find a way to get the required information prior to departure, usually at the airport or through communications with the operator.

One captain reported that on one occasion he had a 4-hour rest period at an overseas location and there was no internet available at the hotel. Due to the short rest period, he had already submitted a flight plan for the next flight prior to departing Sydney. He had another pilot send updated TAFs via text message for the next flight. However, he did not obtain updated wind information and instead relied on the forecast winds for the relevant time period that he had already obtained.

There was no formal guidance in the OM about what to do if a pilot was having difficulties obtaining the required weather or briefing information. However, all captains reported that if they

[180] The SPFIB is prepared using the NAIPS database of meteorological, NOTAM and chart information. The briefing is generated for the estimated time of departure provided by the pilot for each flight stage. After the SPFIB has been generated, it can be updated to include any new information that has become available since the submission of the initial request.

were having difficulties they would call the Westwind standards manager. If the standards manager was not available, they would call another pilot or the operations manager, who would be able to contact another pilot to assist. Pilots stated they knew they could call the standards manager anytime. As far as they could recall, he was always available or they would leave a message and he would call back straight away. Captains also said they knew they could always ask the standards manager to prepare a flight plan at any time of the day, and many of them reported having done so.

The Westwind standards manager reported he was generally available and prepared to receive calls from pilots 24 hours a day. If he did not answer the call it would be taken by a personal answering service, who could take message details and he would return the call promptly. He said he was able to obtain weather and briefing information, prepare a flight plan or provide information on what resources were available to assist at an aerodrome. He was able to fax relevant information if required.

The operator reported that the Westwind standards manager prepared flight/fuel plans for about half of the operator’s air ambulance and charter flights in Westwind aircraft. This was more likely to be in cases when captains encountered difficulties preparing a flight plan due to limited time or resources, or due to the complexity of the flight.

The Westwind operations manager also reported she was available 24 hours a day. If she was on leave then a pilot would be appointed to conduct her role. The operations manager was not a pilot and did not assist directly with flight planning requirements. However, she was available to obtain technical assistance for a flight crew if the crew requested it.

As noted in *Flight planning*, the captain reported he called the Westwind standards manager on the day of the accident flight after encountering internet problems but he did not leave a message or contact other company personnel. At the time, the standards manager was in the operator’s monthly safety management group meeting. The operations manager was in the office and would have been able to contact the standards manager if requested to do so by the captain.

The captain also reported that, prior to the accident flight, he had never had difficulty contacting the standards manager. He also reported he had all the Westwind pilots’ numbers stored in his mobile phone and knew he could call them to assist with flight planning if required. However, he did not think it was necessary to do so on the day of the accident.

Progress monitoring of flights and trips

The operator did not have an operations control centre, nor was such a centre required. Accordingly, the operator did not routinely provide flight crews with weather briefings and other pre-flight information. It also did not maintain constant communications with a flight crew during flight, or actively monitor the progress of each flight, nor was it required to do so. Instead, the operator relied on ATS for maintaining communications with a flight crew and for search and rescue alerting services.

The Westwind operations manager and pilots reported there was regular contact between the flight crew and the operations manager (or Westwind standards manager) during a task. Usually this was in the form of a text message or brief phone call at the start and end of each flight conducted during the task, and at other times as required.

On the day of the accident, at Apia, the captain and operations manager were in frequent contact with each other regarding the progress of the task. They exchanged text messages soon after the aircraft landed at Apia. The operations manager subsequently sent two text messages and briefly called the captain once,[181] and the captain sent four text messages to the operations manager, including one just prior to departure. The operations manager later reported that the captain did

[181] The phone call occurred at 0324 UTC, just prior to when the captain reported he commenced flight planning activities.

not advise her at any stage that the crew had experienced delays getting access to their hotel rooms, or that he had experienced difficulties with internet access and flight planning.

Pilots reported one of the operator's Westwind aircraft was fitted with a satellite phone. However, most of them, including VH-NGA, were not fitted with this type of phone. Nevertheless, pilots reported they rarely, if ever, experienced any difficulties contacting the operator during tasks when on the ground.

The air ambulance provider's medical teams generally carried a portable satellite phone, and one was carried on the accident flight.[182] The medical personnel would contact the air ambulance provider's case manager throughout the task (when on the ground) to advise on progress with the patient or the flights. This included calling the case manager before and after each flight. The Westwind operations manager and the air ambulance provider's case manager kept in regular contact as required during the course of a task.

Availability of flight planning tools

The operator provided pilots with some standard flight/fuel plans for Westwind operations. However, they were restricted to the operator's regular freight operations. They were not applicable to the vast majority of the ad hoc air ambulance and charter work conducted by the Westwind fleet.

The Westwind standards manager had a flight planning software tool that incorporated performance data from the 1124 OPM and was able to import forecast wind information. It did not calculate CPs (and the additional fuel required) or PNRs. As noted above, the operator reported the standards manager probably compiled a flight/fuel plan for about half of the Westwind fleet's air ambulance and charter flights.

The operator provided a computer with internet connection for flight planning at each of the main bases used by the Westwind fleet (that is, Sydney, Darwin and Perth). These computers had the same flight planning software tool installed as was used by the standards manager. However, some pilots reported the version installed on the computers had limited functionality and was not able to import forecast wind information. One pilot provided correspondence from mid-2009 that indicated the software tool's licence had expired, which reduced its functionality.

The standards manager stated flight crew were not required to use the flight planning software tool that was provided. His recollection was that the version of the software on the base computers should have had the functionality to import wind information. During the reopened investigation, the ATSB asked the operator to confirm the functionality of the flight planning software tools available at its Sydney base prior to the accident. However, given the time since the accident, it was not able to source appropriate information.

Some pilots reported they purchased their own flight planning software tools that had better functionality than the one provided by the operator. They stated they imported fuel planning figures from the operator's OM into the software tools. The operator did not have any means of checking or controlling the fuel planning data the pilots used in their personal software tools.

The captain of the accident flight said he found the software tool provided by the operator cumbersome to use, so he preferred to manually prepare flight/fuel plans. Several other captains also reported they manually prepared fuel plans rather than use a flight planning software tool.

Some Westwind pilots stated they had reported their concerns about the lack of suitable flight planning tools and resources to the Westwind standards manager and/or the chief pilot during

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[182] These satellite phones used the handset antenna and could not be used effectively during flight. The handset could work if the antenna was within line-of-sight view to the satellite through the cabin side windows, but depended on the aircraft's heading relative to the satellite's location. The signals for the satellite telephone would be attenuated by the aircraft's fuselage and the heated elements of the front cockpit windows. To be effective for inflight communication, the satellite phone would need to be plugged into an aircraft-mounted satellite phone antenna.

2009. However, management had not effectively resolved the issue prior to the accident. As noted above, the standards manager's recollection was that the provided tool had adequate functionality. The chief pilot could not recall any specific details about any concerns which were raised. However, he believed the difficulties of providing suitable tools at that time would be more likely to be associated with logistics and the availability of suitable, portable flight planning tools for pilots rather than cost.

The operator provided forms for pilots to use for flight planning and in-flight monitoring. One form, titled a 'navigation log' (see also *In-flight fuel checks*), included a table that could be used to record fuel planning calculations. The table included spaces to record the flight time and fuel required for the climb and cruise, as well as alternate fuel, variable reserve, fixed reserve, holding fuel, taxi fuel, total fuel required and margin (that is, the fuel on board minus the total fuel required). There was no designated space to record the additional fuel required for aircraft system failures.

Information about specific aerodromes

CAR 219 stated:

> A pilot is qualified to act in the capacity of pilot in command of an aircraft employed in charter operations if the pilot is qualified for the particular route to be flown in accordance with the following requirements:
>
> (a) the pilot shall have an adequate knowledge of the route to be flown, the aerodromes which are to be used and the designated alternate aerodromes, including a knowledge of:
>
> (i) the terrain;
>
> (ii) the seasonal meteorological conditions;
>
> (iii) the meteorological, communication and air traffic facilities, services and procedures;
>
> iv) the search and rescue procedures; and
>
> (v) the navigational facilities;
>
> associated with the route to be flown;
>
> (b) if the flight is to be conducted under the Instrument Flight Rules, the pilot shall have demonstrated either in flight or by simulated means that he or she is proficient in the use of instrument approach-to-land systems which he or she may utilise in operations on that route.…

There were no such requirements for aerial work operations. In addition, there was no formal requirement for a pilot's proficiency for a charter flight on a particular route to be checked prior to conducting an operation on that route. There was also no specific requirement to include relevant information about routes or aerodromes in the operator's OM.[183]

The operator's OM restated the requirements of CAR 219, and also stated these conditions applied for aerial work operations as well as charter operations. The OM contained detailed information about operations between Sydney and Auckland, as the operator used to conduct an RPT freight operation on this route. This information included general weather information, potential weather hazards, available facilities, communication frequencies and relevant contact details for Auckland and suitable alternate aerodromes.

There was no information in the OM about each of the other common destination aerodromes that the Westwind fleet operated to, including Norfolk Island. There was also no advice about operations to remote islands. In a section titled 'tropical regions', the OM noted flights in such regions were often associated with heavy rain and reduced visibility, particularly in the afternoon. It

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183 CAR 218, CAO 82.3 and CAO 82.5 provided additional requirements for RPT operations regarding routes and aerodromes. These included proficiency check and recent experience requirements for pilots in command. In addition, for RPT operations, the operator was required to provide relevant information about the route and/or aerodrome in the operations manual.

indicated the ability to carry sufficient fuel to divert to an alternate aerodrome was often 'very helpful'.

The operator's AOC stated that, for international operations:

> The certificate holder shall comply with the operational standards and procedures, which apply to the operation of the aircraft within Australia for the class of operation and category of flight, except where the host country specifies a more stringent standard, in which case the higher standard shall be met.

The operator's OM did not prescribe any requirements for specific international destinations (except for Auckland, as noted above). It stated:

> Pilots are reminded that operations must comply with the rules and regulations of foreign countries entered or being over flown. The Jeppesen manuals have detail in their various sections regarding specific rules and differences that apply for various countries.

The operator provided the flight crew of an international flight an international trip pack, which included the relevant Jeppesen manuals. Each pilot provided their own set of Jeppesen manuals for Australian operations.

Some pilots reported they had copies of a Royal Australian Air Force (RAAF) publication titled *En Route Supplement Regional*. It provided the same type of information as the ERSA but for aerodromes in countries such as the Solomon Islands, Indonesia, Papua New Guinea and New Caledonia. As noted in *Advisory material regarding meteorological conditions at Norfolk Island*, the ERSA information for Norfolk Island (or any other aerodrome) did not include seasonal meteorological information or other meteorological information.

Pilots reported that it was expected they use their own initiative to acquire information about destination aerodromes during their operations. They also knew that the Westwind standards manager had a substantial amount of experience and could provide useful information, if requested, on almost all of aerodromes used during their operations.

One pilot reported discussing the lack of guidance material about specific aerodromes with the Westwind standards manager and offered to develop a guidance document. The pilot reported the standards manager declined the offer as he was concerned about the difficulty of maintaining a controlled copy of such a document.

Information provided about Norfolk Island

The Westwind standards manager recalled that on one flight to Norfolk Island before 2007 he had to divert to Auckland due to adverse weather. He also recalled one flight in 2007 where the weather was poor, due to significant crosswinds, and he had to go around off the first approach before landing successfully off the second approach.[184] Overall, on most of the times he went to Norfolk Island he thought the weather was 'not too bad', but he was aware the conditions could be adverse and they could change quickly.

Other Westwind pilots who had frequently operated to Norfolk Island advised the weather conditions at the island were never ideal and they could change quickly. One pilot recalled a flight in 2007 where the weather (low cloud) deteriorated during the flight to be worse than the forecast, but they were able to land off the first approach (see *Appendix O – Review of Westwind flights from Samoa/American Samoa to Norfolk Island*). Another flight in early 2009 had to divert to Auckland due to low cloud (which had been forecast).

In terms of flight crew guidance about Norfolk Island, several pilots reported they had been given advice from the Westwind standards manager or other senior pilots about the potential problems with weather conditions at that location prior to the accident. These pilots had conducted flights to Norfolk Island with these experienced pilots. Two pilots, including the captain of the accident flight,

[184] The available information for this flight shows that the crosswinds were forecast prior to the flight departing, and the aircraft had more than sufficient fuel to divert after a missed approach.

could not recall being provided with such information. They had not operated to Norfolk Island with another captain before having to conduct a flight there as captain.

Time available for flight planning

The operator and Westwind pilots reported that for air ambulance flights there was a requirement for the flight crew to be ready for departure within 2 hours of being notified of the task. This included the time required to travel to the airport, conduct flight planning and prepare the aircraft.

The Westwind standards manager and Westwind operations manager stated most air ambulance flights did not need to depart, and did not depart, within 2 hours. Westwind pilots stated they often had to prepare for tasks on the basis of a 2-hour time frame, although the departure was often delayed.

Westwind pilots reported that on occasions where there was a requirement to depart within 2 hours it could be difficult to do the fuel and flight planning, prepare the aircraft, and complete the relevant paperwork, particularly for an international flight. The planning was also more difficult if the trip involved going to an aerodrome they had not been to before, particularly when the destination aerodrome did not have many facilities or an instrument approach. Many pilots reported that in such cases they would usually receive assistance, or additional time, to plan such flights if they requested it.

Pilots reported that for return flights, when away from their home base, there were generally less constraints on the time available for flight planning. In addition, as noted above, for most trips a captain would conduct the flight planning for all the flights in a trip prior to departing their home base.

Evaluation of patient requirements versus operational risk

For air ambulance tasks, the air ambulance provider (CareFlight) requested the aircraft operator's capability to conduct the task and indicated a preferred start time to the operator. This preferred start time was determined by the patient's criticality and need for transportation, the medical insurance company's requirements and a range of logistical factors. These included the patient's availability at the pick-up location and the availability of hospital facilities at the drop-off location.

The operator's management reported that, when assessing their capability to do a task, they were usually provided with little if any information about the patient's condition or criticality and did not use that information as a factor in their decision-making. The operator reported the assessment process for a task involved considering a range of factors, and this process was not formally documented as the nature of the operational assessment varied for each flight. The main factors affecting its capability to conduct a task, and how the task was conducted, included:

- the urgency of the flight
- flight crew and aircraft availability (and the location of the available flight crew and aircraft)
- the location of the retrieval airport
- the time frames involved in the task
- fatigue management requirements
- logistical factors associated with the task, such as aerodrome lighting and fuel availability
- the international flight approval process and approval time frames (including factors such as landing approvals).

The air ambulance provider and the operator's management reported that many of the air ambulance task requests would be approved by medical insurance companies in the late afternoon or early evening, with a preference to commence the flight at night. After discussions with the proposed flight crew, the operator would sometimes negotiate to start these tasks the next day (see also *Rostering practices*).

The operator's management and Westwind pilots reported it was the captain's responsibility to plan the flights, and consider aspects such as weather conditions and other operational safety factors. If the captain was not satisfied that the task could be conducted safely, it was their responsibility to advise the operator.

Personnel from the operator and the air ambulance provider both reported there was no formal or structured process to compare the patient's criticality or need for transportation with operational safety factors. This was the case prior to the start of the task and during the progress of a task. Pilots said that, once a task commenced, there was a general expectation that it would continue as initially planned, unless the flight crew identified changes in the operational safety factors that impacted on their ability to conduct the task. Some pilots reported that occasionally they had perceived subtle or implied pressure from the air ambulance provider or the operator to conduct a flight when they were not comfortable doing so. However, pilots generally reported they were not exposed to any undue pressure when conducting air ambulance flights.

For most air ambulance tasks, patients would be at a location where they were already receiving medical care when they were retrieved. The case of the 17-18 November 2009 trip was unusual as the patient was being retrieved from their home and was not under direct medical supervision at the time. The air ambulance provider's personnel stated this aspect, and the limited information they had regarding the patient's condition, indicated there was a level of importance with getting to the patient quickly.

The doctor on the flight advised that, after they had assessed the patient and provided initial treatment in Apia, the patient was stable at the hotel and did not require immediate transportation to a hospital. He noted that, if he had been asked, he would have advised the patient could have been transported the next day. The captain reported there was always some degree of time pressure associated with flights involving a sick patient. However, on this occasion there was no urgency associated with planning the flight due to the patient's condition. The first officer did not recall any time pressure associated with the departure from Apia.

Guidance regarding the cost of fuel

The Westwind standards manager and the Westwind operations manager both reported flight crews were not provided with information about the operator's quoted price for any particular task, or the cost of fuel associated with a quote. They reported that in most cases the operator paid for the fuel by invoice and the flight crew would not have been aware of the cost of fuel.

The Westwind standards manager stated pilots were not given any directions or guidance regarding the cost of fuel at various locations, or to minimise the amount of fuel they used when departing from any particular aerodrome. He said the operator usually paid a competitive rate for fuel at Australian mainland airports and most international airports. In contrast, the fuel at Norfolk Island and Christmas Island was significantly more expensive than almost all the other destinations they used. The fuel at Apia and similar overseas airports was generally not considered expensive. The manager reported the typical fuel price at each aerodrome was already factored in when they provided quotes for any air ambulance task.

As noted in *Review of the operator's previous flights to remote aerodromes*, for long-distance flights to Australian remote islands, and similar aerodromes internationally, pilots generally departed with as much fuel as possible. They reported they never received negative feedback from management, or heard of others receiving negative feedback, for taking more than the minimum fuel required for a flight. A review of the operator's flight records showed that the Westwind standards manager and other check pilots used a similar approach to fuel planning as other pilots. The review also found there was no apparent difference in the amount of fuel on board flights to a remote aerodrome that departed from an Australian mainland aerodrome versus flights to a remote aerodrome that departed from a remote and/or non-Australian aerodrome.

Some pilots stated they were aware that fuel cost more at some remote aerodromes, but this did not influence their approach to fuel planning for flights to remote islands or similar aerodromes internationally. However, they would not depart with full fuel in situations where it was clearly unnecessary, such as for relatively short flights to an Australian mainland airport that had alternate aerodromes nearby.

The captain of the accident flight reported he had never received any negative feedback or concern associated with the amount of fuel he uploaded on any flight. He also reported that, in his role as a captain, he became aware of the cost of fuel at various aerodromes. He believed that fuel at ‘remotish’ places (including Apia) could be expensive (see also

Application of the captain’s fuel planning method for the subsequent flight), and he thought it was in the operator’s interest to not take unnecessary fuel when departing from such aerodromes.

The ATSB reviewed fuel documentation for the 17–18 November 2009 flight and the captain’s previous trip to Norfolk Island and Apia on 29–30 September 2009. This documentation indicated:

- The operator paid slightly more for fuel at Apia than it did at Sydney on both of these trips (about 1.2 times the price at Sydney).
- The operator paid substantially more for fuel at Norfolk Island than it did at Sydney or Apia (about 2.2 times the price at Sydney).
- The flight crew of the 29–30 September trip paid for the fuel at Apia by credit card, and therefore the captain had access to the price of fuel at Apia. The flight crew of the 17–18 November trip paid for the fuel at Norfolk Island by credit card, and therefore the captain had access to the price of fuel at Norfolk Island.

Checking fuel planning calculations

The OM contained no requirement for a captain’s calculation of the total fuel required or other fuel planning to be checked by another pilot prior to flight.

Westwind pilots reported that some captains would provide a briefing of the flight/fuel plan before a flight, but the level of detail would vary depending on the captain, the first officer and the nature of the flight. As part of their pre-flight duties, first officers would normally load the captain’s flight-planned route into one of the aircraft’s GPS units. However, they would generally only check the fuel plan and estimated flight times after the aircraft departed. Some pilots reported there was often limited time available to check this information prior to departure.

One captain reported that for complex flights he would prepare a flight plan and have the Westwind standards manager prepare a flight plan and then compare the two plans. The standards manager reported that when he prepared a flight plan for another captain he would expect that captain to check what the manager had prepared.

Establishing fuel on board before flight

CAO 20.2 (Air service operations – safety precautions before flight) stated:

> The operator of an aircraft having a maximum take-off weight of more than 5700 kg and engaged in commercial operations must ensure that the operations manual contains instructions and procedures for the pilot in command of the aircraft to verify the quantity of fuel on board the aircraft before flight.

Aspects to consider when establishing the fuel on board include:

- fuel density
- accuracy of the fuel quantity indicating system.

In terms of fuel density, the aircraft’s fuel quantity gauges indicated the weight rather than the volume of the fuel on board (see *Fuel quantity indicating system*). The amount of fuel (by weight) varied according to the density or specific gravity (SG) of the fuel.

When determining the fuel on board, the OM stated that in higher than normal temperatures a captain should consider the effect of a reduction in fuel density on range performance.

The aircraft manufacturer used a specific gravity of 0.803 kg/L when stating the capacity of the 1124 and 1124A fuel tanks, and the operator reported it normally used an SG of 0.79 kg/L.

The SG of the fuel loaded in Apia for the accident flight was estimated to be 0.785 kg/L, which was slightly less than normal or standard values. Consequently, the manufacturer's stated capacity of the main tanks for a 1124A of 7,356 lb was reduced to about 7,190 lb on the day of the accident. The captain normally considered that the fuel on board with full main tanks was about 7,200 lb. Therefore, fuel density aspects had no influence on the planning for the flight.

In terms of fuel quantity gauge accuracy, CAAP 234-1 contained guidance regarding the establishment of fuel quantity before flight. In broad terms, the CAAP allowed two options for establishing the fuel on board:

- full tanks, or a 'totally reliable and accurately graduated dipstick, sight gauge, drip gauge or tank tab reading'
- a cross-check by at least two different methods.[185]

The operator's Westwind pilots regularly refuelled to full fuel (full main tanks and full tip tanks) or full main tanks. By refuelling to a known quantity, they could easily compare the known quantity with the fuel quantity gauge indications.

The operator's OM stated:

> Prior to each flight or before each refuelling, the PIC shall check the fuel quantity on board by:
>
> a) Checking cockpit gauge readings against any dipstick, visual or external gauge readings.
>
> b) Check the above against the 'fuel used counters'.
>
> c) Checking the Fuel Record Log fuel consumed/remaining figure…
>
> After each refuelling, the PIC shall check the fuel quantity on board by:
>
> a) Checking the fuel log consumed/remaining figures.
>
> b) Checking the fuel quantity added.
>
> c) Checking cockpit gauge readings against any dipstick, visual or external gauge readings.

The OM also stated:

> For Company aircraft, when using the crosscheck procedures specified above, the allowable discrepancy shall not exceed 3% of the higher amount.

In other words, if the observed difference was greater than 3 per cent, the flight crew needed to report the discrepancy.

In-flight fuel replanning

CAAP 234-1 stated a flight should not be commenced to the intended destination aerodrome unless it had sufficient fuel to meet the relevant requirements (as outlined in *General requirements*). However, it stated a flight could be planned to depart without this required amount of fuel if:

- the flight was planned via an en route diversion point to a suitable alternate aerodrome
- the aircraft had sufficient fuel to meet the relevant requirements for a flight to the alternate aerodrome
- at the diversion point, the aircraft had sufficient fuel to fly to the intended destination aerodrome and meet all the relevant fuel requirements for a flight from the diversion point to the destination aerodrome.

Similarly, the operator's OM stated:

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185 Prior to May 2006, the guidance in CAAP 234 regarding checks of fuel quantity was included in CAO 20.2 as a regulatory requirement. The requirements prior to May 2006 in CAO 20.2 also required that the cross-check procedures 'must be specified by the operator, together with an allowable discrepancy which must not exceed 3 per cent of the higher amount'. CASA changed the requirements in CAO 20.2 to guidance material as the requirements were unique to Australia.

> The PIC may calculate fuel for a flight on the basis of landing at an intermediate aerodrome but may continue the flight to the destination aerodrome if he/she finds that at or abeam the intermediate aerodrome the remaining reserves are equal to the reserves required for the remainder of the flight.

In other words, even though it is not possible to meet the relevant fuel planning requirements for a flight to an intended destination before flight, it may be possible to meet these requirements at some point during the flight. This will usually be due to the required amount of variable fuel reserve decreasing, or weather-related fuel requirements changing.

In order to commence a flight on the basis of doing in-flight replanning, a PIC was still required to comply with CAR 234 and CAR 239. In other words, a PIC was required to take reasonable steps to ensure the aircraft had sufficient fuel for the proposed flight, considering various aspects including the meteorological conditions. In addition, a PIC was required to conduct a careful study of various sources of information, including whether current weather reports and forecasts were suitable for the flight.

Some operators routinely use in-flight replanning as a means of conducting long-distance flights to isolated aerodromes, or in situations where it is not possible to plan to conduct the flight with all the required fuel reserves. In conducting such operations, these operators conduct the en route replanning in a similar way to conducting the pre-flight planning of a normal flight. In addition, if the forecast weather conditions at the intended destination aerodrome deteriorate below the alternate minima prior to reaching the nominated diversion point, the flight is required to divert to the alternate aerodrome.

With regard to the CAO 82.0 remote island requirements, CASA confirmed that a pilot could use in-flight replanning to conduct a passenger-carrying charter flight to a remote island. That is, a pilot could initially plan to operate to a suitable alternate aerodrome, and then re-plan during the flight to a remote island aerodrome. However, the relevant requirements of CAO 82.0 still needed to be met. For a passenger-carrying charter flight, this meant that at the point of re-planning, the flight required sufficient fuel to be able to conduct a missed approach at the remote island and then divert to an alternate aerodrome with the required fuel reserves, regardless of the weather conditions.

Some Westwind pilots reported they used in-flight replanning at times for very long flights. It was not used on the accident flight.

Extended diversion time operations

CAO 82.0 outlined distance limitations for RPT and passenger-carrying charter operations. Limitations for operations in turbine-engined aircraft were specified in terms of whether the flight was an extended diversion time operation (EDTO). The CAO defined an EDTO as:

> …any flight by a turbine-engined aeroplane where the flight time at the 1 engine inoperative cruise speed (in ISA and still air conditions) from a point on the route to an adequate aerodrome is greater than the threshold time.

The threshold time for an aeroplane with a maximum take-off weight exceeding 5,700 kg and certified to carry no more than 19 passengers was 180 minutes. Operators could only conduct EDTO flights if they were approved to do so by CASA.

For a Westwind, the CAO 82.0 threshold effectively meant that the operator could not conduct a passenger-carrying charter flight if at any stage during the flight the aircraft was more than about 870 NM from an adequate aerodrome. As far as could be determined, this did not apply to any of the operator's flights during 2002–2009.

Fuel planning calculations related to the accident flight

Application of the captain's method to calculate total fuel required for normal operations

As outlined in previous sections, the captain of the accident flight reported his normal method to calculate the flight fuel for a long-distance flight in a Westwind 1124A involved using:

- a block speed of 420 kt (plus or minus the estimated wind component)
- the operator's 23 lb/minute method (including 400 lb for the climb) to obtain the flight fuel
- no allowance made for taxi fuel.

As discussed previously, the captain arranged for the main tanks to be filled prior to the flight, which he assumed to be 7,200 lb.

In his initial interviews with the operator after the accident, the captain stated he always used 1,500 lb as the fuel reserves (including variable reserve and fixed reserve) for flights over 3.50 hours. He initially recalled that, based on his fuel planning calculations, he expected to arrive at Norfolk Island with the 1,500 lb margin, and maybe even 1,700–1,800 lb (or 200–300 lb more than the 1,500 lb fuel reserves). This indicated he calculated the flight fuel to be 5,400–5,500 lb and the total fuel to be 6,900–7,000 lb. He could not recall what flight time he used, but thought it was 4.00 hours (see below). However, when recreating his calculations during an interview he noted 4.00-hours flight time would result in a total flight fuel of about 6,000 lb and therefore 7,200 lb would only allow 1,200 lb for fuel reserves.

In his interviews with the ATSB (conducted after the interviews with the operator), the captain reported he used the operator's normal method of calculating the fuel reserves (that is, 10 per cent of the flight fuel for the variable reserve and 600 lb for the fixed reserve). He recalled that, for the accident flight, he calculated that 7,200 lb was about 200–300 lb more than the total fuel required (including flight fuel and fuel reserves), and he expected to arrive at Norfolk Island with about 1,400 lb remaining. This indicated that he calculated the total fuel to be 6,900–7,000 lb.

In terms of flight times:

- The captain provided an estimated flight time for the submitted flight plan to ATS of 3.50 hours. However, he noted in interviews that the time he nominated in an ATS flight plan was not necessarily the time he used for fuel planning purposes.
- The captain reported he expected a 50-kt headwind component for the flight. Based on using his block speed of 420 kt for the 1,450 NM flight from Apia to Norfolk Island, the estimated flight time for a 50-kt headwind is 3.92 hours.
- The captain reported he normally rounded calculations such as flight times up, and therefore it would be reasonable to expect that he would have used a flight time of 4.00 hours if he calculated a flight time of 3.92 hours.

Table 23 shows calculations of the flight fuel and total fuel required for different flight times. Table 24 shows calculations of the flight time, flight fuel and total fuel required for different average groundspeeds.

Table 23: Calculations of flight time and total fuel required for normal operations using the captain's fuel planning method and different wind components

Flight time (hours)	Average groundspeed (kt)	Flight fuel (lb)	Total fuel (lb) (1,500 lb reserves)	Total fuel (lb) (10% variable and 600 lb fixed reserve)
3.50	414	5,230	6,730	6,353
3.75	387	5,575	7,075	6,733
3.92	370	5,808	7,308	6,989
4.00	363	5,920	7,420	7,112

The highlighted row shows the minimum possible flight time for the distance, captain's normal block speed and expected headwind component. The captain reported he would round calculations upwards, so in practice the minimum total fuel required should be higher than the figure stated in the last column.

Table 24: Calculations of flight time and total fuel required for normal operations using the captain's fuel planning method and different average groundspeeds

Average groundspeed (kt)	Flight time (hours)	Flight fuel (lb)	Total fuel (lb) (1,500 lb reserves)	Total fuel (lb) (10% variable and 600 lb fixed reserve)
400	3.63	5,403	6,903	6,543
390	3.72	5,531	7,031	6,684
380	3.82	5,666	7,166	6,833
370 (420 kt - 50 kt)	3.92	5,808	7,308	6,989
360	4.03	5,958	7,458	7,154
350 (400 kt - 50 kt)	4.14	6,117	7,617	7,329
330 (380 kt - 50 kt)	4.39	6,464	7,964	7,710

The highlighted row shows the minimum possible flight time for the distance, captain's normal block speed and expected headwind component. The captain reported he would round calculations upwards, so in practice the minimum total fuel required should be higher than the figures stated in the last column.

As indicated in the tables:

- If the captain used a fixed amount of 1,500 lb for the fuel reserves and expected the fuel remaining at Norfolk Island to be 1,700–1,800 lb, he would have had to use a flight time of about 3.60–3.70 hours.
- If the captain used the operator's normal process for calculating the fuel reserves and expected the fuel remaining at Norfolk Island to be 1,400 lb, he would have had to use a flight time of about 3.92 hours.
- If the captain used a flight time of 4.00 hours, he should have calculated the total fuel required to be 7,420 lb if he used 1,500 lb reserves (more than the 7,200 lb capacity of the main tanks) and 7,112 lb if he used the operator's normal method of calculating the fuel reserves (less than 100 lb margin).

Based on the available information, the ATSB could not determine the exact process the captain used to calculate the total fuel required for the accident flight for a normal operation.

Comparison of the captain's method with other methods

Table 25 provides calculations of the flight time and total fuel required for a flight from Apia to Norfolk Island using different fuel planning methods. For these calculations:

- The flight distance was 1,450 NM and the average headwind was assumed to be 50 kt.
- The fuel reserves for all methods (other than the captain's method using 1,500 lb) were calculated using 10 per cent of the flight fuel for the variable reserve and 600 lb fixed reserve.
- The taxi fuel for all methods (other than the captain's method) was 150 lb.
- For the 23 lb/minute and hour-by-hour methods, block speeds of 380 kt (as stated in the OM) and 400 kt were used.
- For the hour-by-hour method, ISA+10°C conditions were assumed, as such conditions are common in Australia and the Oceanic/South Pacific area.
- The OPM figures were derived from the planning charts. For the 1124A OPM, no addition for a hot day climb in ISA+10°C conditions was included as no such figure was included in the 1124A planning charts. For the 1124 OPM, an addition of 240 lb was included for a hot day climb in ISA+10°C conditions in accordance with the relevant planning chart.
- The aircraft's take-off weight was assumed to be 21,800 lb (relevant to the OPM methods only).[186]

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[186] The aircraft's weight prior to engine start was estimated to be 21,830 lb, and the weight at the start of the take-off roll was about 21,700 lb.

- The additional fuel required to allow for aircraft system failures was not considered (see next section).

Table 25: Calculations of flight time and total fuel required for the flight from Apia to Norfolk Island with 50 kt headwind using different methods and scenarios

Method	Condition	Flight time (hours)	Taxi fuel (lb)	Flight fuel (lb)	Fuel reserves (lb)	Total fuel (lb)
Captain's method with 1,500 lb reserves	block speed 420 kt	3.92	0	5,808	1,500	7,308
Captain's method with operator's normal reserves	block speed 420 kt	3.92	0	5,808	1,181	6,989
23 lb/minute method	block speed 380 kt	4.39	150	6,464	1,246	7,860
	block speed 400 kt	4.14	150	6,117	1,212	7,479
Hour-by-hour method	block speed 380 kt, ISA+10°C	4.39	150	6,229	1,223	7,602
	block speed 400 kt, ISA+10°C	4.14	150	5,954	1,196	7,300
1124A OPM	FL 350, Mach 0.72, ISA+10°C, take-off weight 21,800 lb	4.00	150	5,900	1,190	7,240
1124A OPM	FL 350, long-range cruise, ISA+10°C, take-off weight 21,800 lb	4.80	150	5,600	1,160	6,910
1124A OPM	FL 370, Mach 0.72, ISA+10°C, take-off weight 21,800 lb	4.00	150	5,600	1,160	6,910
1124A OPM	FL 370, long-range cruise, ISA+10°C, take-off weight 21,800 lb	4.70	150	5,600	1,160	6,910
1124 OPM	FL 350, Mach 0.72, ISA+10°C, take-off weight 21,800 lb	4.10	150	6,290	1,229	7,669
1124 OPM	FL 350, long-range cruise, ISA+10°C, take-off weight 21,800 lb	4.50	150	5,990	1,199	7,339
1124 OPM	FL 370, Mach 0.72, ISA+10°C, take-off weight 21,800 lb	4.10	150	6,140	1,214	7,504
1124 OPM	FL 370, long-range cruise, ISA+10°C, take-off weight 21,800 lb	4.60	150	6,090	1,209	7,449

The OPM figures were based on using planning charts. The 1124A OPM did not include an addition for a hot day climb, whereas the 1124 included an addition of 240 lb. The planning charts are provided for odd-numbered flights levels (for example, FL 350, FL 370).

As indicated in the table:

- Using the hour-by-hour method or the 23 lb/minute method and the operator's specified block speed of 380 kt resulted in a minimum total fuel required of significantly greater than 7,200 lb (that is, 7,602–7,860 lb). If the block speed of 380 kt was increased to 400 kt to allow for the improved performance capability of the 1124A, the minimum total fuel required was still more than 7,200 lb (7,300–7,479 lb).
- The 23 lb/minute method produced slightly higher figures than the hour-by-hour method.
- If the captain used 1,500 lb for the fuel reserves, his method produced a similar result to the operator's hour-by-hour method if that method used a block speed of 400 kt rather than the specified 380 kt. Otherwise, his method produced a lower figure than the operator's methods.

- If the captain used the operator's normal method for calculating fuel reserves, his fuel planning method produced a lower total fuel required than the operator's methods.
- Using the manufacturer's 1124A OPM, the flight could be conducted with 7,200 lb at normal flight levels. For example, the captain's submitted flight plan was for Mach 0.72 and FL 360. Based on using the relevant charts for FL 350 and 370, and including normal fuel reserves and 150 lb taxi fuel, the flight would require 7,075 lb.
- As noted in *Operator's methods*, the 1124A planning charts did not include an addition for a hot day climb. If an addition was derived using the same process used to derive the hot day climb figures in the 1124 OPM, the flight could only be conducted with 7,200 lb if long-range cruise settings were used.
- If the 1124 OPM was used, the flight could not be conducted with 7,200 lb.
- It could be argued that amounts of 600 lb for fixed reserve and 150 lb for taxi fuel are conservative, and slightly lower figures could be used. However, it would also be normal practice for pilots to round up figures during fuel planning calculations, resulting in higher figures than those indicated in the table. In particular, using the planning charts to get precise values can be difficult and takes time. It would be easier, and common practice, when using the charts to simplify the process and be conservative, resulting in higher values (for example, using 1,500 NM instead of 1,450 NM, or using 22,000 lb instead of 21,800 lb).
- Using a distance of 1,500 NM instead of 1,450 NM increased the total fuel required in each scenario by about 150 lb. Similarly, increasing the headwind from 50 kt to 60 kt (to be more consistent with the forecast winds) increased the total fuel required in each scenario by a similar amount.

In summary, for an assumed 50-kt headwind, flight distance of 1,450 NM, take-off weight of 21,800 lb and ISA+10°C conditions, it was technically possible to plan the flight for normal operations using the 1124A OPM and get a total fuel required of less than 7,200 lb, depending on the flight level and cruise speed selected. However, applying the methods outlined in the operator's OM resulted in a total fuel required of over 7,200 lb.

Total fuel required including additional fuel for aircraft system failures

The ATSB calculated the critical point (CP) for a two engine depressurised configuration for the flight from Apia to Norfolk Island using Nadi as the alternate aerodrome.[187] The CP was based on an estimated 20-kt headwind from the CP to Norfolk Island and nil wind from the CP to Nadi (after descent).

The ATSB calculated the total fuel required based on the OM using the following parameters:

- 150 lb taxi fuel
- 400 lb for the climb plus 23 lb/minute during cruise up to the CP
- a TAS of 400 kt and a headwind component of 50 kt until the CP
- long-range cruise settings from the CP to the alternate aerodrome at FL 140[188]
- 10 per cent variable reserve for the flight up to the CP and for the flight from the CP to the alternate aerodrome
- 600 lb fixed reserve.

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[187] The critical point based on Nadi was about 104 minutes from both Norfolk Island and Nadi, and represented the closest equi-time point to Norfolk Island. A critical point based on Noumea was about 147 minutes from Norfolk Island and Noumea.

[188] The system of altimetry used in Australia makes use of a transition layer between the transition altitude which is always 10,000 ft and the transition level of FL 110 to FL 125 depending on QNH to separate aircraft using QNH from those using 1013.2 hPa as a datum and cruising in the transition layer is not permitted. In the NZ FIR, the transition altitude is always 13,000 ft and the transition level FL 150. When operating between 13,000 ft and FL 150, vertical position must be maintained reference to the altimeter setting advised by ATS. Cruising within the transition layer requires ATS approval. Within the Noumea and Nadi FIRs the transition altitude was 11,000 ft and the transition level FL 130.

The resulting CP was at DOLSI, and the total fuel required was 7,840 lb.

As noted above, the captain did not calculate the CP and therefore the additional fuel required for a depressurisation for the accident flight. The ATSB calculated the total fuel required using the best estimate of the captain's method with 1,500 lb fuel reserves. More specifically:

- no allowance for taxi fuel
- 400 lb for the climb plus 23 lb/minute during cruise up to the CP
- a TAS of 420 kt and a headwind component of 50 kt until the CP
- an IAS of 340 kt (387 kt TAS) and a fuel burn off of 33 lb/minute from the CP to the alternate aerodrome at FL 130
- 1,500 lb fuel reserves.

The resulting CP was 7 NM north-east of DOLSI, and the total fuel required was 8,045 lb. If the operator's normal fuel reserves were used, the total fuel required was 7,800 lb.

In summary, the flight was required to have at least 7,800 lb of fuel on board at engine start to allow for all required emergency situations.

Estimated fuel on board for the accident flight and other scenarios

The ATSB estimated the fuel status of the aircraft during the accident flight using the best estimate of the aircraft's fuel burn off. Key details are provided in *Flight from Apia to Norfolk Island (accident flight*), and further details and an explanation of the method used are provided in appendix E.

In addition, the ATSB examined the likely fuel status if the aircraft had departed with full fuel (8,670 lb) at 0545 UTC in the following situations:

- climb to FL 340 and cruise at Mach 0.72
- climb to FL 270 and cruise at Mach 0.72
- climb to FL 270 and use long-range cruise settings
- climb to FL 340 and then step climb to FL 390 and cruise at Mach 0.72.

The ATSB also examined the likely fuel status if the aircraft had departed with full main tanks (7,190 lb), climbed to FL 270 and cruised at long-range cruise settings.

Table 26 provides summary results, including the fuel status at the top of descent at Norfolk Island.[189] Based on these results:

- For none of the selected scenarios departing with full fuel would the aircraft have been able to conduct a missed approach at Norfolk Island then divert to Noumea and arrive with the required fuel reserves.
- For the FL 270 with long-range cruise settings and full main tanks scenario, there would have been insufficient fuel to plan the flight with a fixed reserve and variable reserve for normal operations. The aircraft would have arrived at Norfolk Island with about 130 lb less than the accident flight.
- For the FL 270 with Mach 0.72 and full fuel scenario, the aircraft would not have had sufficient fuel to divert from the top of descent. In addition, the aircraft would have had about 1,140 lb after conducting a missed approach at Norfolk Island. This was about 200 lb more than the accident flight, which departed Apia with 7,190 lb and used higher flight levels.
- The FL 340 with Mach 0.72 scenario and full fuel and the FL 270 with long-range cruise settings and full fuel scenario resulted in a similar fuel burn off. In both cases, the aircraft would have had

[189] The fuel status at top of descent for the three scenarios assumed that the variable reserve was not consumed from Apia to the top of descent.

sufficient fuel to divert with the required fuel reserves to Noumea from the top of descent.[190] In addition, both scenarios would have resulted in the aircraft having about 2,000 lb remaining after completing a missed approach at Norfolk Island. This would have been sufficient fuel to hold for about 60 minutes at 2,300 ft at Norfolk Island (excluding the fixed reserve and fuel to conduct another instrument approach).

- The aircraft did not have the performance capability to climb direct to FL 390 on departure from Apia with full tanks. If the aircraft had initially climbed to and cruised at FL 340 at Mach 0.72 and then climbed to FL 390 at DUNAK, it would have had sufficient fuel at top of descent to divert with the required fuel reserves to either Noumea or Auckland. If the aircraft had continued to Norfolk Island, it is likely it would have arrived at the top of descent at about 0935 with 2,670 lb and had about 2,240 lb at the end of the first missed approach. This would have been sufficient fuel to hold for about 75 minutes at 2,300 ft at Norfolk Island (excluding the fixed reserve and fuel to conduct another instrument approach).
- Although not shown in the table, the ATSB also estimated the likely fuel status if the aircraft had descended from FL 340 to FL 270 after being requested to do so by the Auckland air/ground operator at 0628 UTC, and then cruised at FL 270 using long-range cruise settings. In that case there would have been insufficient fuel to continue the flight with a fixed reserve and a variable reserve from the point of replanning. If the flight had continued, it is likely it would have arrived at the top of descent at about 1026 with 1,090 lb and had about 720 lb at the end of the first missed approach.

Table 26: Fuel status for the accident flight and other scenarios (focussing on the top of descent)

	Scenario					
	Accident flight (full mains)	**FL 270, long-range cruise (full mains)**	**FL 270, long-range cruise (full fuel)**	**FL 270, Mach 0.72 (full fuel)**	**FL 340, Mach 0.72 (full fuel)**	**FL 340 to DUNAK then FL 390, Mach 0.72 (full fuel)**
Fuel on board at engine start	7,190 lb	7,190 lb	8,670 lb	8,670 lb	8,670 lb	8,670 lb
Top of descent time	0940 UTC	1028 UTC	1016 UTC	0914 UTC	0929 UTC	0935 UTC
Fuel on board at top of descent	1,360 lb	1,200 lb	2,410 lb	1,530 lb	2,440 lb	2,670 lb
Fuel on board at end of first missed approach	940 lb	810 lb	2,020 lb	1,140 lb	2,10 lb	2,240 lb

Application of the captain's fuel planning method for the subsequent flight

During the accident flight, the captain prepared a flight plan and fuel plan for the next flight from Norfolk Island to Melbourne via overhead Sydney). Based on the flight crew's conversations

190 Calculations for a diversion were based on using long-range cruise speed and thrust settings from the diversion point to overhead the alternate aerodrome and winds from the GPWT forecast available prior to the flight from the diversion point to the alternate aerodrome. For the FL 340 scenario, the aircraft would also have been able to divert from top of descent to Auckland. In neither case could the aircraft have diverted to Nadi from the top of descent with the required fuel reserves.

(recorded on the CVR), the captain planned the flight via overhead Sydney, which resulted in a flight distance of 1,288 NM and a total fuel required of 7,500 lb. The first officer suggested they use full fuel for that flight, and the captain replied they would refuel to 7,500 lb (or 300 lb more than full main tanks). He stated to the first officer this was a good idea because the fuel was expensive at Norfolk Island, and they had no known requirements for the flight from Norfolk Island to Melbourne.

To obtain a total fuel required of 7,500 lb for a 1,288-NM flight using the captain's normal method required a flight time of about 4.06 hours and an average groundspeed of about 320 kt if 1,500 lb fuel reserves was used. This implied that the captain considered a headwind component of 100 kt if he used a block speed of 420 kt.[191] If he used the operator's normal fuel reserves, he would have calculated a longer flight time, which meant he would have used an even higher headwind component.

The captain later reported he would have based his fuel planning for the flight from Norfolk Island to Melbourne on the forecast winds he had for the outbound flight from Sydney to Norfolk Island and the winds the aircraft encountered on that flight the previous night. As noted in *Outbound flight from Sydney to Norfolk Island*, the forecast and actual winds were about 45 kt for the Sydney to Norfolk Island flight.

In summary, for the 1,288-NM flight from Norfolk Island to Melbourne, the captain calculated a total fuel required of 7,500 lb. For the 1,450-NM flight from Apia to Norfolk Island, he calculated he needed less than 7,200 lb. However, he reported he would have used a similar headwind component for both flights. The reason for this discrepancy could not be determined.

Review of the operator's previous air ambulance flights

The ATSB reviewed the fuel on board (prior to engine start) and related aspects for the operator's long-distance Westwind flights from 1 January 2002 to 17 November 2009. The review focussed on air ambulance flights as such flights generally did not have restrictions on the amount of fuel that could be uploaded due to weight. In addition, such flights provided a more relevant comparison to the accident flight than freight flights or other types of flights.

The ATSB's analysis focussed on flights with a flight time of 3.25–4.24 hours. This was because, for the accident flight from Apia to Norfolk Island:

- The captain's submitted flight plan included an estimated flight time of 3.50 hours. This time could be compared to flights with a flight time in the range 3.25–3.74 hours.
- The captain's normal fuel planning method resulted in an estimated flight time of 3.92 hours, which would typically be rounded up to 4.00 hours. This time could be compared to flights with a flight time in the range 3.75–4.24 hours.

Figure 35 shows the fuel on board and flight time of the 828 air ambulance flights with a flight time of 3.00–4.75 hours, and compares these to the accident flight (in terms of the submitted flight plan time, the flight plan time based on using the captain's normal flight planning method and the actual flight time to the first missed approach).

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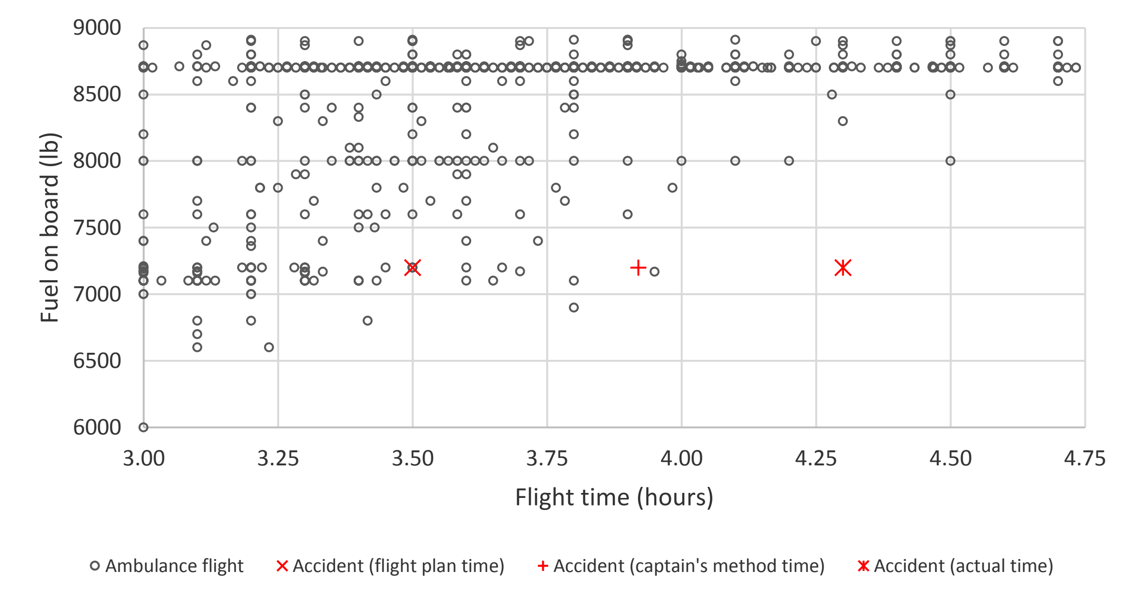
[191] Melbourne airport required up to 15 minutes holding fuel for operations at specified times of day, which equated to about 300 lb for a 1124/1124A. However, holding fuel was only required between 2100 and 1400 UTC. The flight would have been expected to arrive at about 1500 UTC.

Figure 35: Fuel on board and flight time for the operator's long-distance air ambulance flights to all destinations (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation. Notes: The markers for many of the flights that departed with full fuel overlap on the graph and therefore the number of these flights cannot be clearly seen. This graph does not include 26 flights with a flight time over 4.75 hours, all of which departed with full fuel.

As indicated in the figure, most of the 580 air ambulance flights with a flight time of 3.25–4.24 hours departed with full fuel. More specifically:

- For the 378 flights of 3.25–3.74 hours, 72 per cent departed with full fuel, 19 per cent departed with more than full main tanks but less than full fuel, and 8 per cent departed with full main tanks or less.
- For the 202 flights of 3.75–4.24 hours, 93 per cent departed with full fuel, 6 per cent departed with more than full main tanks but less than full fuel, and 1 per cent departed with full main tanks or less.
- All of the 119 flights with a flight time of 3.25–4.24 hours that departed with less than full fuel landed at an Australian mainland airport or an international airport with an ILS approach. None of the flights landed at a remote aerodrome.
- There were 3 flights with a flight time of 3.75 hours or more that departed with full main tanks, and these landed at Darwin, Townsville and Sydney. The longest flight had a flight time of 3.95 hours. Each of these flights had alternate aerodromes available en route and/or relatively close to the destination airport.

For almost all of the flights, there was insufficient information available to determine the fuel planning requirements and therefore how much of the total fuel on board was discretionary fuel. However, it was possible to estimate the total fuel required for a normal operation (including taxi fuel, flight fuel, variable reserve and fixed reserve, but excluding alternate fuel, holding fuel and additional fuel for aircraft system failures),[192] and how much of the fuel on board was excess fuel for a normal operation.

The captain reported that during his fuel planning for the accident flight he calculated that a fuel load of 7,200 lb provided 200–300 lb of excess fuel for a normal operation. In comparison, 92 per cent of air ambulance flights with a flight time of 3.25–3.74 hours had more than 1,000 lb of excess fuel for a normal operation, and 96 per cent of flights with a flight time of 3.75–4.24 hours had more than 1,000 lb of excess fuel. For some flights at least some of this excess fuel would

192 The estimate of the total fuel required used the actual flight time and included 23 lb/minute, 400 lb for climb, 10 per cent variable reserve, 600 lb fixed reserve and 150 lb for taxi.

have been required during fuel planning. However, for most flights most of the excess fuel was probably discretionary fuel.

Air ambulance flights involving the captain of the accident flight were similar to the overall pattern for the operator's Westwind fleet. After becoming a captain in November 2008, he conducted 21 air ambulance flights with a flight time of 3.25–4.24 hours. Most (8) of the 13 flights with a flight time of 3.25–3.74 hours departed with full fuel, and only 2 flights departed with full main tanks, the longest being a 3.45-hour flight from Bali, Indonesia to Perth. All 8 flights with a flight time of 3.75–4.24 hours departed with full fuel. Flights involving the first officer of the accident flight were also similar to those of other Westwind pilots, as were flights involving the captain before he became a captain in November 2008.

In summary, the use of full fuel was significantly more common than full main tanks for air ambulance flights of 3.25 hours or more, regardless of the destination aerodrome. More specifically, the use of only full main tanks:

- was relatively uncommon (8 per cent of the time) for air ambulance flights of 3.25–3.74 hours
- was rare (2 per cent of the time) for air ambulance flights of 3.75–3.99 hours
- had not occurred before for flights of 4.00 hours or more.

Appendix M provides more information about the ATSB's review of the operator's long-distance Westwind flights from 1 January 2002 to 17 November 2009.

Review of the operator's previous flights to remote aerodromes

Fuel on board for flights to remote aerodromes

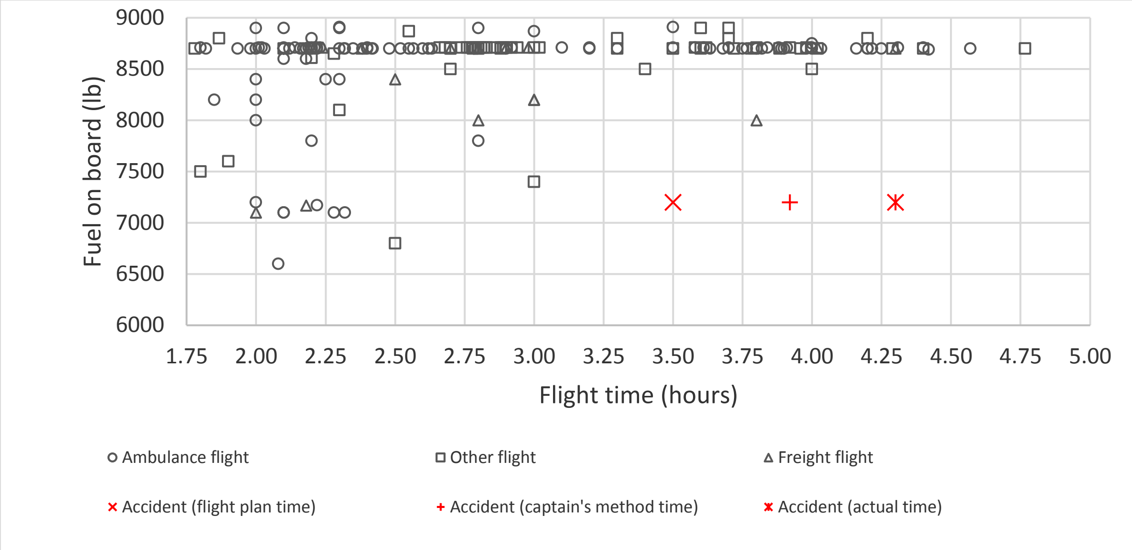
The ATSB reviewed the fuel on board (prior to engine start) and related aspects for the operator's Westwind flights to remote aerodromes from 1 January 2002 to 17 November 2009. Key results are provided in this section, with more details provided in appendix N.

Of the operator's 185 flights to remote aerodromes during the period 1 January 2002 to 17 November 2009:

- 158 (85 per cent) departed with full fuel (1.80–4.77 hours flight time)
- 12 (6 per cent) departed with 8,000–8,400 lb (1.85–3.80 hours)
- 5 (3 per cent) departed with 7,400–7,800 lb (1.80–3.00 hours)
- 10 (5 per cent) departed with full main tanks or just less than full main tanks (1.80–2.50 hours).

Figure 36 shows the fuel on board and the flight time for the 184 flights that landed at a remote aerodrome, and compares these to the accident flight (in terms of the submitted flight plan time, the flight planned time based on using the captain's normal method and the actual flight time to the first missed approach).

Figure 36: Fuel on board and flight time of the operator's Westwind flights to remote aerodromes (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation. Note: The markers for many of the flights that departed with full fuel overlap on the graph and therefore the number of these flights cannot be clearly seen. For further details see appendix N. One of the 185 flights to a remote aerodrome successfully diverted to Auckland and is not included in the chart. This flight had full fuel on board and would have had a flight time of about 2.00–2.40 hours if a successful landing at Norfolk Island had been conducted.

In terms of the fuel on board for different flight times:

- All 8 flights with a flight time of 4.25 hours or more departed with full fuel.
- Almost all (29) of the 30 flights with a flight time of 3.75–4.24 hours departed with full fuel. A 3.80-hour freight flight during the day from Darwin to Christmas Island departed with 8,000 lb.
- All 19 flights with a flight time of 3.25–3.74 hours departed with full fuel.
- Most (33) of the 38 flights with a flight time of 2.75–3.24 hours departed with full fuel. Of the 5 flights that departed with less than full fuel, all departed with more than full main tanks and none had a flight time over 3.00 hours.
- The longest flight that departed with full main tanks or less was a 2.50-hour charter flight at night from Bonriki, Kiribati to Honiara that departed with 6,800 lb (just less than full main tanks).

The ATSB was particularly interested in the 128 flights to Norfolk Island and Christmas Island, given these aerodromes have a significant number of days each month where cloud is below the alternate minima (see appendix H). For these flights:

- Both of the flights with a flight time of 4.25 hours or more departed with full fuel.
- Almost all (26) of the 27 flights with a flight time of 3.25–4.24 hours departed with full fuel. The exception was the 3.80-hour freight flight from Darwin to Christmas Island which departed with 8,000 lb.
- Almost all (20) of the 22 flights with a flight time of 2.75–3.24 hours departed with full fuel. The exceptions were a 3.00-hour freight flight at night from Nuku'alofa to Norfolk Island which departed with 8,200 lb and a 2.80-hour air ambulance flight at night from Broome to Christmas Island which departed with 7,800 lb.
- The longest flights that departed with full main tanks were 2 air ambulance flights of 2.30 hours from Sydney to Norfolk Island.

For the 107 air ambulance flights to all remote aerodromes:

- All 5 flights with a flight time of 4.25 hours or more departed with full fuel.
- All 26 flights with a flight time of 3.25–4.24 departed with full fuel.
- Almost all (8) of the 9 flights with a flight time of 2.75–3.24 hours departed with full fuel. The exception was the 2.80-hour flight from Broome to Christmas Island that departed with 7,800 lb.

- All 14 flights with a flight time of 2.32–2.74 hours departed with full fuel.
- The longest flight that departed with full main tanks was a 2.30-hour flight from Sydney to Norfolk Island.

For almost all of the flights to remote aerodromes there was insufficient information available to determine the fuel planning requirements and therefore how much of the total fuel on board was discretionary fuel. However, it was possible to estimate the total fuel required for a normal operation (including taxi fuel, flight fuel, variable reserve and fixed reserve, but excluding alternate fuel, holding fuel and additional fuel for aircraft system failures).

The captain reported that during his fuel planning he calculated that a fuel load of 7,200 lb provided 200–300 lb of excess fuel for a normal operation. In comparison, 96 per cent of the flights to remote aerodromes had more than 1,000 lb of excess fuel for a normal operation. In addition, all 27 flights that departed with less than full fuel had more than 1,000 lb of excess fuel, and all 10 flights that departed with full main tanks had more than 1,800 lb of excess fuel. Although for some of these flights at least some of this excess fuel would have been required during fuel planning, for most flights most of the excess fuel was probably discretionary fuel.

Capacity for a diversion for flights to remote aerodromes

For the accident flight, and for most of the operator's flights to a remote aerodrome, there was no formal requirement to carry alternate or holding fuel. Nevertheless, the ATSB examined the capacity of flights to a remote aerodrome to be able to divert after conducting a missed approach at the destination aerodrome with the required fuel reserves. The purpose of the review was to provide an indication of the amount of fuel that was generally carried for contingencies and for discretionary purposes.

In terms of the operator's 185 flights to remote aerodromes, 159 flights (86 per cent) had sufficient fuel remaining to conduct a missed approach and divert. For the 26 flights classified as unable to divert:

- 25 departed with full fuel
- 1 charter flight from Learmonth to the Cocos Islands departed with 7,400 lb (which may have been as much fuel as possible given there were passengers and freight on board).

In terms of specific locations:

- 73 of the 76 flights to Norfolk Island were able to divert
- all of the 52 flights to Christmas Island were able to divert
- none of the 4 flights to the Cocos Islands were able to divert.

Basic details of the three flights to Norfolk Island that were unable to conduct a missed approach and divert are presented in Table 27 (see also appendix O).

Table 27: Basic details of flights from Apia or Pago Pago to Norfolk Island

Date	Departure aerodrome	Destination aerodrome	Type	Flight time (hours)	Fuel on board	Fuel remaining	Day / night
Jan 2004	Pago Pago	Norfolk Island	Ambulance	4.00	8,700 lb	2,000 lb	Day
Sep 2009	Apia	Norfolk Island	Ambulance	4.57	8,700 lb	1,500 lb*	Night
Oct 2009	Apia	Norfolk Island	Charter	4.20	8,800 lb	1,800 lb	Night

* This may have been 1,800 lb (see main text).

With regard to these flights:

- None of the 3 flights had a weather-related operational requirement to carry alternate or holding fuel.
- All 3 flights departed with full fuel.
- All 3 flights departed with sufficient fuel to allow for an aircraft system failure.

- Two flights had sufficient fuel to divert from the top of descent and land with the required fuel reserves. The other flight (30 September 2009 flight from Apia to Norfolk Island) had a recorded fuel remaining after engine shutdown at Norfolk Island of 1,500 lb. This flight was conducted in VH-NGA by the captain of the accident flight. At the time of the flight, the aircraft's fuel quantity gauges were probably underreading by about 300 lb (see appendix F). Accordingly, the aircraft probably had about 1,800 lb remaining at engine shutdown, which would have meant it had sufficient fuel to divert from the top of descent.
- For all flights, the actual conditions were better than the alternate minima throughout the flight.

Although none of the 3 flights had a weather-related requirement to carry alternate or holding fuel, the October 2009 flight was a passenger-carrying charter flight to a remote island, and therefore in accordance with CAO 82.0 it was required to carry alternate fuel. The Westwind standards manager was the captain of this flight. He initially recalled that the flight met the CAO 82.0 requirements (see also *October 2009 flight*). As noted in *Operator requirements for flights to remote aerodromes*, he also reported his interpretation of CAO 82.0 was that it did not specifically require the carriage of alternate fuel. As noted above, the flight could have diverted to Noumea from the top of descent into Norfolk Island, and the weather conditions at Norfolk Island at that time were significantly better than the alternate minima.

Overall, 92 of the 107 air ambulance flights (86 per cent) were able to conduct a missed approach at the remote aerodrome and divert. The 15 air ambulance flights that were unable to divert all departed with full fuel.

The forecast weather conditions for the destination aerodromes were obtained for many of the 26 flights that were unable to divert. In each case the conditions were better than the alternate minima. The actual weather conditions were also obtained for many of the flights, and in almost all cases the conditions were better than the alternate minima.

Other than the 3 flights to Norfolk Island (from Apia or Pago Pago), the other 23 flights that were unable to divert were to destination aerodromes that had a single runway. All of these flights were international operations, except 3 of the 4 flights to the Cocos Islands.

Capacity for holding for flights to remote aerodromes

The captain of the accident flight initially reported that, based on his fuel planning calculations for the accident flight, he expected to have 1,700–1,800 lb of fuel remaining after arriving at Norfolk Island (assuming none of the fuel reserves were used). He subsequently reported he expected to have 1,400 lb of fuel remaining. The ATSB's analysis of the fuel remaining during the accident flight indicated there would have been about 1,000 lb remaining after engine shutdown if the first approach was successful (appendix E).

In comparison, all 27 previous flights to remote aerodromes that departed with less than full fuel had at least 2,400 lb of fuel remaining after engine shutdown (sufficient for at least 90 minutes holding plus the fixed reserve). Of the 158 flights that departed with full fuel, 126 (80 per cent) had at least 2,400 lb remaining, 16 (10 per cent) had 2,100–2,300 lb remaining, 13 (8 per cent) had 1,800–2,000 lb remaining and 2 (1 per cent) had 1,500–1600 lb remaining (see below).

For the 26 flights to remote aerodromes classified as unable to divert:

- Six flights departed with full fuel and had 2,400 lb or more fuel remaining after engine shutdown (at least 90 minutes holding plus the fixed reserve).
- Six flights departed with full fuel and had 2,100–2,300 lb of fuel remaining (at least 75 minutes holding plus the fixed reserve).
- Eleven flights departed with full fuel and had 1,800–2,000 lb of fuel remaining (at least 60 minutes holding plus the fixed reserve).
- One flight departed with full fuel and had 1,600 lb of fuel remaining (at least 45 minutes holding plus the fixed reserve). This charter flight (without passengers) was conducted from the Maldives to the Cocos Islands.

- One flight departed with full fuel and had 1,500 lb of fuel remaining (at least 45 minutes holding plus the fixed reserve). This air ambulance flight was conducted from Apia to Norfolk Island in VH-NGA on 30 September 2009 (see *30 September 2009 flight from Apia to Norfolk Island*).
- One flight departed with 7,400 lb and had 2,400 lb of fuel remaining (at least 90 minutes holding plus the fixed reserve). As indicated above, this charter flight from Learmonth to the Cocos Islands carried passengers and freight and may have departed with as much fuel as possible.

Flights to semi-remote aerodromes

In addition to remote aerodromes, the ATSB also examined flights to semi-remote aerodromes. These were defined for Westwind 1124/1124A aircraft as an aerodrome where there was no suitable alternate aerodrome available for normal operations within 240 NM. In other words, there was an aerodrome available within 240 NM that could be used for an emergency landing but this aerodrome was not suitable for normal operations.

The operator conducted 199 flights to semi-remote aerodromes from 1 January 2002 to 17 November 2009. These included 182 flights to Noumea, 8 flights to Makassar, Indonesia and 6 flights to Rarotonga, Cook Islands.

In terms of the fuel on board for the 199 flights:

- Both flights with a flight time of 4.25 hours or more departed with full fuel.
- Almost all (12) of the 13 flights with a flight time of 3.25–4.24 hours departed with full fuel. A 3.40-hour freight flight during the day to Noumea departed with full main tanks.
- Almost all (18) of the 19 flights with a flight time of 2.75–3.24 hours departed with full fuel. A 2.90-hour air ambulance flight during the day from Singapore to Makassar departed with full main tanks.

At least 191 of the 199 flights (96 per cent) were able to divert to a suitable alternate aerodrome for normal operations. For the 8 flights classified as unable to divert or potentially unable to divert to a suitable aerodrome for normal operations, all departed with full fuel.

Flights to remote aerodromes involving the flight crew of the accident flight

Including the 30 September 2009 flight from Apia to Norfolk Island, the captain conducted 9 previous flights to remote aerodromes. These included 3 flights from Sydney to Norfolk Island, 3 flights to Christmas Island, 1 flight to Honiara and 1 flight to Funafuti, Tuvalu.

With the exception of a 2.08-hour flight from Sydney to Norfolk Island, all of these flights to remote aerodromes departed with full fuel. Seven of the 9 flights had sufficient fuel to conduct a missed approach and divert to an alternate aerodrome. The exceptions were the 30 September 2009 flight from Apia to Norfolk Island and the flight to Honiara, which departed with full fuel and had 2,400 lb of fuel remaining after engine shutdown.

The first officer conducted 5 previous flights to remote aerodromes, including 3 flights from Sydney to Norfolk Island, the flight to Funafuti and a flight to Honiara. Except for 1 flight to Norfolk Island, all of these flights were conducted with the captain of the accident flight. All the flights departed with full fuel, and all had sufficient fuel to conduct a missed approach and then divert to a suitable alternate aerodrome except the flight to Honiara.

The captain also conducted 12 flights to semi-remote aerodromes (including 11 flights to Noumea) and the first officer conducted 6 flights to semi-remote aerodromes (including 5 flights to Noumea). All of these flights departed with full fuel.

30 September 2009 flight from Apia to Norfolk Island

The 30 September 2009 flight was reviewed in more detail as it involved the captain of the accident flight, involved the same aircraft as the accident flight (VH-NGA), occurred 7 weeks prior to the accident flight, and was the operator’s flight to Norfolk Island that had the lowest recorded amount of fuel remaining after engine shutdown (1,500 lb).

The circumstances leading up to the flight included:

- The aircraft departed Sydney on an air ambulance task to Apia via Norfolk Island on the evening of 29 September 2009. Two flight crew and two medical personnel were on board.
- The aircraft landed at Apia at 1806 UTC (0706 local time) on 30 September 2009. Soon after landing, the flight crew were advised there had just been an earthquake and there was a tsunami warning for the area. The crew could not clear customs and, after discussions between the operator and the air ambulance provider, it was agreed that they should depart for Nadi, Fiji to rest and re-evaluate the situation and return to Apia to pick up the patient when safe to do so. The crew uploaded some fuel to the aircraft and departed to Nadi.
- Following a short rest period, the crew returned to Apia to pick up the patient and two other passengers.[193]
- After landing at Apia during the evening on 30 September, it was 2 hours before the flight crew could get the aircraft refuelled. The aircraft was refuelled to full fuel.
- The TAF for Norfolk Island for the 30 September 2009 flight included showers of rain, scattered cloud at 1,500 ft, broken cloud at 3,500 ft and visibility at least 10 km. These conditions were better than the alternate minima.
- The flight eventually departed Apia at 1209 UTC (or 0309 local time).

The flight time from Apia to Norfolk Island was 4.57 hours, which was the longest of the operator's flights to Norfolk Island.

On 15 October 2009, the operator's safety management group noted the flight crew's fatigue-related scores (see *Operator's use of FAID*) on 30 September 2009 had exceeded the operator's threshold score. The meeting's minutes noted this exceedance was associated with the return flights from Apia to Sydney experiencing extreme headwinds and therefore the flights (and the associated duty period) were longer than expected. As required by the operator's fatigue management processes, the captain was requested to submit a report about the 'fatigue occurrence'.

The captain submitted a report on 15 November 2009 (3 days prior to the accident flight). The report stated:

> Having arrived in Apia for the second time we were delayed 2 hours as the refueller was unable to be located. Once we had refuelled and departed, the forecast 70kt average headwind turned out to be 155kt. This extra head wind cost us a further 2 hours, for a total delay of around 4 hours. Both these delays were unforeseen and unavoidable.

Table 28 provides the starting time, flight time, groundspeed, forecast wind component and estimated actual wind component for the outbound flights from Sydney to Apia (via Norfolk Island) and the return flights from Apia to Sydney (via Norfolk Island) on 29–30 September 2009. As indicated in the table, the estimated analysis winds for each flight were close to the forecast winds.[194]

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193 The Australian Department of Foreign Affairs and Trade asked the air ambulance provider if the aircraft could carry two additional Australian passengers from Apia to Sydney. As a result, seven people were on board the flights from Apia to Norfolk Island and from Norfolk Island to Sydney (that is, two flight crew, two medical personnel, a patient and two passengers). No payment was received by the operator for the additional passengers. Consequently, the flight was classified as an aerial work (air ambulance) flight for the purposes of Australian regulatory requirements.

194 Forecast winds were derived using data from the United States' National Centers for Environmental Prediction (NCEP) Global Forecast System, using the data most likely used during pre-flight planning stages. The analysis winds provided the best estimate of the actual winds, and were derived using the closest available data from the NCEP Climate Forecast System Reanalysis.

Table 28: Forecast and estimated analysis winds for VH-NGA flights on 29–30 September 2009[195]

Depart	Arrive	Departure time (UTC)	Landing time (UTC)	Flight time (hours)	Average ground-speed (kt)	Forecast wind component (FL 340 / 385)	Analysis wind component (FL 340 / 385)
Sydney	Norfolk Island	1152	1357	2.08	435	70 / 80 kt	70 / 80 kt
Norfolk Island	Apia	1442	1806	3.40	426	55 / 60 kt	55 / 60 kt
Apia	Norfolk Island	1209	1643	4.57	317	-70 / -75 kt	-80 / -80 kt
Norfolk Island	Sydney	1732	2045	3.22	281	-135 / -150 kt	-140 / -150 kt

The wind component increased significantly in the time period between the outbound flights and the return flights. For the route from Apia to Norfolk Island:

- Using the forecast data available when the outbound flight departed Sydney on 29 September 2009, the average wind component between Apia and Norfolk Island was expected to increase by about 15 kt at FL 340–385 during the 24 hours between the outbound and return flights.
- The analysis data indicated the average wind component increased by about 20–25 kt at FL 340–385 during the 24 hours between the outbound and return flights.
- The analysis data indicated the wind component at the reporting point DUNAK, located about halfway between Apia and Norfolk Island, increased by about 35 kt at FL 340 and 15 kt at FL 385 in the 24 hours between the flights.
- The analysis data indicated the wind component at the reporting point DOLSI, located 435 NM north-east of Norfolk Island, increased by about 45 kt at FL 340 and 35 kt at FL 385 in the 24 hours between the flights.

The increase was significantly greater between Norfolk Island and Sydney. More specifically:

- Using the forecast data available when the outbound flight departed Sydney on 29 September 2009, the average wind component between Norfolk Island and Sydney was expected to increase between about 65–70 kt at FL 340–385 during the 30 hours between the outbound and return flights.
- The analysis data indicated the average wind component increased by about 70 kt at FL 340–385 during the 30 hours between the outbound and return flights.
- The analysis data also indicated the wind component at the reporting point TEKEP, located 272 NM south-west of Norfolk Island, increased by about 70 kt at FL 340–385 in the 30 hours between the flights.

During the reopened investigation, both flight crew recalled there was nothing unusual with the flight levels used during the return flights. However, the actual flight levels used during the flight from Apia to Norfolk Island could not be determined.

When interviewed during the reopened investigation, the captain reported he thought his comments on the 2009 safety report about the actual winds on the return flights being significantly

195 Forecast and analysis wind components have been rounded to the nearest 5 kt. The crosswind component during these flights was minimal, and therefore the effective headwind or tailwind was similar to the headwind / tailwind component.

more than the forecast winds probably referred to the flight from Norfolk Island to Sydney rather than the flight from Apia to Norfolk Island. As indicated in Table 28, the statement in the safety report of ‘forecast 70kt’ winds is consistent with the forecast winds for the flight between Sydney and Norfolk Island on 29 September, and the statement regarding 155 kt is consistent with the highest actual winds experienced during the return flight from Norfolk Island to Sydney 30 hours later.

The ATSB could not determine what updated wind and temperature forecast information the flight crew obtained prior to conducting the return flights from Apia to Sydney via Norfolk Island on 30 September.

Using the captain’s normal fuel planning method (with a block speed of 420 kt) and the forecast headwind component (about -75 kt) for the return flight from Apia to Norfolk Island results in a flight time of 4.20 hours, a minimum flight fuel of 6,200 lb and a minimum total fuel required of 7,700 lb (if using 1,500 lb for the fuel reserves). Therefore, the captain elected to depart with at least 1,000 lb of excess fuel in addition to the required fuel reserves. Together with the fuel reserves of 1,500 lb, the captain could have expected to arrive at Norfolk Island with about 2,500 lb. If he used a smaller headwind component (based on the winds forecast or encountered for the outbound flight), he could have expected to arrive with more fuel.

The flight crew recorded on the flight record that there was 1,500 lb of fuel remaining after engine shutdown. As noted in *Review of flight records to evaluate the accuracy of the fuel quantity gauges*, the fuel quantity gauges were probably underreading by about 300 lb at the time, and therefore the aircraft probably had about 1,800 lb remaining. The extent to which the crew of the 30 September flight were aware of the potential problem with the fuel quantity gauges during the flight could not be determined.

Summary

None of the operator’s previous 185 Westwind flights to remote aerodromes were similar to the accident flight in terms of the fuel on board and flight time (that is, a flight carrying passengers at night to a remote aerodrome that departed with only full main tanks for a planned flight of 3.50–4.00 hours). More specifically, none of the flights over 2.50 hours departed with only full main tanks, and none of the non-freight flights over 3.00 hours departed with less than full fuel. A similar pattern occurred for 199 flights to semi-remote aerodromes.

Overall, 26 of the 185 flights to remote aerodromes did not have sufficient fuel remaining after arriving at the destination aerodrome to conduct a missed approach and then divert to a suitable alternate aerodrome. Almost all (25) of these flights departed with full fuel. The other flight may have departed with as much fuel as possible, and it had 2,400 lb remaining after engine shutdown, which was sufficient fuel for over 90 minutes holding (excluding the fixed reserve).

If the captain used his normal flight planning method for the accident flight, and departed with full main tanks, he should have expected to land at Norfolk Island with about 1,400 lb remaining. Only two of the 26 previous flights that were unable to divert had less than 1,800 lb of fuel remaining after engine shutdown, and both of these flights departed with full fuel.

Of the 27 flights to remote aerodromes that did not depart with full fuel, almost all (26) had sufficient fuel remaining after arriving at the destination aerodrome to divert to an alternate aerodrome. As indicated above, the other flight had 2,400 lb remaining. In comparison, the accident flight would have had about 1,000 lb remaining if the flight crew had been able to land off the first approach.

In-flight fuel management

General requirements

There was no explicit requirement in the CARs or CAOs that stated pilots needed to monitor the aircraft's fuel level and ensure there was sufficient fuel for the remainder of the flight. However, AIP ENR 1.1 paragraph 70.1 stated:

> The pilot in command is responsible for taking appropriate diversion action based on information received. The pilot must provide the latest diversion time from the destination or from a point en route and, if required, the time interval.

This effectively required a flight crew to monitor their fuel situation, the weather conditions and other factors throughout a flight and make an appropriate decision regarding whether to continue to the destination aerodrome or divert to an alternate aerodrome.

The operator's OM included requirements for the flight crew to regularly check the fuel remaining, and also calculate and monitor the point of no return (PNR). The remainder of this section discusses:

- in-flight fuel checks
- calculating and monitoring the point of no return (PNR)
- factors to consider when deciding whether to divert
- obtaining weather information during flight.

In-flight fuel checks

Use of navigation / fuel logs

CAR 78 (Navigation logs) stated a PIC was required to maintain a log in flight of navigational data to enable them to determine the geographical position of the aircraft at any time. The log was required to include information such as positions (point of departure, turning points or waypoints, destination), track, wind speed, heading, TAS, and estimated times of arriving at positions. There was no specific requirement in CAR 78 or other regulatory requirements to record the estimated or actual fuel remaining during a flight.

The operator's OM required flight crews to complete a navigation log for each IFR flight. In addition, in the section titled 'In-flight Fuel Checks', it stated:

> For international operations the PIC shall ensure that fuel checks are carried out in-flight at regular intervals. This means at the end of each leg or every 30 minutes whichever comes first, the fuel remaining shall be annotated on the navigation log…
>
> The remaining fuel must be recorded and evaluated to:
>
> a) Compare actual consumption with planned consumption.
>
> b) Check that the remaining fuel is sufficient to complete the flight, and
>
> c) Determine the expected fuel remaining on arrival at the destination…

In a section titled 'International operations', the manual also stated flight crew were required to record the expected time interval (ETI) for each leg of a flight, the actual time to reach each waypoint, and the actual fuel remaining at each waypoint (or every 30 minutes, whichever came first).

The operator provided a navigation log form for flight crews to use. It contained columns for parameters such as position, flight level, TAS, wind, heading, groundspeed, distance, ETI, estimated elapsed time (EET), estimated time of arrival (ETA), revised ETA and actual time of arrival (ATA). There was no column to record the estimated or actual fuel remaining.

For flight crews who used the operator's flight planning software tool, the tool normally produced a log that could be used to record the key parameters of a navigation log. It also included a column with the estimated fuel remaining at each waypoint, and a column to record the actual fuel remaining at each waypoint.

Westwind pilots stated fuel checks were conducted at each waypoint rather than routinely every 30 minutes.

The captain of the accident flight reported he normally used a navigation/fuel log he had developed that included columns with position, track, distance, ETA, revised ETA, ATA and fuel remaining. However, for the accident flight the flight crew used a copy of the operator's navigation log provided by the first officer. The captain recalled that during the flight he was regularly reviewing the fuel remaining and the fuel they would have on arrival at Norfolk Island.

Position reports

For the accident flight between Apia and Norfolk, the aircraft passed waypoints at the following times:

- LANAT: 0609 (at FL 310)
- KILAN: 0636 (on climb to FL 390)
- APASI: 0709 (at FL 390)
- DUNAK: 0736 (at FL 390)
- DOLSI: 0839 (at FL 390).

The captain reported he normally did not commence doing detailed in-flight fuel calculations until the aircraft was established at cruise level. In general, if he had done a fuel check at each waypoint up to DUNAK, this would have equated to a fuel check at about every 30 minutes. There was a 63-minute interval between DUNAK and DOLSI, and the extent to which in-flight fuel checks were done during this period could not be determined.

In procedural airspace, where there is no radar information or other automatic surveillance data available for aircraft, flight crews need to advise ATS of the expected time they will reach the next waypoint. Accurate times are essential to ensure ATS can maintain aircraft separation standards. Accordingly, flights crews are required to notify ATS when they realise their estimated time of passing a waypoint is in error by more than 2 minutes.

For the accident flight on 18 November 2009:

- The aircraft reached waypoints LANAT and APASI 3 minutes later than the estimated time provided to ATS.
- The captain estimated passing DOLSI at 0838. At 0841, the Auckland A/G operator proactively contacted the flight crew for an update of their position rather than wait for the flight crew report. The aircraft passed DOLSI at 0839.[196]

These differences between the estimated and actual times during the 18 November flight were consistent with the flight crew using the aircraft's GPS to provide the estimate for the next position. The GPS estimated the time of the next position based on the current groundspeed, whereas the wind was gradually increasing throughout the flight until DOLSI.

On the 17 November 2009 flight from Norfolk Island to Apia, the captain's initial estimate for passing DOLSI (at the FIR boundary) was 1700. He provided this estimate on initial contact with the Auckland A/G operator at 1553, when the aircraft was climbing through FL 180. He did not revise this estimate during four subsequent communications with the A/G operator between 1557 and 1624 (passing FL 250, maintaining FL 350, requesting FL 370 and maintaining FL 370). At 1651, the captain contacted the Nadi IFISO to report they had passed DOLSI at 1648. At 2148,

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196 Airways advised that if a flight crew had not provided a position report within 3 minutes of the last estimated time, the Auckland A/G operator was provided with an alert. The A/G operator also proactively sought an updated estimate for LANAT at 0608.

Airways submitted an occurrence report to the New Zealand CAA that stated the aircraft had arrived at the reporting point (and FIR boundary) 12 minutes earlier than estimated.

Based on the available information, there was no other significant discrepancies in the estimated positions for reporting points during the 17 November flight. However, the aircraft reached the waypoints DUNAK and KILAN 2 minutes later than the estimated time provided to ATS.

These differences between the estimated and actual times during the 17 November flight were consistent with the flight crew using the aircraft's GPS to provide the estimate for the next position. The GPS calculated the time of the next position based on the current groundspeed, whereas the wind was gradually changing throughout both flights, and increasing as the aircraft climbed.

Airways advised it had not submitted any other occurrence reports associated with the operator's flights during 2005–2009 (prior to the accident flight).

The ATSB reviewed its database for occurrences involving the operator's aircraft where flight crews had not provided accurate, updated estimates for a reporting point. There were four other occurrences during 2005–2009. All were reported by Airservices Australia, and all involved Westwind aircraft on flights to or from Australia. Further details included:

- Three occurrences involved the aircraft arriving at a reporting point earlier than previously estimated (6 minutes, 11 minutes and 13 minutes). All three occurred at the first reporting point for the flight, which occurred at about or soon after the top of climb. The reporting points were all at an FIR boundary.
- One occurrence involved an aircraft arriving at the reporting point 6 minutes later than previously estimated. The notification indicated that the crew reported they had provided an updated estimate on HF but reception was poor and they had not received an acknowledgement.

Approach briefing

In addition to the in-flight fuel checks, the OM required the flight crew consider the aircraft's fuel level as part of the approach briefing. More specifically, it stated that prior to commencing descent, the pilot flying shall brief the other pilot regarding 'minimum divert fuel and diversion options'.

Other than the approach briefing, there was no specific requirement for a flight crew to discuss the fuel status during the flight.

Calculating and monitoring the point of no return (PNR)

General information about PNRs

A point of no return (PNR) is the furthest point in the flight from the departure aerodrome to the destination aerodrome that an aircraft can proceed to and still have sufficient fuel to divert (with the required fuel reserves) to a suitable aerodrome. In other words, it is the latest point in a flight where a flight crew must decide whether to continue to the intended destination aerodrome or divert to a suitable alternate aerodrome.

In various guidance documents and manuals, the definition of a PNR was sometimes restricted to a diversion back to the departure aerodrome. For example, Part B of the operator's OM stated:

> The PNR is defined as the furthest point in a flight to which an aircraft can proceed under normal operation and still have sufficient fuel to return to departure point with statutory reserves intact.

However, more generally the term PNR was used to refer to a diversion either back to the departure aerodrome or to a suitable alternate aerodrome. For example, Part A of the operator's OM stated:

> The PNR is defined as the point farthest removed from a suitable aerodrome, to which an aircraft can fly to, with statutory reserves of fuel remaining.[197]

This broader interpretation is obviously more useful. As the PNR gets closer to the destination aerodrome, the time period where the flight crew are committed to land at the destination aerodrome is reduced. Therefore, the risk of the weather conditions deteriorating or other problems occurring at the aerodrome to prevent a landing are reduced.

Three different PNRs can be calculated:

- PNR for normal operations – after this point, the flight crew are committed to proceeding to the destination aerodrome.[198]
- PNR for OEI – if an engine failure occurs after this point, the crew are committed to proceeding to the destination aerodrome.
- PNR for loss of pressurisation – if a loss of pressurisation occurs after this point, the crew are committed to proceeding to the destination aerodrome.

In general, the PNR for a loss of pressurisation will occur during the flight before the PNR for OEI, which will occur before the PNR for normal operations. An engine failure and loss of pressurisation are very rare events, but still need to be considered. However, decisions regarding the PNR for normal operations are more commonly required, mainly due to weather-related considerations.

Operator's requirements

The operator's OM stated:

> The PIC shall calculate a PNR on appropriate flights over water greater than 200 nm from land and on flights where the availability of an adequate aerodrome is critical. The PIC shall calculate the PNR based on the most critical case between normal, one engine inoperative and all engines depressurised operations…
>
> The PIC shall calculate the PNR before flight. The PIC shall update the PNR immediately after reaching top of climb and prior to reaching each PNR position.

In the section titled 'In-Flight Fuel Checks', the OM also stated:

> If, as a result of an in-flight fuel check on a flight to a destination aerodrome, the expected fuel remaining at the point of last possible diversion is less than the sum of:
>
> a) Fuel to divert to an enroute alternate aerodrome; and
>
> b) Variable reserve fuel; and
>
> c) Fixed reserve fuel.
>
> The PIC shall either:
>
> a) Divert; or
>
> b) Proceed to the destination, provided that two separate runways are available and the expected weather conditions at the destination enable a successful approach and landing…
>
> A PIC shall ensure that the amount of usable fuel remaining in-flight is not less than the fuel required to proceed to an aerodrome where a safe landing can be made, with fixed reserve fuel remaining…
>
> The PIC shall declare an emergency when the actual usable fuel on board is less than fixed reserve fuel.

In a section titled 'Latest Divert Time/Point', the OM stated:

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[197] When dealing with the case of a diversion to an en route alternate aerodrome, terms such as 'last point of safe diversion' (LPSD) or 'point of safe diversion' (PSD) are also used.

[198] There are occasions when a flight may pass a PNR with the required fuel on board, but subsequently a landing at the destination aerodrome cannot be conducted. Therefore a flight crew may elect to divert even though they will arrive at the alternate aerodrome with less than the required fuel reserves.

> If a successful approach and landing at the destination aerodrome appears marginal due to weather or any other reason, the PIC shall determine the latest divert time or position to proceed to a suitable alternate. The divert time/position shall be determined so as to allow the aircraft to land at the alternate with the required fixed reserves intact.

Although the OM used different terms such as ‘point of last possible diversion’, ‘latest divert point’ and PNR, these terms appeared to be referring to the same decision point. The term PNR is used in the remainder of this report.

As indicated in the OM, when calculating a PNR, a flight crew needs to ensure that, at the diversion point, the fuel on board will be sufficient to allow for the required flight fuel, variable reserve (from the diversion point), fixed reserve and holding fuel (if required).

Distinction between a PNR and a CP

Although a PNR and a CP have similarities, they also have important differences. A flight crew needs to calculate a CP to decide which aerodrome they can get to most quickly if an emergency occurs. In contrast, a flight crew need to calculate a PNR to determine when they are committed to proceeding to the destination aerodrome. A CP is based on the equi-time point between the two nearest aerodromes, whereas a PNR is based on fuel remaining (or endurance). Using the same alternate aerodrome, the CP will occur prior to the PNR during a flight.

As indicated above, the OM stated the captain shall calculate the PNR based on the ‘most critical case’. This text appeared to indicate that only the PNR for loss of pressurisation was required to be calculated, given that this is almost always the most critical case. The same text was also included for a CP, and in that context the requirement is more relevant, as calculating the CP for the most limiting situation will help determine the total fuel required for a flight. However, the exclusive requirement has limited relevance for a PNR, as the PNR for normal operations is just as important as the other PNRs and will be more commonly required.

On track versus off track PNRs

There are many methods that can be used to calculate a PNR. When the alternate aerodrome is on the track between the departure aerodrome and the destination aerodrome, then a simple formula or a navigation computer can be used. When the alternate aerodrome is not on the flight-planned track, the PNR calculation will generally be more difficult and time consuming, primarily because different wind components need to be considered.

There are several methods available to calculate a PNR to an off-track alternate aerodrome that are taught by aviation theory training providers. Most of these methods involve using aircraft performance data, forecast wind information, a navigation chart and basic geometric principles to estimate a PNR. The methods then involve checking the result and modifying the position accordingly.

For example, one of the methods involves plotting a point on the flight plan track that is abeam the alternate aerodrome. The available fuel endurance at the abeam point is calculated taking into account the reserve fuel requirements. The required fuel endurance from the abeam point to the alternate aerodrome is then calculated and the difference between the two fuel figures is used to determine whether the PNR is before or after the abeam point.

Using these geometric methods to calculate a PNR in-flight would generally be difficult due to the limited work area available in the cockpit, and they also can involve a significant amount of time. The methods are better suited to calculating the PNR before flight, after which it is relatively easy to adjust the PNR during flight, on the basis of actual fuel on board and the actual conditions being encountered.

Another approach is to use a graphical flight progress chart, commonly known as a ‘how-goes-it’ or ‘howgozit’ chart. The horizontal axis of the chart has distance in nautical miles with navigation waypoints indicated along the axis at the appropriate distances. The vertical axis has fuel on board values. The planned fuel on board at each waypoint can be plotted on the chart, as well as the fuel required to the alternate aerodrome to show the approximate position of the PNR.

Guidance for calculating a PNR

CAAP 234-1 (Guidelines for aircraft fuel requirements) did not provide guidance on calculating a PNR. CAAP 215-1 (Guide to the preparation of operations manuals) provided operators with a framework and guidance for presenting essential information in an operations manual. Appendix 1 of the CAAP listed subjects that 'may only have relevance to a small number of operators'. These included 'calculation of critical point' and 'calculation of a PNR'. No further guidance was provided.

CASA advised it did not provide any formal guidance material on calculating a PNR or CP because PNRs and CPs were both examined in theory examinations that flight crew were required to pass in order to obtain a CPL and an ATPL. In terms of flight crew licence theory examinations, CASA stated:

> There are multiple different methods that are commonly taught by theory [training] providers, and if applied correctly, give the same answer. Which method a candidate uses, is their choice. The aspect examined is whether the candidate can determine the correct position of either a CP or PNR, not which method they use to solve the problem contained in the examination. In the CPL exams, CP and PNR questions are relatively simple exercises involving one wind and airfields which are on track. In the ATPL exams, the questions presented are a little more complex and may include:
>
> - more than one wind;
> - the use of off track airfields;
> - determination of fuel policy requirements for PNR questions; and
> - consideration of change of aircraft performance and fuel flows with variations in gross weight and temperature;
> - questions may be based on either normal or abnormal operations, which includes depressurised operations and/or one engine in-operative scenarios.

CASA also advised, with regard to ATPL examinations:

> A Point of No Return (PNR) is typically one of the hardest questions that occur in the Flight Planning exam and requires knowledge and understanding of the procedures to solve. An average candidate will spend about 15 - 20 minutes to solve just one PNR question, consequently it is awarded a five mark allocation, the highest mark allocation CASA gives to any question.
>
> A Critical Point (CP) question, whilst simpler and easier than a PNR to solve, is still time consuming. Typically a well prepared candidate will take about 10 - 12 minutes to solve. It is typically awarded three marks. Just as a PNR may be calculated for different operations, so may a CP. Most CP questions are based on abnormal operations, either CP/Depressurised or CP/1 Engine Inoperative.

The operator's OM stated in-flight calculation or revision of the PNR should be based on observed, actual data. The manual also included guidance for using a simple formula or a navigation computer to calculate a PNR. As with a CP, this guidance did not cover the situation involving a diversion to an off-track alternate aerodrome.

The Westwind standards manager reported how-goes-it charts were introduced into Westwind operations several years prior to the accident. He stated he used a how-goes-it chart to calculate PNRs. He also thought that other Westwind pilots were taught this technique, and he expected that other pilots were using this technique to calculate PNRs and monitor the progress of relevant long-distance flights. Some Westwind pilots reported they routinely used how-goes-it charts for relevant flights. However, most pilots, including the captain of the accident flight, reported they did not use the charts and had not been taught how to use them.

The OM indicated a how-goes-it chart could be used to calculate a CP, but there was no mention of such charts in relation to a PNR. The standards manager agreed that such graphs are used for calculating PNRs rather than CPs.

The ATSB reviewed the operations manuals of several Australian operators who conducted air ambulance activities in jet aircraft. Most of these manuals had guidance similar to the operator's OM for calculating PNRs and CPs (that is, restricted to an on-track alternate aerodrome). One operator's manual included guidance on how to use a how-goes-it chart.

Flight crew practice

Westwind pilots reported they generally carried more than sufficient fuel to reach the destination aerodrome and then divert to an alternate aerodrome if required. Therefore, PNR calculations were generally not considered necessary.

Many pilots (including the captain of the accident flight) reported that if a PNR was relevant to the flight, they generally conducted the calculations after they were established in cruise rather than before flight. They noted it was only when they were established at their initial cruise level that they could get an accurate appreciation of their likely fuel situation and expected performance for the flight. Some pilots also noted they were often busy prior to departure. Other pilots reported calculating PNRs prior to flight where they were clearly going to be required, and some of these pilots reported the flight planning software tool they used provided the PNR calculation for them.

Westwind pilots also reported there was no standard way within the fleet of calculating PNRs. For a PNR to an on-track alternate aerodrome, many pilots (including the captain of the accident flight) reported they used the simple formula in the OM. For a PNR to an off-track aerodrome:

- the standards manager and another captain reported they used a how-goes-it chart
- one check pilot reported using a geometric-based technique
- one captain relied on the PNR calculated by his flight planning software tool (which only calculated a PNR for an on-track alternate)
- one captain stated he would do regular checks in-flight of whether he could divert to an alternate aerodrome from his present position, and from the trend of these checks he would build an appreciation of the PNR time[199]
- other captains (including check pilots) could not recall how they did the task, although they reported they did not use a how-goes-it chart.

The captain of the accident flight reported that, for a situation involving an off-track alternate aerodrome, he would initially work out if he could fly from the destination aerodrome to the alternate aerodrome with the required fuel reserves. If not, he would identify the last waypoint he could reach and still divert with the required fuel reserves. He would then know that the PNR was beyond this waypoint. This involved using the aircraft's GPS to determine the distance and/or flight time to the last waypoint he could reach, and charts to determine the distance from that waypoint to the alternate aerodrome.

After the captain had passed the last waypoint he could reach, his method involved conducting periodic checks of whether he was still able to divert from his current position. This involved using the aircraft's GPS to calculate the distance to the alternate aerodrome.

The captain reported that when checking his capacity to divert, he would use the aircraft's current fuel flow and his best estimate of the expected groundspeed, given the aircraft's current groundspeed and what information he had regarding the winds if he diverted. For the accident flight, the captain stated he would have based his diversion wind estimates on the current wind he was experiencing. Given that he did not have the current TAFs and NOTAMs for Nadi and Noumea, he would have based his estimations of the PNR on the assumption that these aerodromes were suitable for landing (that is, not also affected by adverse weather).

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199 This captain also reported he always ensured that he had alternate fuel when conducting flights to remote islands or similar aerodromes overseas. A review of the operator's flight records confirmed that this was the case.

There was no requirement in the OM for PNR calculations to be cross-checked between the flight crew. Some Westwind pilots reported PNRs would be discussed between the crew on some occasions, but this would depend on the captain, the first officer and the situation.

The first officer stated she knew how to do PNR calculations, and she reported she had done calculations on some flights. However, she could not recall doing PNR calculations on the accident flight.

Calculation of PNRs for the accident flight

The calculation of a PNR involves many variables, and the result can vary depending on a range of assumptions made about these variables. The ATSB estimated the pre-flight PNR for normal operations based on the captain's method for calculating the total fuel required for a long-distance flight and the data that should have been available during flight planning. Based on these calculations:

- the pre-flight PNR for Noumea was 123 NM before the DOLSI waypoint
- the pre-flight PNR for Nadi (including 60 minutes holding fuel) was 73 NM before the DOLSI waypoint.

The ATSB also estimated the in-flight PNR for normal operations based on:

- current thrust settings and actual fuel flow at FL 390 until the PNR (1,310 lb/hour)
- current winds experienced en route at FL 390 until the PNR
- long-range speed and thrust settings at FL 390 after diverting from the PNR to overhead the alternate aerodrome
- winds from the GPWT forecast available prior to the flight from the PNR to the alternate aerodrome
- adding 1 minute fuel burn for the turn onto the diversion track
- adding 10 per cent of the flight fuel for the variable fuel reserve for the remainder of the flight from the PNR
- no specific allowance for an instrument approach[200]
- adding 600 lb for the fixed fuel reserve.

Table 29 provides the results of these in-flight PNR calculations. As can be seen, the PNR nearest to Norfolk Island involved a diversion to Nadi at about 0900 (for a flight crew unaware that holding fuel was required at Nadi). If actual winds rather than forecast winds were used for calculations of the fuel burn after the diversion point, the PNR for Nadi was about 0903.

Table 29: In-flight PNR calculations of the accident flight using long-range cruise settings and forecast winds

Alternate aerodrome	Estimated PNR time	Estimated PNR position	Fuel on board (at diversion point)	Distance to alternate (from diversion point)
Nadi (with 60 minutes holding)	0833	DOLSI - 35 NM	2,820 lb	437 NM
Noumea (no holding)	0844	DOLSI + 25 NM	2,590 lb	486 NM
Nadi (no holding)	0900	DOLSI + 114 NM	2,240 lb	561 NM

As noted in the previous section, the captain of the accident flight reported he used a method that involved checking the capability to divert. The ATSB applied this approach at selected times during the flight using the following information and assumptions:

[200] ATSB calculations showed that calculating the fuel flow in cruise to overhead the alternate aerodrome involved a similar fuel burn off to estimating the fuel flow for a cruise to the top of descent, the descent and then an instrument approach to the alternate aerodrome.

- the captain's understanding of the fuel on board at the selected time (the estimated fuel quantity gauge indication plus 300 lb)
- (if prior to DOLSI) current thrust settings, TAS and perceived fuel flow for the flight to DOLSI and then overhead the alternate aerodrome (1,100 lb/hour)
- (if at or past DOLSI) current thrust settings, TAS and perceived fuel flow to overhead the alternate aerodrome (1,100 lb/hour)
- current wind information (direction and speed) to estimate the wind component during the diversion
- no specific allowance for the turn onto the diversion track
- no specific allowance for the descent and instrument approach
- adding 10 per cent of the flight fuel for the variable fuel reserve for the remainder of the flight from the diversion point
- adding 600 lb for the fixed fuel reserve.

Table 30 presents the results of using the captain's reported method. As can be seen, using this method, if a PNR check was done prior to reaching DOLSI then the captain would have become aware the PNR was significantly past DOLSI. The estimated PNR using the captain's method involved a diversion to Nadi at about 0903.

Table 30: In-flight PNR calculations of the accident flight using captain's method

Time	Position	Capacity to divert to Nadi	Capacity to divert to Noumea
0803	DOLSI - 209 NM	Divert at DOLSI with 860 lb margin	Divert at DOLSI with 370 lb margin
0839	DOLSI	Divert with 800 lb margin	Divert with 270 lb margin
0847	DOLSI + 44 NM	Divert with 520 lb margin	Divert with 20 lb margin
0852	DOLSI + 70 NM	Divert with 430 lb margin	PNR – divert with 10 lb margin
0855	DOLSI + 90 NM	Divert with 320 lb margin	40 lb less than required
0903	DOLSI + 130 NM	PNR – divert with 10 lb margin	90 lb less than required
0907	DOLSI + 152 NM	130 lb less than required	180 lb less than required
0912	DOLSI + 180 NM	170 lb less than required	120 lb less than required
0929	YSNF - 162 NM	900 lb less than required	420 lb less than required

Note: The above fuel figures do not exhibit a linear trend due to the relationship between the flight planned track and the location of Nadi and Noumea, the changing of the diversion tracks as the aircraft continued toward Norfolk Island, and the differences in wind velocity between 0803 and 0929 as the aircraft proceeded into stronger wind conditions.

Factors to consider when deciding whether to divert

Regulatory requirements and guidance

CAR 257 (Aerodrome meteorological minima) included the following paragraphs:

> (4) If an element of the meteorological minima for the landing of an aircraft at an aerodrome is less than that determined for the aircraft operation at the aerodrome, the aircraft must not land at that aerodrome…
>
> (5) Subregulation (4) does not apply if an emergency arises that, in the interests of safety, makes it necessary for an aircraft to land at an aerodrome where the meteorological minima is less than that determined for that aircraft operation at that aerodrome.
>
> (6) This regulation does not prevent a pilot from:
>
> (a) making an approach for the purpose of landing at an aerodrome; or
>
> (b) continuing to fly towards an aerodrome of intended landing specified in the flight plan;
>
> if the pilot believes, on reasonable grounds, that the meteorological minima determined for that aerodrome will be at, or above, the meteorological minima determined for the aerodrome at the time of arrival at that aerodrome.

The landing minima, which are required to be considered during the approach, are always lower than the alternate minima, which are required to be used when flight planning. CASA stated there is no mandatory requirement to use alternate minima for in-flight decision-making. More specifically, it stated:[201]

> The provisions and requirements for the nomination of an alternate aerodrome are planning requirements. There is no requirement in the Aeronautical Information Publication, or in the regulations, regarding an in-flight requirement for the alternate minima to set the landing minima at the destination. Once airborne, and not in a planning situation, the pilot in command is required to comply with meteorological [landing] minima for the aerodrome, as required by Civil Aviation Regulation 257 and to consider other operational variables that may exist. The decision to divert is a decision for the pilot in command, based on the many variables that need to be considered at the time…
>
> The legislation, guidance material and the AIP provide no mandate to divert based solely on a weather report or forecast. The pilot-in-command is required to formulate a decision to divert or not, taking into account all available information (which may require requesting additional or updated information). Clearly the amount of fuel remaining is a critical determinant.
>
> … Because of the breadth of guidance that would be required to cover all the possible scenarios for en-route decision-making, any unnecessarily complex guidance material, beyond the scope of fundamental in-flight planning, risks becoming a contributor to unsafe decisions.

With respect to the term 'reasonable grounds' in CAR 257(6), CASA advised:

> In order for a pilot in command to make a decision "on reasonable grounds" he or she needs to refer to as much pre-flight and in-flight information that can be practically sourced. The information can be obtained from various sources, for example, pre-flight planning information, in-flight meteorological reports and reports from other pilots. If the meteorology reports, whether they are forecasts or observations, indicate, "on reasonable grounds" that the weather has improved or deteriorated, as the case may be, then the pilot in command is expected to make the appropriate decision to either continue or divert.

Operator requirements and guidance

The operator's OM stated flight crew were required to use the published landing minima when conducting an instrument approach. The manual did not specify, nor was it required to specify, explicit criteria to use for in-flight decision-making.

With regard to en route decision-making associated with weather conditions, the OM provided the following guidance:

> A diversion due to weather (either enroute or from a destination) is a contingency that can occur on virtually any flight. If the weather conditions are known to be marginal, such diversions should be allowed for during planning. However the weather can deteriorate rapidly and unexpectedly and unplanned diversions may become necessary.
>
> The primary consideration in such a situation is the safety of the aircraft and its occupants, and communications are an important aspect. When in controlled airspace, the PIC should request an amended clearance to enable clearance to be granted before diversion is necessary. When remaining OCTA [outside controlled airspace], the PIC shall keep ATC [and] other traffic informed of his intentions.…
>
> The main factor in selecting an airport as an emergency diversion is its operational suitability. However, the following aspects are also important:
>
> a) Availability of fuel.
>
> b) Availability of accommodation and surface transport, particularly if passenger's [sic] are carried.

[201] CASA response to written questions on notice during the Senate Inquiry into Aviation Accident Investigations (questions issued on 15 February 2013). Available at http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/Completed_inquiries/2012-13/pelair2012/submissions.

c) Communications – Without telephone facilities it will be difficult to notify CAA [the regulator] and the Company of arrival, and to plan future movements.

d) Protection of aircraft.

Flight crew practice

The operator's Westwind pilots stated diversions due to weather were rare, with most pilots not able to recall having had to divert due to weather.

The ATSB obtained information from a range of pilots regarding the criteria and factors they would consider when making a decision regarding continuing a flight to the destination aerodrome or diverting to an alternate aerodrome. These pilots included some of the operator's Westwind pilots as well as pilots from other operators.

Some pilots reported that if the observed or forecast weather conditions deteriorated during the flight to below the alternate minima before the PNR, they would be required to divert to the alternate aerodrome. Other pilots reported that just because the conditions deteriorated below the alternate minima did not mean they were required to divert. Rather, the decision to divert was more complex and required considering a range of factors. These included:

- the trend of the conditions (or rate of deterioration)
- the extent the conditions were above the landing minima at the destination aerodrome
- the extent to which the forecast conditions and observed conditions at the destination aerodrome were consistent
- the weather conditions at the alternate aerodrome
- the types of instrument approaches and other facilities available at the destination aerodrome and the alternate aerodrome.

The captain of the accident flight reported he did not consider the alternate minima as being a mandatory basis for a diversion during flight. That is, if the forecast conditions or reported conditions deteriorated below the alternate minima, he did not believe he was required to divert. The first officer stated that she thought if the forecast weather conditions deteriorated below the alternate minima prior to the PNR, there was an obligation to divert.

Obtaining weather information during flight

Regulatory requirements and guidance

As noted above, CAR 239 and the AIP required a pilot in command to consider forecasts and observation reports during pre-flight planning. There was no corresponding guidance for application to flight crews' in-flight planning. As a result, the ATSB sought clarification from CASA on the extent to which pilots are able to use observation reports (including METARs) for in-flight planning decisions, such as to continue to the destination or initiate a diversion.

CASA, in its response, stated 'ultimately the decision [to continue to the destination or initiate a diversion] rests with the pilot in command, but only can be based on available forecasts (TAF), Aerodrome Weather Reports (METAR/SPECI), Aerodrome Weather Information Service (AWIS) or observations'. In addition, CASA clarified that there was no 'strategic difference between an in-flight scenario and a pre-flight plan' in relation to the use of forecasts.

In relation to the use of observation reports for in-flight planning, CASA noted 'weather observations are not a legal instrument to determine if an alternate should be held or for fuel planning, unless the observation has a trend appended to it (eg TTF[202]…)…'. However, it further stated '…a pilot is able to use both a valid forecast and observation information'.

Further to the use of observation reports, CASA's advice noted:

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[202] Trend forecast (TTF): an aerodrome weather report (METAR or SPECI) that has a statement of trend appended.

> The usefulness of the observation is dependent directly on how far away the aircraft is from the aerodrome. For example, a report showing an improvement in the weather may be useful to an aircraft in the holding pattern directly overhead the aerodrome, to decide on whether or not to fly the approach or not. Conversely, if the aircraft is a distance away (eg one hour) the observation should be viewed with caution.

In terms of obtaining forecasts and weather reports in flight, as noted in *Flight information service*, the provision of flight information services in the Auckland Oceanic FIR and the Nadi FIR was subject to the workload of ATS personnel, with the provision of aircraft separation functions having priority over the provision of FIS. The same principle also applied in other countries (see ATSB report AO-2013-100).[203]

Accordingly, flight crews could not rely on being automatically provided with relevant information, and hence they were responsible for ensuring they requested sufficient information to make effective decisions. The Australian AIP section on FIS provided very specific statements regarding the responsibility of the pilot in command to obtain information (see *Provision of flight information service in Australian FIRs*).

There was no specific regulatory requirement for a flight crew to check whether there had been an amended TAF issued during a flight. There was also no published guidance material discussing how to weight the relative importance of TAFs or observations during in-flight decision-making.

Operator requirements and guidance

The operator's OM contained no specific requirements or guidance material regarding the types of weather information to obtain during flight and when to obtain this information. A review of other air ambulance operators' operations manuals found they also did not provide any specific guidance in this area.

Flight crew practice

Westwind pilots reported they would generally obtain weather observations during long flights, and they would certainly obtain updated weather observations prior to the PNR for flights where a PNR applied. They stated they would not routinely request updated TAFs for the destination aerodrome during flight, and they would generally expect ATS to notify them if the TAF had been amended.

Some pilots noted that if weather conditions started deteriorating, they would request additional information. This may include asking about updated TAFs as well as other pilot reports of the weather conditions.

In addition, some pilots noted they generally would not expect to be proactively provided with updated weather information in the Oceanic/South Pacific region, except perhaps from Australia and New Zealand ATS. Therefore they would assume they had to obtain any weather information they needed.

Previous occurrences involving unforecast adverse weather conditions

During 1998–1999, there were a series of occurrences at Norfolk Island where the weather conditions encountered on arrival were worse than those forecast (see appendix I). There also have been many other cases where this has occurred at other locations in Australia, although generally the flight crews were provided with advice of the deteriorating weather prior to their arrival at the destination aerodrome. The ATSB report AO-2013-100 provides further details of some occurrences involving unforecast adverse weather conditions.

In the ATSB's interviews with the operator's Westwind pilots, three previous events were identified where a flight departed with the forecast conditions at the destination aerodrome being above the

[203] ATSB AO-2013-100, Landing below minima due to fog involving Boeing 737s, VH-YIR and VH-VYK, Mildura Airport, Victoria, 18 June 2013. Available from www.atsb.gov.au.

alternate minima but the actual conditions then deteriorated below the landing minima prior to arrival without the crew being made aware of the problem. Further details included:

- One event occurred on a freight flight to Alice Springs several years prior to 2009. The crew included a check pilot. The airport had an ILS approach, and the crew landed in conditions below the landing minima. The aircraft reportedly did not have sufficient fuel to divert to an alternate aerodrome.
- One event occurred on a freight flight to Darwin several years prior to 2009. The airport had an ILS approach, and the crew landed in conditions below the landing minima. The aircraft reportedly did not have sufficient fuel to divert to an alternate aerodrome.
- One event occurred on a freight flight to Broken Hill in 2009. The crew included a check pilot. The crew were able to land off the third approach, which was conducted to the opposite runway to the first two approaches. A crew member recalled they probably did not have sufficient fuel to divert to an alternate aerodrome. However, a review of the flight record indicated the flight probably did have sufficient fuel to divert.

None of these events were reported to the ATSB or its precursor, the Bureau of Air Safety Investigation.[204] The 2009 event also was not formally reported to the operator.

Flight crew training and checking

Training and checking organisation

CAR 217 (Training and checking organisation) stated:

> An operator of a regular public transport service, an operator of any aircraft the maximum take-off weight of which exceeds 5,700 kilograms and any other operator that CASA specifies shall provide a training and checking organisation so as to ensure that members of the operator's operating crews maintain their competency.
>
> The operator must ensure that the training and checking organisation includes provision for the making in each calendar year, but not at intervals of less than four months, of two checks of a nature sufficient to test the competency of each member of the operator's operating crews.
>
> The training and checking organisation and the tests and checks provided for therein shall be subject to the approval of CASA…

CAO 82.1 (Conditions on air operator's certificates authorising charter operations and aerial work operations) outlined more specific requirements in relation to training and checking for charter and aerial work operators with a CAR 217 training and checking organisation.

The operator's training and checking organisation and manual were approved by CASA. The chief pilot was the head of training and checking (HOTC), but was not a check or training pilot on the Westwind (see *Roles and responsibilities*). The operator's Westwind fleet had two check pilots and additional supervisory pilots. One of the check pilots was the Westwind standards manager.

In terms of the roles of training personnel, the OM stated:

- Check pilots conducted instrument rating renewals, proficiency checks, and line training of endorsed pilots. Some check pilots were also approved to issue aircraft endorsements.
- Training pilots conducted proficiency checks and line training of endorsed pilots.
- Supervisory pilots conducted line training of endorsed pilots.

[204] The Bureau of Air Safety Investigation (BASI) became part of the newly formed multi-modal Australian Transport Safety Bureau (ATSB) on 1 July 1999.

Check and training pilots had to be approved by CASA, whereas supervisory pilots were not required to be approved by CASA.[205]

Flight training

For the Westwind aircraft, pilot endorsement training involved a 1-week ground instruction and typically about 5 hours flight training. A pilot's abilities were then consolidated during line training. The OM contained a detailed syllabus to be covered during endorsement training.

The OM stated 'post-endorsement training' for all captains and first officers needed to include:

> a) Flight Planning Fuel requirements, weather and operational requirements, suitable alternates, Critical Point and PNR, single engine and de-pressurised considerations.
>
> b) Loading Limitations, load security, weight and balance, trim sheet.
>
> c) Systems Knowledge, correct use, limitations and emergency requirements for all aircraft engineering systems; differences that may exist between aircraft of the same type operated by the Company.
>
> d) Performance RTOWs, RLWs, Special Procedures, enroute performance referenced to AFM charts; maximum and critical speeds for all operations including asymmetric flight and un-evaluated runways.
>
> e) Check Lists Use of check lists and the placarded operational information.
>
> f) Flight Procedures Company requirements for all phases of flight including IFR procedures and enroute asymmetric requirements.
>
> g) Navigation Map reading, use of aids, calculation and adjustments to CP and PNR.
>
> h) Route Knowledge Aerodromes/ALAs - both destination and alternate; fuel and oil availability. Terrain, seasonal meteorological conditions, Met and ATC facilities, services and procedures. SAR procedures and navigation facilities.

This training was provided during line operations. Up until April 2009, the operator's line training for Westwind pilots was based out of Darwin, primarily involving freight flights.

The minimum required line training for a first officer before being checked to line was 10 hours for RPT and charter operations. In practice the operator usually conducted about 50 hours line training before conducting a check to line.

Check pilots and supervisory pilots stated first officers received mentoring during line operations to build up their experience. When they had achieved sufficient experience in line operations, they were recommended for command training.

The minimum required line training in command under supervision (ICUS) before being cleared to line as a captain was 50 hours. In practice the operator usually conducted about 70–100 hours line training before conducting a check to line.

Check pilots and supervisory pilots reported the purpose of the line training was to ensure a new captain could handle all the required tasks. Westwind pilots stated command training focussed heavily on managing aircraft system failures and engine failures. They said the training was difficult and overall ensured that they were better prepared to manage abnormal situations under workload or pressure.

The ATSB reviewed the line training records for several captains who completed their line training during 2007–2009. The training record for each day's flying was recorded on a 'Training & Check' form, which consisted of two pages. One page included a checklist of standard items, and the supervisory pilot indicated whether the item was conducted successfully, conducted

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[205] CAO 82.1 stated 'Persons must not be nominated to supervisory positions within the training and checking organisation without the approval of CASA.' A CASA flying operations inspector reported he received advice that supervisory pilots were required to be approved by CASA. Consequently, he advised the operator that supervisory pilots needed CASA approval, and he subsequently approved several supervisory pilots during 2008–2009. Subsequent advice clarified that 'supervisory positions' referred to positions such as chief pilot, HOTC and check pilot, but not a supervisory pilot.

unsuccessfully or 'waived'. A second page allowed for the supervisory pilot to record comments. Usually the comments on the completed forms listed areas requiring improvement rather than outline the specific topics that were covered during that period of line training. Consequently, when reviewing the forms it was difficult to determine what topics and scenarios were covered in each training session.

Overall, the review of training records indicated key areas of focus were aircraft systems knowledge, handing aircraft system failures, handling engine failures, conducting instrument approaches and following procedures and checklists.

Westwind pilots stated fuel planning, flight planning and in-flight fuel management aspects were covered during command line training. However, this was not an area of focus and the scope of their coverage was limited to the freight flights, where standard flight plans were typically used. Pilots also recalled that concepts such as CP and PNR were covered, but they were not discussed in detail or emphasised.

Training records indicated flight planning and fuel planning aspects were covered to some extent during line training. Only one training form for one pilot specifically noted CPs and PNRs were discussed. That training was conducted on an international air ambulance operation in mid-2009, after the regular freight contracts for the Westwind had ceased.

Some of the training activities, such as managing engine failures and some types of aircraft system failures, could only be conducted by a CASA-approved check or training pilot. Training records indicated such training was often done by a supervisory pilot, who did not have CASA approval to conduct this training.

The operator had a significant turnover of pilots in its Westwind and turboprop fleets as many of these pilots progressed to major airlines after working for the operator for a few years. For example, the operator typically had four Westwind captains based in Sydney during 2007–2009, including the Westwind standards manager (who was there the whole period). There were 12 other captains based in Sydney during this period, although a few of them had transferred from Darwin. The flight crew turnover in Darwin was less significant. Due to the high turnover overall, there was often line training being conducted for a new captain and/or new first officer. However, the amount of line training of Westwind pilots decreased as the scheduled freight operations started decreasing in early 2009.

Proficiency checks

Regulatory requirements and guidance

CAR 217(2) required that an operator provide two checks of a pilot's competency each year. In relation to these checks, CASA's *Air Operator Certification Manual* (AOCM) stated the following:

> The CAR 2 definition of "aeroplane proficiency check"[206] ties the proficiency check to the CAR 217 competency requirement. For CASA to be satisfied with an applicant's proposed tests and checks, a CAO 40.1.5 proficiency check, appropriate to the aircraft type and the type of operation, should be regarded as the minimum standard for a competency check for the purposes of CAR 217.
>
> Furthermore, as the stated intent of CAR 217 is to ensure flight crewmember competency in the performance of all their assigned duties, the CAO-defined proficiency check does not completely fulfil the CAR 217 requirement, and therefore additional operator-specific checks should be necessary.
>
> The acceptability of the tests and checks is ultimately one for the project team. However, a competency check programme normally has as its basis substantial sections of the CAO 40.1.5 proficiency check. In practice, most operators will devise a check programme that includes a mix of both line and base checks, conducted in an aircraft or a simulator. These will include the route

[206] CAR 2 defined an 'aeroplane proficiency check' as a check that tested 'the aeronautical skills and aeronautical knowledge relevant to aeroplane flight of the person undertaking the check'.

> check,[207] asymmetric flight, instrument flight, night flying and the other components of the CAO 40.1.5 flight proficiency test.
>
> The FOI [flying operations inspector] must also ensure that the operator's program achieves, as a minimum, the CAR 217 requirements of two checks per year, each of which ensures the competency of operating crew. The program must also achieve annually all the requirements of CAO 40.2.1 for the issue of the appropriate instrument rating.

CAO 40.1.5[208] (Conditions on air transport pilot (aeroplane) licences) contained the contents of the aeroplane proficiency check, which included various components that had to be demonstrated to complete the proficiency check. These components included general flying, instrument flying, twin-engine aircraft emergency manoeuvres, bad weather circuit operations, night flying and general emergency procedures.

CAAP 215-1(0) (Guide to the preparation of operations manuals, September 1997) stated the use of base checks and line checks was an example of one way to meet the requirements of CAR 217(2). It defined a base check as:

> …a test of proficiency specifically directed towards the handling of an aircraft in normal flight manoeuvres and during the emergency or abnormal operation of the aircraft's systems.

It defined a line check as:

> …a test of proficiency involving the performance of a real or simulated company revenue flight on which a crew member is being tested in his assigned role. The test involves an assessment on all phases of the flight except that emergency procedures or other procedures which are prohibited from being tested by CAR 249[209] or could otherwise adversely impact on the nature of a revenue flight will not be tested.

CAAP 215-1(0) also provided examples of elements that would be normally conducted in the two types of checks. Base checks included items such as simulated engine failures, systems failures, stall recovery and instrument approaches. Line checks included all phases of flight except emergency procedures. This included flight planning and in-flight checks.

Operator's procedures

The operator's OM required two proficiency checks to be conducted each year for each pilot. The manual stated each proficiency check shall include a base check and a line check. One of the two base checks each year also included the pilot's instrument rating renewal, and one included a CAO 20.11 proficiency check (except for 'wet drills' items, see *Emergency procedures training and checking*).

The OM stated that for a base check:

> The object is the execution of normal, abnormal and emergency procedures appropriate to the type of aircraft that cannot be practised during the line proficiency check.

The OM did not specify exactly what elements were mandatory. It referred to the Training & Check form, and one page of this form listed the items required for a base check. These included several items, such as a rejected take-off, engine failure during take-off, asymmetric landing, system failures and knowledge of emergency procedures.

For a line check, the OM stated:

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[207] CAR 218 (Route qualifications of pilot in command of a regular public transport aircraft) paragraph (1) stated 'A pilot is qualified to act in the capacity of pilot in command of an aircraft engaged in a regular public transport service if the pilot is qualified for the particular route to be flown…'. There were no specific route check requirements for charter or aerial work flights.

[208] CAO 40.1.5 applied to RPT operators. However, the AOCM discussion on proficiency checks did not differentiate between RPT and other types of operators for the purpose of CAR 217 proficiency checks.

[209] CAR 249 (Prohibition of carriage of passengers on certain flights) prohibited the practice of emergency procedures while passengers were carried on board the aircraft.

> Flight proficiency line check and route checks shall be arranged on flights of reasonable length and shall include a minimum of two sectors…
>
> The proficiency line check forms the second part of the six (6) monthly pilot proficiency check. The check is normally conducted during a revenue flight therefore no abnormal or emergency procedures shall be practiced….
>
> Major factors to be assessed in determining a pilot's qualification to act as PIC over any route are Flight Planning, Loading, Documentation and Pre-flight Inspection.

In terms of flight planning aspects for a line check, the OM stated:

> All flight planning associated with Company operations shall be carried out in accordance with the OM. The flight plan prepared by the pilot under check and predeparture quiz shall reflect his/her satisfactory knowledge of the following:
>
> a) The route and terrain to be flown;
>
> b) Meteorological conditions likely to be encountered;
>
> c) Destination and alternate aerodromes and their particular characteristics;
>
> d) Relevant airways facilities, services and procedures;
>
> e) Survival and SAR procedures associated with the route to be flown;
>
> f) Navigational facilities associated with the route to be flown;
>
> g) Examination and interpretation of the weather forecast;
>
> h) Calculation of fuel requirements, CP and PNR;
>
> i) Conditions requiring an alternate and selection of an alternates;
>
> j) Application of relevant NOTAM information.

The manual also included a detailed list of factors for assessment during a line check. It noted

> It is not anticipated that every point that may arise during a check flight has been covered in the following list of factors, however they shall to be [sic] used as a guide for judging performance. Check Pilots are required, therefore, to exercise common sense and discretion when assessing other points that may arise, bearing in mind that the objective is to attain and maintain the highest possible standard of pilot ability.

The factors for assessment included:

> Assessment of wind velocity…
>
> Ability to compute CP and PNR...
>
> Fuel management…
>
> Fog/low visibility awareness…
>
> Sound interpretation of general meteorological conditions encountered or reasonably expected in flight…

The Training & Check form also listed required items for a line check. These included 'Flight plan', 'Fuel / Weather / NOTAMS / Terrain', knowledge of regulations and procedures, and use of checklists.

Operator's practices

The Westwind standards manager reported that historically, the operator's base checks and line checks were conducted at the same time. The checks used to be conducted on scheduled freight flights. However, after the reduction in freight flights some years prior to the accident, proficiency checks were typically conducted on non-revenue flights on short sectors. He noted that although short flights would not effectively allow flight planning, fuel planning and fuel management aspects to be checked, these aspects could be and were examined using scenarios and asking questions to test the candidate's knowledge.

A review of flight records and flight crew training records during 2007–2009 for the Westwind fleet found that the base check and line check component of each proficiency check were generally conducted together. The checks were generally done on non-revenue flights involving two sectors over short distances, such as Darwin-Tindal-Darwin or Sydney-Nowra-Sydney. On some occasions they included one sector or were simply conducted at one airport.

Westwind check pilots and line pilots reported proficiency checks focussed on handling abnormal and emergency situations. There was minimal coverage of flight planning, fuel planning or in-flight fuel management as such issues were not complex for the flights conducted during the check. They did not recall these subjects being raised as part of scenario discussions or knowledge quizzes.

The chief pilot and the Westwind standards manager had different views on proficiency checks. The chief pilot reported that he believed line checks over short sectors on non-revenue flights, such as Sydney-Nowra-Sydney, did not meet the intent of the regulations and he wanted the line checks to be separated from the base check or be used to demonstrate proficiency on a normal revenue flight. The standards manager believed having separate base checks and line checks was more appropriate for operators where base checks could be conducted in a flight simulator, but it was not necessary when the checks were conducted in an aircraft.

In April 2009, a Westwind check pilot conducted a proficiency check on the Westwind standards manager. The check included a base check, line check and instrument rating renewal in 0.7 hours at Darwin without a flight to another airport. All aspects were classified as satisfactory. The associated form indicated some items, including the mandatory items ‘rejected takeoff’ and ‘night flying’, were waived.

As HOTC, the chief pilot reviewed the associated documentation and was dissatisfied with aspects of the above proficiency check. The documentation was forwarded to CASA for their opinion, and CASA requested explanations from the check pilot and the Westwind standards manager about how the proficiency check met the requirements of the operator’s OM. The check pilot and standards manager both acknowledged they had not completed some mandatory items due to time constraints, and stated another proficiency check had been scheduled to complete the items. The standards manager also indicated the OM could be amended to clarify which elements of a check could be waived.

CASA were dissatisfied with the responses, and requested a meeting with the standards manager, check pilot and chief pilot. A CASA file note about the meeting stated:

- the standards manager and check pilot were told that the check was not conducted according to the standard expected by CASA but there was insufficient evidence for enforcement action
- the chief pilot was advised to review the OM to see if it needed to be more prescriptive and ‘ensure corners could not be cut by finding ‘grey’ areas’
- the chief pilot was cooperative and proactive during the investigation and CASA had confidence in his approach to Pel-Air training and checking.

From September 2009, proficiency checks on the Westwind fleet included a line check with at least two sectors of normal line operations. These were generally domestic charter flights.

As far as could be determined, no proficiency checks were conducted on international flights or air ambulance flights. The Westwind standards manager noted it would be difficult to conduct line checks on air ambulance flights due to their unpredictable timing, and the extra time such checks required would have an impact on the flights.

A review of training and checking records found all the proficiency checks were conducted by CASA-approved check pilots.

Preparation for air ambulance and international flights

As noted above, most captains completed their line training based in Darwin on freight flights. There was no formal training program for captains that covered the unique requirements of air ambulance flights, international flights and/or flights to remote aerodromes. Most pilots had some exposure to such operations during their first officer flying, but the amount varied significantly.

During the time period where they were undergoing line training, some captains conducted an international flight as a first officer with a check pilot. These were not recorded as line training. After pilots were cleared to line as a captain, they rarely conducted any line operations with a check pilot or supervisory pilot.

For example, the captain of the accident flight conducted six international flights as a first officer prior to becoming a captain. These included one flight with a check pilot to Noumea during the period when he was undertaking line training. The only flight he conducted as a first officer to a remote aerodrome was to Christmas Island, which was conducted with a line captain. However, after becoming a captain himself, he never conducted a normal line flight with a check pilot or supervisory pilot, although he did some flights with other recently-approved captains. Some other captains also had a low level of exposure to check pilots and supervisory pilots during normal line operations.

Human factors and crew resource management training

Background information

Human factors is the multi-disciplinary science that applies knowledge about the capabilities and limitations of human performance to all aspects of the design, operation, and maintenance of products and systems. It considers the effects of physical, psychological, and environmental factors on human performance in different task environments, including the role of human operators in complex systems.

In a multi-crew environment, human factors is also concerned with ensuring the crew work in a co-ordinated way with each other, the aircraft systems, and the broader aviation system. Traditionally, this has been known as crew resource management (CRM). CRM has generally been defined as a crew's 'effective use of all available resources - people, equipment, and information – to achieve safe, efficient operations' (Lauber 1984). Effective CRM means all crew members function as a team, rather than as a collection of technically competent individuals.

Training in human factors and CRM is designed to teach flight crew the non-technical skills essential for operating in a complex time-critical environment, especially in a multi-pilot team. Generally, such courses train concepts such as communications, situational awareness, problem solving and decision-making, leadership and 'followership', stress management, interpersonal skills and critiques.

The term 'human factors management' (HFM) has been used by some operators instead of CRM. HFM includes CRM, but also encompasses more training about human factors limitations. Such limitations include fatigue, stress, perception, mental workload and memory.

A further development in CRM has been threat and error management (TEM). TEM is based on the principle that everyone will make errors, and that pilots need to be taught strategies that will help recognise and manage these errors and other threats or hazards before they have a negative consequence.

Formal training in CRM and related topics started being undertaken by air transport operators around the world in the late 1970s in response to the significant proportion of accidents that involved problems with crew communication and coordination (Salas and others 2001).

In Australia, there have been several accidents involving air transport aircraft that involved problems with CRM. These included an accident involving one of the operator's Westwind aircraft conducting a night freight flight from Tindal to Alice Springs in April 1995. During the approach, the crew descended to the incorrect minimum descent altitude before reaching the appropriate segment of the approach.[210] At that time, the operator did not provide, and was not required to provide, CRM training to flight crews.

Requirements for training

Consistent with ICAO Annex 1 (Personnel Licensing), CASA required 'human performance and limitations' awareness training to be undertaken by pilots at each level of pilot licencing. The required syllabus for these licences covered awareness of human factors issues.

In January 1995, BASI issued the following recommendation to CASA:[211]

> The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (CASA) require operators involved in multi-crew air transport operations to ensure that pilots have received effective training in crew resource management (CRM) principles...

CASA provided a series of responses to this recommendation in subsequent years, issued a discussion paper and did other development work. Although no requirements were introduced, it encouraged operators to introduce relevant training, and most Australian air transport operators subsequently introduced some form of CRM training into their operations.

In 2006, ICAO amended Annex 6 Part I to include a requirement for international commercial air transport operators to provide flight crew with training '...in knowledge and skills related to … human performance including threat and error management…'.[212] Subsequently, CASA introduced a requirement for RPT operators to provide training and assessment in human factors and non-technical skills. These requirements were introduced in CAO 82.3 (Conditions on air operator's certificates authorising regular public transport operations in other than high capacity aircraft) and CAO 82.5 (Conditions on air operator's certificates authorising regular public transport operations in other than high capacity aircraft) for RPT operators at the same time as requirements for safety management systems (see *Australian requirements and guidance*).

As of November 2009, there was no regulatory requirement in Australia for a non-RPT operator to provide CRM, TEM or similar training to flight crew.

Operator's CRM training

The operator's OM stated each pilot was required to complete a CRM course within 6 months of joining the organisation, and then a recurrent course every 15 months.

In March 2008, CASA identified during an audit that the operator had not been conducting annual CRM training of its flight crew in accordance with its OM (see *Oversight of flight crew training and checking*). Soon after, the operator re-commenced the training, and it was then conducted every 12 months.

The operator provided its CRM training via a computer-based training (CBT) package. Each pilot viewed a presentation at their own pace and then completed a short exam. No classroom training was involved, and no case studies were included.

The training package covered basic theoretical concepts in human factors and CRM, such as:

- decision-making
- communication style and principles
- leadership

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210 BASI, Investigation Report 199501246, Israel Aircraft Industries Westwind 1124 VH-AJS, Alice Springs, NT, 27 April 1995.

211 BASI recommendation IR19950101. Further information on this recommendation and CASA's response are provided in ATSB Aviation Occurrence Report 200501977, Collision with terrain, 11 km NW Lockhart River Aerodrome, 7 May 2005, VH-TFU, SA227 DC (Metro 23). Available at www.atsb.gov.au.

212 Since 1995, ICAO Annex 6 Part 1 required operators to provide training '… in knowledge and skills related to human performance'.

- adaptability and flexibility
- situation awareness.

In terms of decision-making, the package recommended a decision-making process (AVIATE) as follows:

- Assess the problem
- Verify information from all sources
- Identify solutions
- Anticipate consequences
- Tell others decision and rationale
- Evaluate the decision.

The material also contained other general guidance principles.

Westwind pilots reported the training material was basic in nature and had limited effectiveness. Most of the Westwind pilots had studied similar human factors concepts when undertaking theory examinations for their CPL and ATPL.

The operator's Training & Check form included items labelled 'CRM Co-Ord. / Monitoring', 'Situation Awareness' and 'Use of Checklists' as items to be assessed during line checks. These items were often ticked on completed forms. However, very few comments on the forms referred to CRM-related topics, other than occasional comments regarding the use of checklists or standard procedures during line training.

Westwind check pilots reported good communication principles were taught and encouraged during line training. Some Westwind pilots reported there was no formal multi-crew training, and that CRM principles were not specifically emphasised during line training or proficiency checks. However, they thought the level of CRM within the Westwind fleet was relatively good, particularly in terms of the relationship among the pilots and the ability for crew members to speak up if they were concerned about the conduct of a flight.

Other training and checking

In addition to CRM, the operator's OM also required that pilots receive several other types of training and/or proficiency checking. These included:

- Fatigue risk management system (FRMS) training in accordance with the operator's FRMS (see *Fatigue management training*).
- Emergency procedures proficiency checks in accordance with CAO 20.11 (see Emergency procedures training and checking).
- EGPWS training. In its OM, the operator had a syllabus for conducting EGPWS training, which was required for all flight crew operating an aircraft fitted with an EGPWS. The training was provided via a CBT program. During an audit in March 2008, CASA found no evidence that pilots of aircraft fitted with an EGPWS had undertaken the training course (see *Oversight of flight crew training and checking*). In response, the operator ensured relevant pilots completed the training. This did not include any Westwind pilots as no Westwind aircraft at that time were fitted with an EGPWS.[213] There was no evidence the operator's Westwind pilots had completed the EGPWS training course after VH-NGA was fitted with EGPWS in August 2009.
- ACAS training. CAO 40.0 (Conditions – flight crew licences) stated that before flight crew were able to operate an aircraft fitted with an activated ACAS they were required to complete training (as outlined in the CAO) and be assessed as competent. The operator advised ACAS training had been appropriately conducted for its Saab 340 pilots. VH-NGA was the operator's only

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[213] The OM stated that only the operator's Saab 340 and Metro 23 aircraft were fitted with an EGPWS. Accordingly, the Metro III, Westwind and Learjet aircraft were not fitted with an EGPWS.

Westwind aircraft fitted with an ACAS (known as a TCAS), and there was no evidence the operator's Westwind pilots had completed ACAS training after it was fitted with that system in August 2009. The operator acknowledged that it had not adequately overseen the flight crew training requirements following the installation of new equipment on VH-NGA in August 2009.

- Controlled flight into terrain (CFIT) training. The operator had developed a CBT awareness course relating to CFIT. There was no formal syllabus for this course or requirement for completing the course specified in the operator's OM. Following the CASA audit in March 2008, flight crew completed the course every 12 months.

Emergency procedures and survival factors

Aircraft certification for ditching

Aircraft design requirements

Under US and European aviation regulations, air transport operators conducting operations in larger transport aircraft on extended overwater operations are required to use aircraft that meet the certification requirements for ditching. There are no equivalent Australian requirements. However, given the overseas requirements, larger air transport aircraft used in Australia are generally certified for ditching.

There are no requirements for smaller air transport aircraft, including business jets, to be certified for ditching. However, an aircraft manufacturer can voluntarily request to have an aircraft type certified for ditching. Some, but not all, business jets certified under the US Federal Aviation Regulation (FAR) Part 25 (Airworthiness Standards: Transport Category Airplanes), or equivalent, are certified for ditching. Some manufacturers have noted that certifying an aircraft for ditching is complex and expensive (Flight Safety Foundation 2003).

The 1124 and 1124A were certified for ditching. The applicable US Civil Aviation Regulations (US CARs) that applied to this certification (from 1953) were:

> §4b.361 *Ditching*. Compliance with this section is optional. The requirements of this section are intended to safeguard the occupants in the event of an emergency landing during overwater flight. When compliance is shown with the provisions of paragraphs (a) through (c) of this section and with the provisions of §§ 46.362 (d), 46.645, and 4b.646[214], the type certificate shall include certification to that effect.[215] When an airplane is certified to include ditching provisions established on the basis of these requirements shall be set forth in the Airplane Flight Manual…
>
> (a) All practicable design measures compatible with the general characteristics of the type airplane shall be taken to minimize the chance of any behaviour of the airplane in an emergency landing on water which would be likely to cause immediate injury to the occupants or would make it impossible for them to escape from the airplane. The probable behavior of the airplane in a water landing shall be investigated by model tests or by comparison with airplanes of similar configuration for which the ditching characteristics are known. In this investigations account shall be taken of scoops, flaps, projections, and all other factors likely the affect the hydrodynamic characteristics of the actual airplane.
>
> (b) It shall be shown that under reasonably probable water conditions the flotation time and trim of the airplane will permit all occupants to leave the airplane and to occupy the life rafts… If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances shall be made for probable structural damage and leakage…
>
> (c) External doors and windows shall be designed to withstand the probable maximum local pressures, unless the effects of the collapse of such parts are taken into account in the

[214] US CAR 4b.646 referred to safety equipment and 4b.646 referred to the stowage of safety equipment.

[215] The FAA type certificate data sheet for the 1124A did not specifically state it was certified for ditching. However, the manufacturer confirmed that it had been certified for ditching, and the AFM stated the aircraft was approved for overwater operations.

> investigation of the probable behavior of the airplane in a water landing as prescribed in paragraphs (a) and (b) of this section).

The US CARs were subsequently replaced by the US Federal Aviation Regulations (FARs) in 1965. The 4b.361 requirements became FAR 25.801 and were effectively unchanged.

US CAR 4b.362 (amended 1958) dealt with emergency evacuations, and applied to all transport aircraft. It included:

> (d) *Ditching emergency exits*. Except as otherwise provided in this paragraph, at least 2 exits, one on each side of the airplane, meeting the minimum dimensions of the exits specified in paragraph (b) (3) of this section and located above the water level, shall be provided. In addition, it shall be shown that there is not less than one emergency exit located above the water level for every 35 passengers. …

In addition to ditching requirements, the CARs also set out requirements for emergency landing conditions that applied to all transport aircraft. The applicable CARs (1953) stated:

> §4b.260 General. The following requirements deal with emergency conditions of landing on land or water in which the safety of the occupants shall be considered, although it is accepted that parts of the aircraft may be damaged.
>
> (a) The structure shall be designed to give every reasonable probability that all of the occupants, if they make proper use of the seats, belts, and provisions made in the design…, will escape serious injury in the event of a minor crash landing (with wheels up if the airplane is equipped with retractable landing gear) in which the occupants experience the following ultimate inertia forces relative to the surrounding structure:
>
> (1) Upward… 2.0g (Downward… 4.5g)
>
> (2) Forward… 9.0g
>
> (3) Sideward… 1.5g.
>
> (b) The use of a lesser value of the downward inertia forces specified in paragraph (a) of this section shall be acceptable if it is shown that the airplane structure can absorb the landing loads corresponding with the design landing weight and an ultimate descent velocity of 5 f. p. s. [ft/second] without exceeding the value chosen…
>
> §4b.261 Structural ditching provisions. (For structural strength considerations of ditching provisions see 4b.361 (c).).[216]

A range of other requirements also dealt with the structure and strength (loading) of the aircraft.

Generic design process to meet ditching requirements

The US Federal Aviation Administration (FAA) have commissioned several reports into the risks associated with aircraft accidents involving impact with water. In one report, Johnson (1984) described the aircraft design process for meeting the ditching requirements. He stated:

> …the provisions provide for a determination of fuselage buoyancy and substantiation that the flotation time and aircraft trim (considering exit sill heights, structural damage, and leakage) will allow the occupants a sufficient period to safely evacuate the aircraft. For the aircraft manufacturer's demonstrated compliance to these provisions, the fuselage bottom strength is verified to assure against ditching impact which might lead to excessive water influx to the cabin or lead to adverse ditching behaviour. In addition, an analysis is provided to substantiate aircraft trim buoyancy and flotation periods with and without understructure rupture and impact damage. The methods of analysis vary between demonstrated scale strength model landing tests with and without simulated wave patterns to comparisons with other airplanes of similar configurations whose ditching performance is known.

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216 US CAR 4b.260 was subsequently replaced with FAR 25.561, which was similar although an amendment in 1988 resulted in slightly higher g requirements for upward and downward forces in 1998 and additional requirements. US CAR 4b.261 was subsequently replaced with FAR 25.563, which was effectively the same.

> From a review of these jet transport ditching substantiations, and taking into account various configured aircraft and their landing weights, approach attitudes, speeds, descent rates, flotation characteristics, sea states, etc., several observations were made. First, demonstrated emergency water landing approaches are made in a controlled manner with gear-up (if retractable), full flaps, and at a normal landing speed with an impact descent rate of less than 5 ft/sec. Several aircraft are limited to a maximum vertical descent of 3 ft/sec to preclude fuselage damage and, in such cases experience longitudinal and vertical accelerations (considering perpendicular beam sea approaches) in the 2 to 4g range, respectively. Flotation time, assuming no extensive fuselage damage but allowing the loss of buoyancy at appropriate non-pressurized areas, such as gear wells, fairings, empennage, and wing center sections, has been shown to extend up to a 10- to 45-minute period, depending on aircraft size and configuration.

In a subsequent report for the FAA, Patel and Greenwood (1996) provided additional description of the general design evaluation process relating to ditching certification:

> The manufacturer may emphasize design comparison and/or scale model tests to substantiate ditching compliance…
>
> The manufacturer may demonstrate compliance by showing that the design is similar in both geometry and size to existing designs which have already demonstrated satisfactory hydrodynamic behavior. For example, an aircraft with a wider wing span than the previous configuration would be expected to provide additional buoyancy which would be beneficial for flotation. As long as the shapes are the same, differences in fuselage length alone would normally not be sufficient to cause any significant ditching behavior changes.
>
> The design features of an airplane are important in establishing a qualitative assessment of ditching behavior. For example, the manufacturer would attempt to show that the design characteristics of the wing are beneficial to ditching and flotation.
>
> Wing design characteristics such as low position, large surface area, and low wing loading will provide buoyancy and bear a portion of the impact load with the fuselage…
>
> The use of scale model airplane tests to demonstrate ditching characteristics is not common for the certification of newer aircraft. The expense of performing such a test is costly and frequently the newer designs are derivatives of a previously certified configurations.

With regard to some of the assumptions involved in the design process, they stated:

> A ditching is an emergency landing in water, i.e., planned water contact. For an official "ditching" to occur, certain impact parameters must be present. The descent rate cannot be greater than 5 ft/sec, and the longitudinal and vertical loads must be within aircraft design parameters… When proper ditching procedures are followed, the occupants should have several minutes to prepare for the impact, which is typically less severe than an unplanned impact because the pilot maintains substantial control of the aircraft…
>
> The recommended procedure for an emergency landing on water generally contains the following:
>
> a. If possible, a reduction in weight should be attempted since this would reduce the landing speed.
>
> b. Maximum flaps should be utilized to reduce touchdown speed to a minimum.
>
> c. The final rate of descent should be kept as low as possible.
>
> d. At touchdown, the aircraft should be in a specified noseup attitude. Generally this attitude is between 10 and 14 degrees.
>
> e. The final approach should be made with the aircraft straight and level, with roll correction and yaw angles below 10 degrees.
>
> f. The undercarriage should be retracted if possible.
>
> g. If a pronounced sea is present, the landing should be made parallel to, and not across, the line of the wave crests. If possible the touchdown point should be on the crest or the back side of the wave.

Several other sources also indicate transport aircraft are certified for a ditching on the basis of manufacturer's assuming a relatively low descent rate at impact (3–5 ft/second) and a landing either on calm water or parallel to the swell (for example, To 1986, Climent and others 2006, and the AAIB and NTSB accident reports referred to later in this section). As indicated in appendix B, the estimated descent rate of VH-NGA when it impacted the water was about very likely in the range of 7–12 ft/second (and likely to be about 8–11 ft/second).

Aircraft manufacturer's design process to meet ditching requirements

The manufacturer's certification compliance checklist (CCL) for the Westwind 1124A stated the data supporting compliance with US CAR 4b.361, 362, 260 and 261 were the same as for the 1124. The CCL for the 1124 stated the data supporting compliance was provided by a flotation analysis and behaviour report and the relevant procedures in the AFM.

With regard to US CAR 4b.361 (a), the manufacturer's behaviour analysis referred to aircraft models of a similar size and shape that had already been certified for a ditching, and stated the behaviour of a 1124/1124A would be similar or better. It noted that, relative to some of those other models, the location of a 1124/1124A's wings may be an advantage in a water landing, as the first impact with water would be absorbed by the hydrodynamic shape of the fuselage. Therefore, the contact of the wing with the water would be delayed to almost the end of the ditching event.

In relation to US CAR 4b.361 (b) and 362 (d), the manufacturer's flotation analysis determined that the aircraft would float with a 7° nose-up attitude and both of the emergency exits (Figure 39 and Figure 40) would be above the waterline after a water landing. The analysis was conducted for the maximum take-off weight (least favourable case) and based on various assumptions, including:

- the main aircraft structure is basically undamaged
- the nose gear well traps air and the main landing gear wells flood
- the baggage compartments are intact and airtight
- the fuel tanks remain intact and airtight
- wing leading edges and trailing edges flood, including flaps, ailerons and air brakes
- the radome traps air
- the tail cone floods as far forward as the aft bulkhead of the rear baggage compartment.

No allowance was made for the main entry door or any cockpit or cabin windows to open during impact.

With regard to structural integrity, the aircraft manufacturer stated it generally used a descent rate of 5ft/second for ditching certification. It also stated that it had calculated the pressure distribution due to impact loads with the water during a ditching based on this descent rate and the procedures in the AFM. The fuselage design loads envelope included this load case as one of a number of load cases for the aircraft's fuselage stress structural substantiation.

In relation to US CAR 4b.361(c), the manufacturer could not locate any specific analysis for the main entry door. However, it reported it was not aware of any incidents where the main cabin door of a 1124/1124A had opened in-flight or during a heavy landing or other impact.

In terms of other certification requirements relating to vertical forces, the manufacturer reported the Westwind 1124A was substantiated for the following design criteria:

- manoeuvring load factors of +2.83 g and -1.0 g Limit (in accordance with US CAR 4b.211(a))
- gust load factors calculated as +5.07 g Limit (in accordance with US CAR 4b.211(b))
- landings with a sink speed (descent rate) of 10 ft/sec (600 ft/minute) (in accordance with US CAR 4b.230 (b)).[217]

The aircraft manufacturer noted a ditching impact is a very quick event (less than 0.1 sec). Given the FDR only measured the vertical acceleration eight times a second, it stated it was possible

[217] During a landing, it is expected that the landing gear will absorb some of the impact force.

that the peak accelerations actually sustained during the ditching were higher than those recorded on the FDR, and higher than the certified levels for the aircraft's structural integrity.

Review of previous ditchings

Previous reviews of ditchings (planned emergency landings on water) in transport aircraft have noted they are very rare events (Johnson 1984, Patel and Greenwood 1996, Lindenau and Rung 2009).

A recent review commissioned by Transport Canada and the UK Civil Aviation Authority (R.G.W. Cherry & Associates Limited 2015) defined ditchings as emergency landings on water, whereas other water-related accidents were termed inadvertent water impacts.[218] It identified 43 ditching accidents of western-built aircraft from various sources for the period 1967–2009. It concluded ditchings occurred at a rate of 0.03 accidents per million flights, with the rate being fairly consistent over this period.

In terms of other aspects of exposure to the risk of ditching, the report stated the number of occupants (or people on board aircraft) involved in ditching accidents has generally been less than for inadvertent water-impact accidents. However, over the last decade the annual number of occupants had risen to about 20–30 per year.

With regard to fatalities, the report stated:

> There are insufficient data to identify a trend in the number of ditching accident fatalities.[219] However, it would appear that the majority of fatalities involve accidents with turboprop airplanes with a significant number occurring since 2000. Over the period 1967 to 2009, there were 95 fatalities in turboprops as opposed to 24 in turbojets. Over the period 1967 to 2009 inclusive, only three ditching accidents involved jet airplanes and that two of these three involved ditching into rivers as opposed to the sea. Over the same period no wide body airplanes were ditched.

The review studied 10 ditching accidents in detail. These were accidents for which there were official accident reports available, and seven of these accidents involved fatalities.[220] Based on this review:

> … all [10 accidents] had suffered engine power loss, and eight were due to a total engine power loss. All of the [8] accidents analyzed involving Part 25 airplanes had suffered a total engine power loss which resulted in the ditching. Thus, on the basis of accident experience, it is evident that the most likely cause of a ditching is the total loss of engine power.
>
> For three of these 10 ditching accidents, airplane configuration was an issue. All three demonstrated the difficulty that the flight crew had in attaining the optimum touchdown parameters derived from model testing. In particular, for the SD360 in Scotland, and the SD360 in Libya, it was impossible to configure the airplane's flap position as laid down in the ditching procedure with no engine power. For the ATR72 accident to the east of Palermo, the flaps could not be extended with electrical power supplied by the battery alone.
>
> Although the most likely scenario for a planned ditching is a total engine power loss, it would appear that this is not adequately addressed in the regulatory material. Generally, the advice given in operations manuals does not include ditching procedures under such conditions.
>
> The NTSB, in their final report on the A320 ditching into the Hudson River accident, recognize that "Attaining the touchdown flight condition targets is an exceptionally difficult flight maneuver, and pilots cannot be expected to conduct the maneuver proficiently when the airplane has no engine power."

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[218] The review did not consider events involving hijacking or terrorism, non-survivable accidents or accidents involving water too shallow to be a threat to occupant survivability. Although the focus of the review was on transport category aircraft (certified under FAR Part 25 or equivalent), it also considered smaller aircraft certified under FAR Part 23 or equivalent.

[219] This information was based on reviewing 19 of the ditching accidents for which there was sufficient official textual data available. Fatalities occurred in 10 of these accidents.

[220] These included 8 transport category aircraft certified under FAR Part 25 or equivalent and two aircraft certified under FAR Part 23 or equivalent. The review did not include the ditching of VH-NGA.

The 2015 review noted that for eight out of the 10 accidents, the necessity for ditching occurred at low altitudes and the flight crew had limited time to prepare for the ditching. In another case the flight crew were experiencing high workload associated with the conditions that led to the loss of engine power.

Almost all of the 10 accidents the review studied in detail occurred during the day.

For many ditching accidents, limited information is available concerning the aircraft speed, descent rate and pitch angle at impact, often because the aircraft were not fitted with flight recorders, the flight recorders were not recovered or the flight recorders had stopped recording due to the loss of power to the recorders prior to the impact. However, there were three notable cases:

- In 2001, a Shorts 360 ditched near Granton, Scotland following a double engine flameout shortly after take-off.[221] Due to the power loss, the flight crew were unable to extend the flaps. The resulting ditching occurred with a pitch angle close to the required pitch angle, and the airspeed close to the stall speed. However, the descent rate was significantly greater than the required descent rate, and the aircraft structure broke up on impact. The report noted the required touchdown conditions of low speed, low descent rate and defined pitch angle could only be met when engine power was available and full flap selected.
- In 2005, an ATR 72 was ditched near Palermo, Italy after a loss of engine power due to fuel exhaustion.[222] Due to the power loss, the flight crew were unable to extend the flaps, and had reduced flight instruments available. The resulting ditching impact occurred with a pitch angle close to the required pitch angle and the airspeed close to the stall speed. Although the descent rate at impact was not recorded, the investigation estimated it was probably about 700–800 ft/minute (11–13 ft/second). The heavy impact on the rear part of the fuselage led to the failure of the rear pressure bulkhead. It also resulted in the aircraft nose pitching down and impacting the water, leading to further fuselage break-up. There was probably a slight to moderate sea state, corresponding to a swell of about 1–2 m, and waves from a different direction of about 1 m. The investigation could not determine the aircraft's heading relative to the swell. However, the report noted that, even though the accident occurred during the day in good visibility, the direction of the swell would not have been easy to establish.
- In 2009, an Airbus A320 was ditched in the Hudson River, New Jersey after a loss of thrust from both engines soon after take-off.[223] The flight crew ditched the aircraft on calm water in a river. Associated with a variety of factors, the aircraft had a lower than desired airspeed prior to the ditching, which contributed to difficulties in flaring the aircraft. Although the pitch angle at impact was close to the certification value, and the airspeed was relatively low, the descent rate at impact was 13.5 ft/second, significantly higher than the 3.5 ft/second certification value.

The 1124A manufacturer reported there was no other known cases of the ditching of a 1121, 1123 or 1124 aircraft. There have been a small number of ditchings involving other types of business jets, but none have been the subject of detailed, publicly-available investigation reports (see also Flight Safety Foundation 2003). Johnson (1984) reported:

> … [a] controlled ditching of a smaller Lear Model 23[224] aircraft occurred on Lake Michigan in March 1966 during an approach landing to Meigs Field (Chicago). The 12-passenger aircraft with only the pilot aboard had an engine flame-out on approach and the pilot landed the aircraft on the water (4-foot waves) at approximately 90 knots within 900 yards from the end of runway... The aircraft subsequently

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[221] Air Accidents Investigation Branch (AAIB), Report on the accident to Shorts SD3-60, G-BNMT, near Edinburgh Airport on 27 February 2001.

[222] Agenzia Nazionale per la Sicurezza del Volo (ANSV), Accident involving ATR 72 Aircraft Registration Marks TS-LBB, ditching off coast of Capo Gallo (Palermo – Sicily), August 6th, 2005.

[223] National Transportation Safety Board (NTSB), Loss of thrust in both engines after encountering a flock of birds and subsequent ditching on the Hudson River, US Airways Flight 1549, Airbus A320-214, N106US, Weehawken, New Jersey, January 15, 2009.

[224] The Lear 23 was not classified as a transport category aircraft.

was towed to shore and prior to retrieval remained afloat approximately 24 hours. The damage extended to missing flaps, torn fairings and fuel/hydraulic lines, lost left wing tip tank gear door, and wrinkled fuselage skin. This case points out that for either a planned or unplanned water contact occurrence, if the impact forces are sufficiently low and the aircraft fuselage remains intact without significant rupture and leakage, the chances of occupant survivability, resulting from extended buoyancy and floatation of the fuselage, is substantially increased.

Ditching procedures and guidance

Emergency checklist procedures

The aircraft manufacturer published an emergency procedure checklist for ditching, which was included in the AFM and the Quick Reference Manual located on the aircraft. The checklist had a series of actions for preparation, approach, before touching water and after ditching, as shown in Figure 37. None of the required actions were considered to be immediate action memory items.[225]

Figure 37: Westwind 1124A ditching checklist

PREPARATION

1. Communications – MAYDAY
2. Transponder – CODE 7700
3. Passengers – BRIEFED AND PREPARED
4. Cabin baggage – SECURED
5. CABIN LIGHTS switch – BELTS/NO SMK
6. EMERG LT switch – ARM
7. Cabin altitude controller – SET FOR DESCENT
8. Fuel DUMP pushbuttons – PUSH ON (boosted dump required)

APPROACH

1. Cabin pressurization – MONITOR DEPRESSURIZATION
2. Landing gear lever – UP; WARNING HORN CB – PULL
3. FLAPS lever – 40°
4. AIRSPEED bug and AOA indicator – SET FOR V_{REF} (Figure 5-61)
5. Heading – PARALLEL TO MAIN SWELL

BEFORE TOUCHING WATER

1. Radbar altimeter – SET FOR 50 FEET
2. Attitude – NOSE UP; 10° deck angle when DH light comes on (GO AROUND mode)
3. Thrust levers – CUT-OFF
4. FUEL SHUTOFF switches – CLOSE
5. BATTERY MASTER SWITCH – OFF

AFTER DITCHING

1. Pilot DV window – OPEN to depressurize cabin (after removing loose articles from window and console areas)
2. Emergency escape windows and door – OPEN WHICHEVER IS ABOVE WATER LEVEL
3. Life rafts – TIE STATIC LINE TO ANCHORING POINT AND PREPARE FOR DEPLOYMENT
4. LAUNCH AND BOARD LIFE RAFTS

Source: Israel Aircraft Industries, *1124A-Westwind Airplane Flight Manual*.

As stated in the checklist, the required configuration for the ditching approach was flaps 40° (landing flap) and landing gear UP. The crew was required to set the airspeed bug to V_{REF} and therefore fly the final approach at V_{REF}. In addition, the crew was required to set the AoA indicator

[225] The AFM stated that actions framed with a red border were 'immediate action memory items', which meant flight crews had to be able to perform them without referring to the checklist. Some other emergency procedures (such as engine fire, aborted take-off and rapid decompression) had immediate action memory items. This approach was consistent with that of other aircraft manufacturers.

to V_{REF} (or 1.3 V_S), which would have resulted in the AoA indicator displaying the target AoA for achieving V_{REF}. In addition, to minimise impact forces, the checklist required the crew to conduct the approach parallel to the main swell (or perpendicular to the direction of the swell).

To assist with flaring the aircraft, the flight crew were required to set the radio altimeter decision height to 50 ft. After the aircraft descended through 50 ft above the water, the crew was required to increase the pitch angle to flare the aircraft.

Operator procedures and guidance

The operator's OM provided generic procedures and guidance regarding the conduct of a ditching across its fleets. In terms of cabin preparation, the procedures included:

- Transmit a MAYDAY message, including the aircraft's present position and heading, and the captain's intention.
- Brief the passengers (see also Passenger briefings).
- Ensure luggage and loose items are appropriately secured.
- Activate the emergency lighting in the cabin.
- At 500 ft above sea level alert the passengers to brace for impact.

In terms of the technique for a ditching manoeuvre, the OM stated:

- Set the radio altimeter to 50 ft.
- Determine the ditching heading (best heading usually parallel to the major swell).
- Approach at 200–300 ft/minute descent rate and level off at 8–12 ft above the crest of the swell.
- Contact water at minimum speed and descent rate, and 'DO NOT STALL.'
- In the event of a complete engine power loss, maintain approach speed substantially above V_{REF} to ensure flare and touchdown without stalling the aircraft.

The manual also contained general guidance on evaluating the sea state prior to a ditching.

Ditching manoeuvres are rarely practiced by pilots of air transport aircraft during initial or recurrent training, even for operators with access to flight simulators. The operator conducted its training and checking of Westwind pilots in an aircraft, and therefore pilots did not have the opportunity to practice ditching manoeuvres.

The operator's Training & Check form included an item titled 'Ditching Crew Procedures'. A review of flight crew files indicated this item was regularly ticked during recurrent proficiency checks. Some Westwind pilots recalled ditching procedures were discussed during at least some proficiency checks, and other pilots could not recall there being much discussion about ditching. The first officer recalled ditching was discussed during her last proficiency check, and this helped her prepare for the ditching on the accident flight.

Other guidance

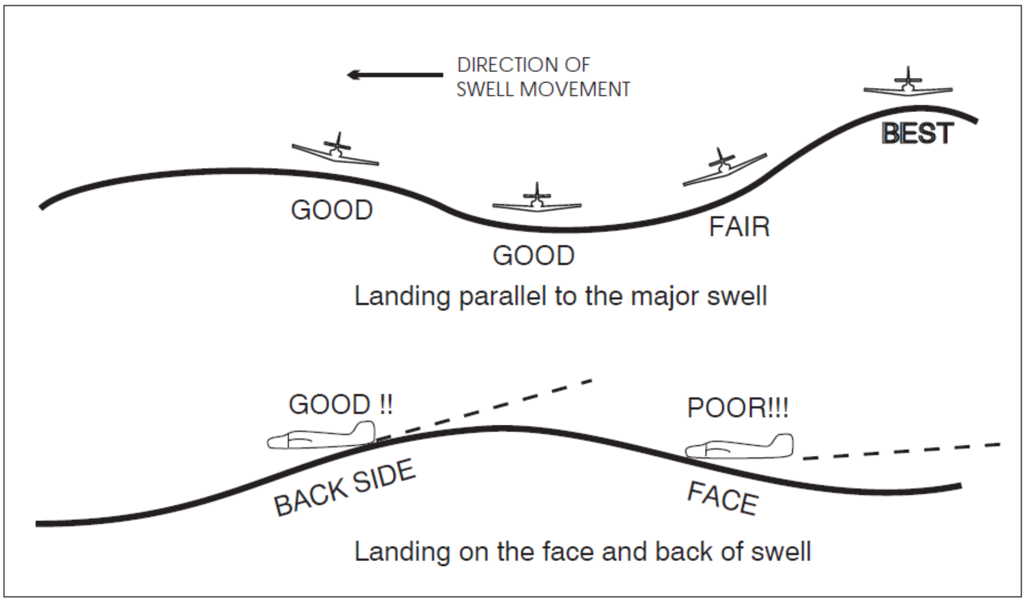
CAAP 253-1(0) (Ditching) provided general guidance to operators and flight crew regarding ditching. It included the following content:

> In general terms it is always preferable to impact the water as slowly as possible, under full control; don't stall the aeroplane in. Keep the wings parallel with the surface of the water on impact, i.e. wings level in calm conditions. One wing tip striking the water first will cause a violent uncontrollable slewing action…
>
> In ideal conditions you should always ditch into wind because it provides the lowest speed over the water and therefore causes the lowest impact damage. This process is effective provided the surface of the water is flat or if the water is smooth with a very long swell inside which the aeroplane will come to rest…
>
> If the swell is more severe, including breaking waves, it is more advisable to ditch along the swell, accepting the cross wind and higher speed over the water, because this is preferable to ditching into the face of a wave and nosing in. Ditching into the face of a wave is very likely to cause extreme

> damage to the aeroplane and violent deceleration with severe implications for passengers and crew. The final approach will result in considerable drift which you must control to achieve the required tracking over the water. You must be careful to maintain sufficient airspeed to ensure that any action you take in controlling the path of the aeroplane does not lead to a stall. You must retain complete control of the aeroplane…
>
> Make every effort to precisely control airspeed and rate of descent, both should be as low as possible, consistent with maintaining full control of the aeroplane. If you are conducting a glide approach you must consider approaching at a higher speed which will provide the lift energy necessary for the larger than usual round-out to reduce the rate of descent at impact to one which is appropriate…
>
> If possible make the approach using power. If the ditching has to occur because of impending fuel exhaustion make the approach before all the fuel is expended. A powered approach provides for the greatest potential to execute a successful round-out and hold off enabling the aeroplane to have almost no descent rate at impact…
>
> Judging height over water can be extremely difficult particularly when the water is calm or on a very dark night. An aneroid altimeter will be of little use unless you have an accurate QNH. The best device to use is a radio/radar altimeter if you have one. If all else fails set up a low rate of descent, less than 200 feet a minute and wait. This is another good reason for conducting a powered approach if power is available.

The US Federal Aviation Administration's *Aeronautical Information Man*ual (AIM) also provided guidance for conducting a ditching, which included detailed advice regarding sea states. Figure 38 from the AIM illustrates the importance of the aircraft's heading relative to a swell when ditching.

Figure 38: Suitable landing directions



Source: Federal Aviation Administration, *Aeronautical Information Manual.*

The AIM stated it was desirable to land just above the stall speed. However, this reduction in speed should occur when the aircraft was low over the water. More specifically:

> Touchdown should be at the lowest speed and rate of descent which permit safe handling and optimum nose up attitude on impact. Once first impact has been made, there is often little the pilot can do to control a landplane…
>
> The aircraft should be flown low over the water, and slowed down until ten knots or so above stall. At this point, additional power should be used to overcome the increased drag caused by the nose up attitude. When a smooth stretch of water appears ahead, cut power, and touchdown at the best recommended speed as fully stalled as possible… Care must be taken not to drop the aircraft from too high altitude or to balloon due to excessive speed. The altitude above water depends on the aircraft. Over glassy smooth water, or at night without sufficient light, it is very easy, for even the most experienced pilots to misjudge altitude by 50 feet or more. Under such conditions, carry enough power

> to maintain nine to twelve degrees nose up attitude, and 10 to 20 percent over stalling speed until contact is made with the water…

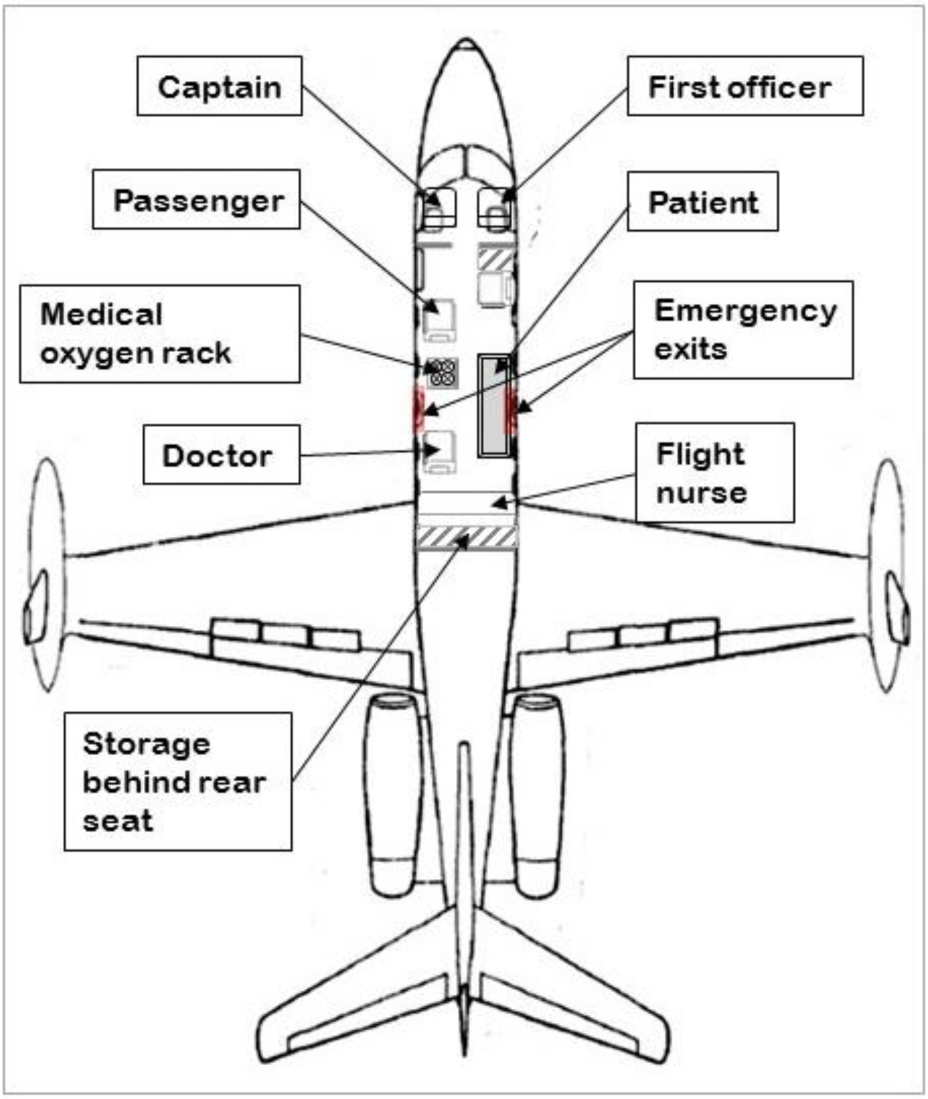
The Flight Safety Foundation (2003) also produced a large guidance document regarding ditching and overwater operations for business jets. It included a generic checklist for a ditching. The actions included airspeed as per the manufacturer's manual ('typically, slowest speed at which control can be maintained').

The ATSB reviewed the ditching checklists for a number of different business jets. Most of these checklists explicitly stated the airspeed for the final approach to a ditching be conducted at V_{REF}, and many of the checklists also explicitly stated the descent rate be 200–300 ft or as low as possible.

Cabin layout

Figure 39 shows the seating position of each of the occupants of VH-NGA during the ditching. The main entry door was located on the left side, just rear of the cockpit. The two emergency exits were located just forward of the wings, one on each side.

Figure 39: Plan view of aircraft cabin, depicting seating positions at the time of the ditching



Source: Israel Aircraft Industries, modified by ATSB.

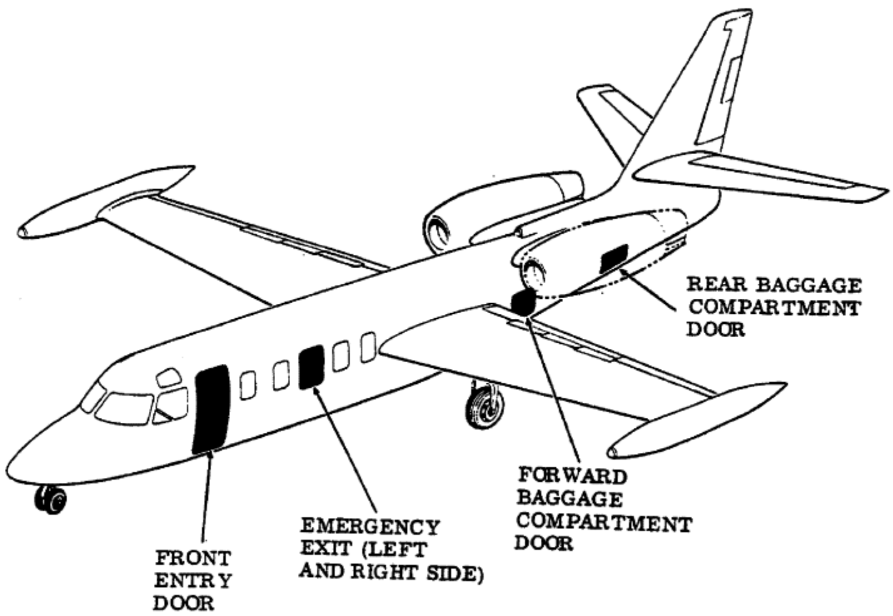
The stretcher was located on the right side of the cabin. Although the stretcher was located in front of the right emergency exit, its height was about halfway between the cabin floor and the bottom of the exit.[226] The stretcher was approved to be used by a patient during take-off and landing. The patient was secured to the stretcher via an over-the-shoulder four-point harness and straps around the waist and thighs.

During the accident flight, the doctor and flight nurse used portable equipment to monitor the patient. They reported this was more comfortable for the patient than using the stretcher bridge, which can be placed over the patient's legs and supports various types of monitoring equipment. The patient was not intubated.

Main entry door

The main entry door to the cabin and cockpit was located on the left side, just rear of the cockpit (Figure 40). It was a plug-type door.[227]

Figure 40: Location of doors and emergency exits on 1124A aircraft



Source: Israel Aircraft Industries Ltd, *1124A-Westwind Aircraft Maintenance Manual*.

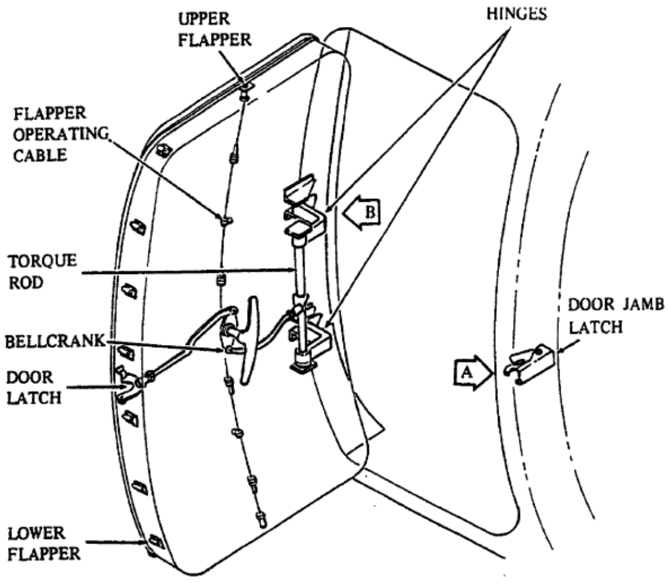
The door was secured in place by two hinges on the right side (looking from inside the cabin) and a single, centrally-located latch on the left side (Figure 41). When the door was in the closed position, the upper and lower door seal was pressed against the door frame by an upper and lower flapper. To open the door from the inside, an occupant needed to rotate the handle counter-clockwise to disengage the latch and retract the upper and lower flappers. The flappers were not designed to provide any latching or resistance to the door being opened.

The door would open initially inwards around the axis of the torque rod (Figure 41) before the occupant then pushed the left side of the door to swing the door at an angle through the entrance out of the cabin.

[226] The installation of the stretcher, stretcher base and other medical equipment was in accordance with a supplemental type certificate.

[227] An aircraft door that is larger than the doorway and has tapered edges to increase the security of a pressurised fuselage. In-flight pressurisation loads force the plug door more tightly against the doorframe.

Figure 41: Components of the main entry door



Source: Israel Aircraft Industries Ltd, *1124A-Westwind Aircraft Maintenance Manual*.

The main entry door and doorway extended from the cabin floor to near the ceiling. From the manufacturer's flotation analysis, the bottom of the main entry door would probably be below the waterline following a water landing, although this would depend to some extent on the aircraft's weight and centre of gravity.

The aircraft's maintenance records indicated the main entry door was last inspected as part of a scheduled maintenance check on 6 November 2009. This inspection included examining the door hinges, locking mechanism and door seal condition.

Impact, flooding and evacuation sequence on the accident flight

In terms of the impact and initial flooding, the occupants recalled the following:

- The captain recalled there was three impacts, with the forces being more vertical than longitudinal. He thought the vertical forces and the longitudinal deceleration at the end were milder than he anticipated, and the aircraft stopped quicker than he expected.
- The first officer recalled two impacts, with the aircraft skipping on the first impact. On the last impact, the aircraft went nose-first into the water. She said the last impact was like hitting a wall, and her chest hit the control column and she lost consciousness.
- The passenger, seated just rear of the front door, reported there were two impacts and then a third impact when the aircraft 'ploughed' into the water. He thought the longitudinal deceleration from the last impact was more significant than the vertical impacts. During the last impact, the main entry door 'burst open' and he was 'deluged' with water.
- The doctor recalled there were two loud impacts and then violent shuddering. He thought that most of the deceleration was due to the forces of the waves rather than in the downward direction. He saw that, immediately after the impacts, the main entry door had opened inwards and water was flooding into the cabin.
- The flight nurse recalled two impacts, with the first impact involving a very significant vertical force. She was briefly unconscious. She also recalled there was instantly a smell of sea water and water rising around her feet, and she thought the water was probably coming from behind her.
- The patient recalled there was two or three 'big bangs' as the aircraft hit the water, but had little recollection of the rest of the sequence.

In terms of the evacuation sequence, the occupants recalled the following:

- The captain reported he immediately released his safety harness, checked the first officer was responsive and then moved rearwards towards the cabin. He saw the main entry door had opened and was at an unusual angle, with water rapidly rushing into the cabin. He knew the door could not be properly opened, and he immediately proceeded rearwards to the emergency exits. He opened the left emergency exit, and water started 'gushing' into the cabin. He exited the cabin through the exit against the flow of the water. He thought at that stage the water in the cabin was probably at thigh height.
- The doctor recalled that the captain quickly moved into the cabin, shouting to open the emergency exits. As the captain opened the left emergency exit, the doctor was releasing his seat belt and standing up. He then opened the right emergency exit, and water started flowing into the cabin from that exit. At this point the water was about thigh to waist deep. He held onto the rim of the emergency exit with one hand and started undoing the straps securing the patient to the stretcher with his other hand.
- The flight nurse said she initially had difficulty undoing her seatbelt because the strap had twisted during the impact sequence. After releasing her belt, she assisted the doctor with releasing the patient's straps.
- After the doctor and flight nurse had released the patient, the doctor, patient and nurse exited the aircraft through the right emergency exit, holding onto each other as they departed 'in a train', with the nurse last. The nurse recalled that when she exited the aircraft the water level was up to her chest or neck.
- The passenger recalled the captain moving quickly past him to open an emergency exit. The passenger struggled to undo his seat belt and get to his feet in the incoming water. The cabin flooded quickly, which pushed him towards the top of the cabin, and at some point he was hit by a wave inside the aircraft. He found the emergency exit by touch and pulled himself out, and then swam upwards to get to the surface.
- The first officer did not recall the captain leaving the cockpit. She recalled waking up in the dark with water up to her chest. She moved back to the main entry door and could not open it. At about this time the fuselage tilted nose down and a quantity of equipment or baggage fell on her. She swam up towards the rear of the fuselage, located an emergency exit by touch, and exited the aircraft. She swam upwards to get to the surface.

The occupants reported that, after they exited the aircraft, they could see the aircraft was in two sections. The captain recalled seeing the front section of the aircraft disappear soon after he exited the aircraft.

Emergency procedures and equipment: general requirements

CAR 253 (Emergency and life-saving equipment) included the following requirements:

> (1) An operator shall not assign a person to act as a crew member of an aircraft, and a person shall not act as a crew member of an aircraft, unless the person is competent in the use of the emergency and life-saving equipment carried in the aircraft.
>
> (2) An operator shall ensure that crew members are periodically tested as to competency in the use of the emergency and life-saving equipment carried in the aircraft to which they are assigned.
>
> (3) The operator of an aircraft which is used in over-water flights shall ensure that each crew member is instructed in ditching and abandon ship procedures in so far as is practicable and that he or she is periodically tested as to his or her knowledge of those procedures.
>
> (4) The operator of an aircraft shall detail a crew member to ensure that passengers are made familiar with the location of emergency exits in the aircraft in which they are travelling and the location and use of emergency equipment carried in the aircraft.

CAO 20.11 (Emergency and life saving equipment and passenger control in emergencies) provided more detailed requirements regarding life-saving equipment, passenger safety briefings, emergency procedures and crew training for emergencies. CAO 20.16.3 (Air service operations –

carriage of persons) also contained requirements regarding the carriage of persons who require assistance due to sickness, injury or illness.

The following sections discuss emergency procedures, training and equipment relevant to a ditching.

Crewmember roles during an aircraft emergency

In terms of crewmember roles for RPT and charter flights, CAO 20.11 stated:

> The operator and, where appropriate, the pilot in command, … shall assign to each category of required crew member, as appropriate, the necessary functions to be performed in an emergency or situation requiring emergency evacuation. These functions shall be realistic, practicable and such as to ensure that any reasonably anticipated emergency can be adequately handled and shall take into consideration the possible incapacitation of individual crew members.

CAO 20.11 did not specify role requirements for aerial work flights. However, all the Westwind pilots conducted passenger charter flights as well as air ambulance flights. The operator's OM included a range of procedures and requirements for emergencies, and no differentiation was made between charter and air ambulance flights.

CAO 20.16.3 stated, with regard to people who require assistance due to 'sickness, injury or disability', an operator and captain shall ensure there were procedures in place 'to enable particular attention to be given to be given to any such passenger in an emergency'. Similarly, the OM stated, for overwater flights with a patient in a stretcher, the captain:

> … shall ensure that special arrangements have been made to evacuate the patient as well as the attendants in case of a ditching.

With regard to air ambulance operations, the OM also stated:

> The Doctor/Nurse assigned to the flight are responsible for the care and comfort of the patient…
>
> The requirements of the patient are to be tempered with the Captains responsibility for the safety of the aircraft and its occupants.

The OM listed specific duties for different personnel for air ambulance operations. In terms of patients, the duties of a doctor and flight nurse included:

> Assist patient in any aircraft emergency.

The Westwind standards manager reported the medical personnel were meant to be part of the aircraft crew and were provided with aircraft familiarisation training (see below). The air ambulance provider reported that, in regard to aircraft emergency procedures, the medical personnel were meant to be treated as passengers rather than crew.

Some Westwind pilots reported they assumed the medical personnel would be responsible for evacuating a patient in the event of an emergency. They noted flight crew had not been trained in how to secure or release a patient from the stretcher. Other pilots could not recall any defined roles for the flight crew and the medical personnel with regard to evacuating a patient.

Emergency procedures training and checking

Flight crew training and checking

CAO 20.11 stated crew members who were assigned duties on an RPT or charter flight were required to pass a proficiency test on emergency procedures annually. Appendix IV stated the proficiency test shall cover the emergency procedures that a crewmember may be required to perform. These included:

> **Emergency evacuation procedures**. Operation and use of each type of normal and emergency exit, evacuation slide and escape rope and procedures for evacuation…
>
> **Ditching procedures**, where applicable:

> (a) fitting and inflation of life jackets and location and use of equipment stowed as part of the life jacket. Additionally, for initial qualification each crew member shall demonstrate competency in the use of the life jacket in the water; and
>
> (b) removal from stowage, launching and inflation of life rafts. For initial qualification each crew member shall demonstrate proficiency in his or her assigned duties. Thereafter all crew members shall be given an annual demonstration of launching and inflation and shall demonstrate competency in boarding procedures and the use of the life raft and its equipment…

Subject to CASA approval, the CAO allowed for alternative options to demonstrate proficiency if the cost of replacing emergency equipment would require an 'excessive amount of maintenance action'.

The OM outlined the operator's requirements for emergency procedures training and checking. It stated that, prior to commencing line operations, a pilot would be provided with training and then annually they needed to pass a proficiency test on a range of topics. The test had to include practical demonstration and oral examination. Specific items to be tested included:

- demonstrate knowledge of operation of emergency exits/doors and associated evacuation procedures
- specify procedures for handling 'handicapped',[228] sick and stretcher passengers
- demonstrate knowledge of location of all on board emergency equipment
- for life jackets:
  - demonstrate knowledge of the method of donning and securing the life jackets
  - demonstrate inflating the life jacket
  - demonstrate the location and use of equipment carried on the life jacket
- for life rafts:
  - demonstrate knowledge of the stowage position(s) of the life raft
  - demonstrate method of deployment and inflation
  - demonstrate method of passenger control and boarding procedures
  - demonstrate operation of survival beacons and specify use of survival equipment.

The manual noted that, for 'initial qualification', the crew member had to demonstrate competency in using a life jacket and a life raft in the water. It stated recurrent training for using a life raft

> … may be conducted using a step by step pictorial checklist, practical scenario and application, covering stowage, deployment and boarding of the life raft(s) carried, erection of the canopy, activation of survival beacons and the use of survival and location equipment.

The operator conducted annual checks of emergency procedures proficiency. For the Westwind fleet, this check was conducted by a check pilot during one of the pilot's two proficiency checks each year (that is, a combined base and line check). The operator's training and check form listed several relevant items, such as life rafts, life jackets, ditching procedures and emergency evacuation, and these items were routinely ticked on completed forms. Westwind pilots confirmed that emergency procedures aspects were covered during proficiency checks. They recalled that the checks were primarily knowledge-based and generally conducted while sitting in the aircraft.

In March 2008, CASA identified during an audit that many of the operator's pilots across all fleets had not undertaken a proficiency check using life jackets in the water and using life rafts as required by CAO 20.11 (see *Oversight of cabin safety and emergency procedures*).[229]

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[228] 'Handicapped' was not defined in the operator's OM. CAO 20.11 defined a 'handicapped person' as 'a person requiring special attention because of illness, injury, age, congenital malfunction, or other temporary or permanent incapacity or disability makes that person unable without special facilities or assistance to utilise air transport facilities and services as effectively as persons who are not so affected'.

[229] CASA had also identified this problem in an audit in 2005, following which the operator organised for its pilots employed at that time to undertake a wet drills training course (see *Oversight of flight crew training and checking*).

Accordingly, all pilots who had not undertaken such training completed a ‘wet drills’ training course conducted by an external training provider. The training focussed on the use of life jackets and life rafts in the water. However, no recurrent training was conducted the following year for life rafts, as required by CAO 20.11. The captain of the accident flight recalled that the wet drills training he had conducted definitely assisted him during the evacuation and subsequent period.

CASA files indicated the Westwind standards manager, while still the chief pilot, contacted CASA in September 2008 regarding the requirements of annual life raft drills. CASA also reported that, in early November 2009, the operator’s new chief pilot contacted CASA to clarify the requirements of annual wet drills training. However, no recurrent wet drills training was undertaken prior to the accident.

Westwind pilots did not recall there being any discussion in their wet drills training or other emergency procedures training or checking regarding the process of evacuating a stretcher patient in the event of an emergency.

Medical personnel training

The operator’s OM stated:

> For optimum patient care to continue during flight it is essential that the medical attendants be familiar with the cabin environment, communications system, equipment stowage locations and in-flight procedures. Therefore, patient transport missions shall be crewed by personnel familiar with the Westwind and its operation.

The air ambulance provider and the operator reported medical personnel were provided a half-day familiarisation course on the Westwind. The course was delivered by the Westwind standards manager or another experienced pilot. It covered topics such as the location and use of emergency equipment, the location and use of exits, use of the stretcher and other equipment on the aircraft, the general nature of air ambulance tasks and the types of destinations that would be encountered.

The familiarisation course did not include practical training in the use of life jackets or life rafts, and no demonstration equipment was used. The course did not meet and was not intended to meet the requirements of CAO 20.11, and there was no formal assessment of participants’ proficiency.

As noted in *Medical personnel*, the doctor and the flight nurse of the accident flight had both undertaken a HUET course. However, the nurse reported she had not seen one of the life jackets used by the operator out of its packaging prior to having to prepare for the ditching on the accident flight.

Personnel from the air ambulance provider reported they were not provided with a copy of the operator’s OM, or any written documentation regarding emergency procedures other than the aircraft’s safety briefing card. The medical personnel on the accident flight reported they had not been provided with any specific guidance regarding how to evacuate a patient on a stretcher during an emergency.

In mid–late 2009, personnel from the air ambulance provider and the operator developed a PowerPoint presentation to be used during the familiarisation training for new medical personnel. The presentation provided information on emergency equipment and procedures for the Westwind aircraft. The content included instructions on the use of emergency exits, the typical locations of life jackets and life rafts, pictures showing an uninflated and an inflated life jacket and the components of a life jacket, the aircraft manufacturer’s ditching checklist, and a brief list of cabin duties to be conducted prior to a ditching. The content also included portable oxygen and portable fire extinguishers, but did not include portable distress beacons.

Passenger briefings

Pre-flight safety briefing

CAO 20.11 stated an operator shall ensure all passengers are provided with an oral safety briefing before each take-off. In addition, for overwater flights, passengers were required to be orally briefed on the method for donning and inflating a life jacket and the location of life rafts. For RPT and charter flights, the briefing was required to include a demonstration of the method for donning and inflating a life jacket.

The operator's OM outlined procedures for passenger safety briefings that were consistent with CAO 20.11. More specifically, the OM required the captain ensure all passengers were provided a safety briefing prior to the start of a flight that included:

- use and adjustment of seat belts
- location and method of operation of the emergency exits
- location of the safety briefing card
- location of life jackets (where applicable)
- location of life rafts (where applicable)
- use of supplemental oxygen.

For flights over water, the OM required passengers be orally briefed on the location and use of the life jacket. The briefings were required to use a demonstration life jacket to show:

- donning and securing the life jacket
- inflating the life jacket by pulling the pull handles to actuate the compressed air
- manually inflating the life jacket by using the mouthpiece
- the purpose and use of the whistle.

The manual did not indicate that different briefings were required or permitted for different types of flights. Therefore, the requirements applied to passenger charter and air ambulance flights.

CAO 20.16.3 also stated an operator and captain must ensure any person who required assistance due to sickness, injury or disability was provided an individual briefing on emergency procedures. CAO 20.11 included a similar requirement.

Consistent with these requirements, the operator's OM stated:

> When a handicapped person is being carried, that person shall be given an individual briefing, appropriate to his/her needs, in respect of the following:
>
> a) All relevant aspects of the general passenger briefing; and
>
> b) The procedures to be followed in the event of an emergency evacuation of the aircraft including the emergency exit to be used and the most appropriate manner of assisting that person from the aircraft.

The OM stated it was a duty of the first officer to conduct passenger briefings. The operator's normal checklists for Westwind operations did not include an action for a pre-flight safety briefing.

In terms of safety briefings on the operator's Westwind aircraft:

- Most pilots recalled that the first officer was generally responsible for doing the safety briefing. Some pilots noted the captain may have done the briefing on some occasions, particularly if they were the pilot not flying or the last pilot to board the aircraft.
- Most pilots reported the safety briefing would be abbreviated if the only passengers were medical personnel and they had flown with the personnel before. This was generally done with the agreement of the medical personnel.
- Pilots reported they did not have demonstration equipment available to conduct safety briefings. In terms of life jackets, some pilots stated the safety briefings were generally limited to noting

where the jackets were located rather than how to use them. Other pilots reported they described how to don and inflate a life jacket.

Personnel from the air ambulance provider had similar recollections to the Westwind pilots about what briefings occurred on air ambulance flights.

Safety briefing card

CAO 20.11 required that operators of RPT or charter flights in aircraft with a seating capacity of more than six people (including the crew) shall supplement the oral briefing with printed matter in a convenient location. The material was to include diagram of the emergency exits and their operation, instructions 'necessary for the use of emergency equipment' and the brace position for an emergency landing or ditching. There was no requirement for operators of aerial work flights to provide printed matter regarding emergency procedures and equipment.

The operator's Westwind aircraft had passenger safety briefing cards located in the cabin. The one-page, A4-sized card consisted of diagrams about several topics, such as:

- the use of seat belts
- location and use of exits
- brace position
- location and wearing of life jackets
- securing and boarding a life raft.

The diagrams were sourced from a passenger safety briefing card from a major airline. Of note:

- The diagrams for the main entry door depicted a door handle that was not the same as that on the Westwind.
- The diagrams for the emergency exits were consistent with those on the Westwind.
- The diagrams indicated life jackets were underneath each seat.
- The diagrams indicated how to don a life jacket, but did not indicate how to inflate a life jacket or when they were to be inflated. The depicted jackets had only had one pull handle for inflation, which was not consistent with the type of life jackets used by the operator (see below).[230]

Briefing prior to a ditching

The operator's OM stated that, prior to a ditching, the flight crew was required to alert the passengers to prepare for the ditching. More specifically, the procedures stated the first officer was required to go to the cabin, don their own life jacket and ensue all passengers had their life jackets on correctly.

The OM also stated passengers had to be instructed on the impact (brace) position, and instructed that there may be more than one impact. If possible, passengers were required to be moved next to an emergency exit and instructed on how to use the exit.

Emergency lighting

The aircraft was fitted with an emergency lighting system that was independent of the normal cabin lighting. The emergency lighting system was located above the main entry door, in the same assembly as the entrance door light. It included an inertial switch and a 24 volt dry-cell battery pack.

When the emergency lighting system was activated, it would illuminate the entrance door light and a light located above each emergency exit. More specifically:

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[230] The passenger safety briefing cards used by some major airlines also do not indicate how to inflate a life jacket. However, these airlines provide a demonstration prior to each flight about how to use the life jackets on board the aircraft.

- If the emergency lighting system was selected to the ON position, the lights would illuminate using the aircraft's normal electrical power. If there was an impact, the inertial switch would activate and the dry-cell battery pack would supply the power to the lights.
- If the emergency lighting system was selected to the ARMED position, the dry-cell battery pack would supply the power to the lights if either there was an impact, or the normal electrical power system failed.

The operator's OM required that, prior to each flight, the emergency lighting system was tested. This involved selecting the system to the ON position. The OM also required that, as part of the pre-flight checklists, the crew select the emergency lighting system to the ARMED position. The emergency procedure for a ditching also required the emergency lighting system be selected to the ARMED position.

The aircraft's maintenance records indicated the emergency lighting system was last inspected as part of scheduled maintenance on 6 November 2009. This included checking the batteries.[231]

The occupants in the cabin reported some cabin lights were on after the aircraft came to rest. The captain, doctor and the flight nurse recalled there was lighting present at least until the time that they exited the aircraft. The passenger could not recall what the lighting conditions were like when he evacuated. The first officer recalled there was no lighting present when she exited the aircraft. At that stage the emergency lighting system may have been affected by water. The system was not designed, or required to be designed, to operate under water.

Emergency exits

The emergency exits were located on each side of the aircraft, just in front of the wings (see Figure 40). Both emergency exits were a standard design, and required the occupant to pull down an emergency handle located at the top and pull the hatch inwards.

The aircraft's maintenance records indicated the emergency exits were last inspected as part of scheduled maintenance on 6 November 2009. This inspection involved checking the release mechanism but not removing the exits.

As noted in *Evacuation*, the captain opened the left emergency exit and the doctor opened the right emergency exit. Both the captain and doctor reported they had no difficulty opening the emergency exits.

Neither the captain nor the doctor had previously been provided the opportunity to open an emergency exit on a Westwind. Several Westwind pilots also reported they had never opened an emergency exit prior to the accident. Some pilots, including the first officer, stated they had been provided an opportunity to open an emergency exit, but generally this opportunity was ad hoc rather than a structured part of their training.

Life rafts

For a twin turbine-engine aircraft conducting flights more than 120 minutes or 400 NM from land, CAO 20.11 required the aircraft to have sufficient life rafts so that each person on board had a place on a raft. The rafts were required to be stowed so that they were readily accessible in the event of a ditching 'without appreciable time for preparatory procedures'. If the rafts were stowed in compartments or containers, these compartments or containers had to be conspicuously marked.

The operator's OM required that, for all aircraft operations over water at a distance greater than 100 NM from land, sufficient life rafts were carried to provide a place for every person on board.

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[231] The emergency lighting system's batteries were required to be checked every 200 airframe hours or every 3 months. Maintenance records indicated the batteries were regularly checked, with the previous check prior to 6 November 2009 occurring on 15 October 2009.

The operator advised that, according to its records, VH-NGA carried two four-person life rafts at the time of the ditching. The life rafts were manufactured by Hoover (model number FR-4). The rafts' packed dimensions were such that they could fit through the emergency exits, and their weight and dimensions were such that they would float in their as-stowed condition.[232]

The OM stated a captain shall ensure there were sufficient life rafts on board. The OM also stated a first officer's duties included checking that all emergency equipment was on board and serviceable prior to departure. The first officer stated that, prior to departing Sydney on 17 November 2009, she confirmed that there were two life rafts on board. One was located behind the rear bench seat and the other was located in front of the oxygen cylinders (that is, just behind the passenger's seat) (see Figure 39).

The OM indicated it was a crew member function to deploy the life raft(s). The manual provided guidance on how to deploy a life raft following a ditching. However, it contained no information about where or how life rafts were to be stowed on the aircraft. The OM procedures included:

> Before opening doors or removing the emergency exit, remove the life raft from its stowage and have it ready to be passed through the exit onto the wing.

Another section of the OM also stated:

> After the aircraft has come to rest, the rafts should be removed from storage and placed near window exits.

When asked during the reopened investigation where life rafts should be placed prior to a ditching, the operator stated life rafts should remain in their securely stowed position unless, as part of an appropriate briefing prior to a ditching, they could be removed and properly secured. It noted rafts could be securely strapped to a spare seat near the exits using a seat belt. The operator also noted that, depending on the number of passengers, there may not be a secure cabin location for the rafts near the exits. However, rafts must not be removed from their secure stowage unless they could be secured satisfactorily in another location.

As noted in *Preparation for the ditching*, during the accident flight the first officer instructed the doctor to remove the life rafts from where they were stowed prior to the ditching. The doctor located the life rafts and placed them in the aisle near his seat, which was near the emergency exits.

The first officer later reported she thought the rafts needed to be easily accessible, and she did not think they were easily accessible in their stowed locations. She could not recall whether she had been provided with specific training regarding where the rafts were to be placed prior to a ditching. Other pilots recalled that the life rafts were generally stored towards the rear of the cabin. They could not recall whether they had been provided with any guidance where to place the life rafts prior to a ditching. The Westwind standards manager stated it had been discussed that life rafts had to be retrieved from behind the rear seat prior to a ditching. He noted that although there was no convenient location to secure the life rafts in the cabin near the exits, one available option would have been to strap a raft into the seat near the exits.

The doctor reported he placed the rafts in the aisle so they would be easy to access after the impact. The doctor and other CareFlight personnel could not recall receiving any training about where to place life rafts, and how to secure life rafts, prior to a ditching.

The PowerPoint presentation that was developed for CareFlight medical personnel in mid-late 2009 (see *Medical personnel training*) listed some cabin duties to be conducted prior to a ditching. This included:

- LIFE RAFTS – Position next to Exits (consider security)…

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232 That is, the weight of water displaced by the physical volume of the packed raft was more than the raft's weight.

This presentation was not developed until after the medical personnel on the accident flight had completed their familiarisation training and commenced air ambulance work on the operator's aircraft.

During the impact sequence, it is very likely the life rafts, sitting unrestrained in the aisle, were thrown forwards in the cabin and away from the emergency exits. The doctor could not recall noting where the life rafts went during the impact. He reported that, after he and the flight nurse released the patient from the stretcher, they had to evacuate immediately due to the level of the water. He did not have time to look for the rafts.

Life jackets

Number and location of life jackets

For a multi-engine aircraft conducting a flight more than 50 NM from land, CAO 20.11 required the aircraft to have one life jacket for every person on board. Life jackets were required to be stowed at or immediately adjacent to each seat. It also stated they should be stowed so that one life jacket was easily accessible to each occupant and, for passengers, within easy reach of their seats. The operator's OM included life jacket requirements that were consistent with the CAO.

The operator advised that, based on its maintenance records, there were six life jackets on board VH-NGA at the time of the ditching. It also advised it was possible there may have been additional life jackets that were not indicated in their records.

The operator and Westwind pilots reported life jackets within the cabin were generally stored under each seat, in the seat pocket behind a seat, under the rear bench seat, or in a storage cabinet at the front of the aircraft. The operator reported a patient's life jacket was treated the same as all passenger life jackets. There was no specific, dedicated location for a life jacket for a patient being transported in a stretcher.

The OM stated a captain was responsible for ensuring there were sufficient life jackets on board and that they were 'immediately accessible' by each occupant. The OM also required that, when a stretcher patient was being carried on overwater flights, the patient had a life jacket 'in place'.

According to the OM, a first officer's duties included checking that all emergency equipment was on board and serviceable. The first officer of the 18 November 2009 flight reported her normal procedure was to check there were sufficient life jackets on board and that each jacket was within its validity period. However, she could not recall how many jackets were on board the aircraft at the beginning of the 17–18 November 2009 trip.

For the accident flight, the occupants' recalled there was one life jacket stowed under the passenger's seat, one under the doctor's seat and one in the seat pocket in front of the flight nurse. The flight crew and the operator reported the pilots' life jackets would have been stowed directly behind their seats. The location of the sixth life jacket could not be determined.

Personnel from the air ambulance provider reported that although they had been shown and knew the general locations where life jackets were on each aircraft, they could not recall being shown exactly where a life jacket for a patient would be. The doctor and flight nurse reported that when preparing for the ditching they quickly looked for a life jacket for the patient behind and under the rear bench seat but could not find one.

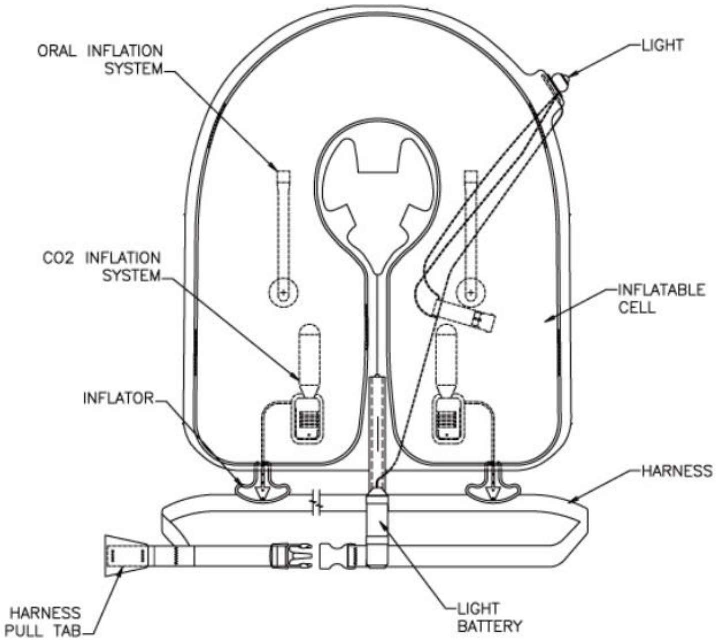
Life jacket design

Airworthiness Bulletin (AWB) 25-013 (Life jacket and flotation device approved standards, issue 1, November 2007) outlined the required standards approved by CASA for life jackets. The AWB listed several acceptable standards, including Federal Aviation Administration (FAA) Technical Standard Order TSO-C13d, TSO-C13e and TSO-C13f.[233]

The life jackets on board VH-NGA were model number KSE-35L8, manufactured by Eastern Aero Marine (EAM) Worldwide to comply with TSO-C13e. The life jacket, also known as a life vest or life preserver, was a commonly-used model in the airline industry. It was designated as an 'adult/child life preserver'.

Figure 42 shows the basic design of the life jacket. It has two inflatable cells or chambers, one in front of the other. As required by TSO-C13e, the life jacket is reversible, so it can be worn with either cell in the front position and perform its intended function. The life jacket is secured via a simple harness around the waist/chest, with a single clip. This was consistent with the TSO requirements, which stated the 'means of retaining the life preserver on the wearer must require that the wearer secure no more than one attachment and make no more than one adjustment for fit'.

Figure 42: Basic design and components of the KSE-35L8 life jacket



Source: EAM Worldwide. Note the life jacket has two inflatable cells (front and back), with each having its own CO_2 inflation system, pull handle and oral inflation tube.

In terms of inflation:

- Each cell can be inflated by pulling the associated red pull handle down. This action actuates the release of carbon dioxide (CO_2) into the cell from a small CO_2 cylinder.
- Alternatively, each cell can be manually inflated using the associated oral inflation tube positioned near the top of the jacket. The oral inflation tube can also be used to reinflate the cell if needed due to gradual air loss. A valve at the end of the inflation tube prevents air from being released. The cell can be deflated by placing a finger or other object in the tube and gently pressing the valve inwards to release air.

In terms of flotation attitude, TSO-13e stated:

> The life preserver must, within 5 seconds, right the wearer, who is in the water in a face-down attitude. The life preserver must provide lateral and rear support to the wearer's head such that the mouth and

[233] TSO-C13e was issued in April 1986. TSO-C13f was issued in September 1992, and it included relatively minor changes to TSO-c13e.

nose of a completely relaxed wearer is held clear of the water line with the trunk of the body inclined backward from its vertical position at an angle of 30 degrees minimum.

The light assembly consists of a light bulb fixed to one side of the top of the jacket, and a water-activated battery attached to the harness at the bottom of the life jacket. TSO-13e stated the light assembly had to meet the requirements of TSO-85, which required that the light emit an effective intensity of 1 candle for a minimum period of 8 hours. EAM Worldwide had produced KSE-35L8 life jackets with light assemblies manufactured by four different organisations, although one of those models was only used for a brief period of time.

TSO-13e did not require a whistle to be fitted to the life jacket. However, AWB 25-013 stated a life jacket had to have a whistle fitted in a suitable stowage. The KSE-35L8 life jackets could be purchased with a whistle, and the jackets used by the operator had a whistle attached. The whistle was secured to the top of the life jacket at the same point as the light bulb. The lanyard for attaching the whistle was approximately 36 cm long. The whistle floated in water and had a flat, rectangular shape, which differentiated it from the circular manual inflation tube.

Serviceability of life jackets

According to the life jacket manufacturer's maintenance manual, the life jacket was required to be inspected every 60 months (5 years).[234] There was no published service life limit for the jacket or any of the components, including the CO_2 cylinders, light or water-activated battery.

The operator's maintenance system monitored the currency of its life jackets. Prior to exceeding its required inspection date, the operator sent each life jacket to an approved maintenance organisation for inspection. The life jackets would then be returned in a sealed pouch, and installed on the aircraft in the sealed pouch.

Maintenance records showed all six life jackets assigned to VH-NGA had been last inspected within 5 years of November 2009. More specifically, the dates of the last inspections ranged from February 2005 to July 2008 (see also Table 31).

Use of the life jackets on the accident flight

The doctor assisted the passenger with the donning of his life jacket, and he had no difficulty donning his own life jacket. The flight nurse recalled she initially had difficulty in working out which way to put the life jacket on, and the doctor assisted her with orienting the life jacket correctly.

In terms of inflating the life jackets:

- The doctor reported that, after he entered the water, he pulled the pull handles on his life jacket and both cells inflated successfully.
- The passenger reported that when he was in the water he pulled one of the pull handles and was surprised that it only inflated half of his life jacket. He was aware the jacket had two pull handles but he thought pulling either one would fully inflate the jacket. He struggled to find the other pull handle. The doctor noticed his difficulty and swam across and pulled the other handle, which inflated the other cell of his life jacket.
- In her initial interview with the ATSB in December 2009, the flight nurse stated she tried to balance on the edge of the emergency exit when leaving the aircraft. She pulled the left pull handle of her life jacket and one of the cells inflated. Initially the passenger held on to the patient. However, after the occupants moved away from the wreckage, the nurse held the patient on her right side. She recalled the doctor and first officer told her only one of the cells of her jacket was inflated but she thought that was okay as the life jacket was still holding her up. She was aware

[234] More specifically, for a new life jacket the first inspection needed to be completed within 63 months after the date of manufacture. Subsequent inspections were required within 60 months of the previous inspection.

there was a manual inflation tube, but she found using it was difficult because she was holding the patient.

- During 2015, the flight nurse reported to the ATSB that she was aware at the time of the ditching that the life jackets had two pull handles, one for each cell. She thought she had tried to pull the other handle when she was in the water. However, her right arm had been injured in the impact[235] and she was holding the patient around the waist with her right arm, which made pulling the handle difficult. She also reported she found it difficult to hold the manual inflation tube in her mouth due to the sea conditions and holding the patient.[236]

In relation to the lights on the life jackets, the occupants reported all three lights worked when the occupants entered the water. However, the doctor recalled one of the life jacket lights failed at some point during the time they were in the water, and he thought the other lights had started to dim. The captain reported the flight nurse's light became dimmer prior to the occupants being rescued. When the occupants were rescued, a crew member on the rescue vessel reported sighting the lights on the life jackets when they were about 1 NM from the occupants.

In terms of the whistles on the life jackets:

- The doctor could recall looking for a whistle but could not recall whether he found one on his jacket. In trying to find the whistle he found the manual inflation tube and inadvertently deflated his jacket a little. He was able to manually reinflate his life jacket.
- The passenger reported he could not find a whistle on his life jacket.
- The occupants reported there was a whistle on the flight nurse's life jacket. However, it was difficult to access as the string attaching the whistle to the jacket was either too short or tangled.

During their time in the water, the doctor was holding the first officer and the flight nurse was holding the patient. The occupants were also swimming towards lights they could see on the island. In terms of other aspects of the life jackets:

- The doctor reported his life jacket was easy to wear if he rolled on his back and let it support him. However, it was awkward to wear when swimming and holding another person up as that meant leaning on his front. The jacket also kept folding up over his ears and he could not hear what other people were saying. He also believed this may have been due to his relatively low body position in the water as he was holding up another person.
- The passenger reported he found the life jacket awkward to wear as it was forcing his neck forward. Whenever he was hit by a wave it seemed he was being pushed into the wave and his mouth filled with water.
- The flight nurse reported the inflated cell of her life jacket was on the left side of her neck, forcing her head over to the right, which was uncomfortable. The patient was also holding on to her, and she was holding on to the patient with her right arm.

Initial examination of the life jackets

The three life jackets worn by the doctor, flight nurse and the passenger were recovered by the Norfolk Island police after the occupants were rescued on the night of 18 November 2009. The police then placed the life jackets in evidence storage. After the initial interviews with the aircraft occupants, the ATSB did not identify a need to locate and examine the life jackets.

After the investigation was reopened in December 2014, the ATSB ascertained the Norfolk Island police still had custody of the life jackets, and it obtained the life jackets from the Norfolk Island

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[235] During the Senate Inquiry, a submission in 2012 by an associate of the flight nurse stated the nurse suffered permanent damage to her right arm from the sustained exertion of holding the patient for 90 minutes in the water. In 2015, the nurse advised the ATSB the permanent damage to her right arm was due to the impact rather than the difficulty associated with holding the patient in the water with a half-inflated life jacket.

[236] The flight nurse thought two of the other occupants had also attempt to manually inflate the second chamber of her life jacket. However, neither of these occupants reported doing so in their initial interviews, and neither could recall doing so when reinterviewed in 2015.

police. The model number and serial numbers of the three jackets matched those of three of the six life jackets that had previously been provided by the operator as being on the aircraft. Table 31 provides the basic details of these life jackets.

Table 31: Details of the three life jackets recovered following the accident

Model number	Serial number	Date of manufacture	Last inspected	Placed on VH-NGA
KSE-35L8	33948	Jun 1996	Feb 2005	Aug 2006
KSE-35L8	92860	Jan 1997	Jul 2005	Sep 2005
KSE-35L8	92865	Jan 1997	Jul 2008	Aug 2008

In an initial examination of the life jackets, the ATSB noted:

- For life jacket 92865, the safety pin and actuator arm for one of the CO_2 inflation assemblies were still in place, indicating the pull handle had not been successfully pulled to activate the gas cylinder. The cell associated with this mechanism was also still slightly inflated, whereas none of the other cells of any of the three life jackets were visibly inflated.
- The batteries and lights for all three jackets were in place. The batteries had all swollen, indicating they had been activated in the water. The batteries for life jackets 33948 and 92860 were model number L200 manufactured by McMurdo Ltd, and the battery for life jacket 92865 was model number L8-4, manufactured by ACR Electronics Inc. The manufacturing dates for the batteries were 2003 (life jacket 33948), 1998 (life jacket 92860) and 1996 (life jacket 92865).
- For life jacket 92860, the attachment point for the whistle was ripped or torn, and a whistle was not attached. Life jackets 33948 and 92685 had whistles attached. The length of the lanyard in each case was approximately 36 cm, which was consistent with the lanyards for newly-manufactured life jackets.

Detailed examination of the life jackets

In June 2015, the ATSB inspected the life jackets at an approved maintenance facility, with representatives from the life jacket manufacturer and the operator present, together with the flight nurse on board the accident flight. The primary purpose was to examine the serviceability of the inflation mechanisms and cells. Key findings from the testing were:

- For life jacket 92865, the pull handle (of the cell with the unactivated CO_2 inflation assembly) was pulled. The gas cylinder activated to inflate the cell of the life jacket. The force at the time of activation was 10 lb, less than the maximum acceptable force of 15 lb.
- The oral inflation tubes on both cells of all three jackets worked.
- For all three life jackets, both cells were inflated and the pressure was adjusted to 2 psi. After 4 hours, the pressures were measured. A pressure of 1.80 psi or more meant that the cell was suitable for service.[237] After 4 hours:
  - Both cells of life jacket 92860 were above 1.80 psi and therefore passed the test.
  - The cell of life jacket 92865 that was found with the gas cylinder activated had a pressure above 1.80 psi and therefore passed the test.
  - The cell of life jacket 92865 that was found with the gas cylinder not activated had a pressure of 1.62 psi, just less than the required standard.
  - The cells of life jacket 33948 had pressures of 1.54 psi and 0.64 psi, less than the required standard. Subsequent inspection found that the latter cell was leaking from the manual inflation tube.

It was noted the life jackets had been worn during the impact and evacuation, and then worn for 85 minutes in the sea before being stored for over 5 years in a cardboard box. Therefore, the

[237] The procedure used for the examination was the same as the manufacturer's procedures for checking the serviceability of a life jacket's cells.

conditions of the life jackets at the time of testing may not have been representative of their condition at the time of the ditching.

The manufacturer reported it was not aware of any cases where a person had pulled a pull handle with the required force and the gas cylinder had not activated to inflate the cell. However, it noted on some occasions people did not pull the handle with sufficient force. The authorised service agency reported it had seen cases during emergency procedures training where people wearing a life jacket with two cells only pulled one of the pull handles.

It was concluded that the flight nurse was almost certainly wearing life jacket 92865. It was also concluded both cells of this jacket were capable of being inflated and would have retained adequate inflation during its period of use. The occupants of the other two jackets reported no issues with the inflation of their jackets and it was therefore assumed these jackets' chambers also provided adequate inflation during their period of use.

The ATSB tested the light bulbs on all three jackets and they were functional. The batteries were not able to be effectively inspected as they had already been exposed to water and depleted.

The life jacket manufacturer reported that problems with some water-activated batteries had been identified during routine inspections over the years.[238] The problems were typically associated with the batteries swelling because they were exposed to wet or humid conditions prior to the proper repackaging of the life jacket. The manufacturer stated the L8-4 battery had the best reported performance of all the batteries it had used. It also noted it had stopped using the L200 battery in 2010 (as it was no longer available), but it could not recall any unusual problems with that model. Overall, the manufacturer reported the number of batteries rejected during inspections was less than 10 per cent, and this rejection rate was higher for another model of batteries (WAB-H12/WAB-H18) than the L200 or L8-4.

The Australian authorised service agency for EAM life jackets reported it had not noted any concerns with L8-4 batteries over the years and it had limited experience with the L200 battery. It had identified problems with WAB-H18 batteries, but the manufacturer of those batteries had introduced changes to minimise these problems. It had also identified problems with the repackaging of some life jackets after inspections.[239]

A search of the CASA service difficulty database identified no reported problems associated with the L200 or L8-4 batteries during 2000–2016.[240] However, there were some reports of problems associated with model WAB-H12/WAB-H18 batteries, which were an approved type of battery for KSE-35L8 life jackets and also used on other manufacturers' life jackets.[241]

The ATSB tested the whistles found on two of the life jackets, and both were functional. There was no means of determining how or when the other whistle was separated from its life jacket or whether it was present or otherwise in the first instance.

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238 The inspection of the battery involves a visual examination, a measurement of the battery's case to ensure there has been no swelling, and use of an external device to check the ability of the battery to illuminate the light.

239 AWB 25-028, issued 26 June 2014. None of the three life jackets on board VH-NGA were last serviced by the service agency referred to in the AWB.

240 A search of the FAA service difficulty database identified two reports of an L8-4 battery being identified as swollen in 2003. It is likely that problems with batteries would often be identified and rectified without resulting in a service difficulty report.

241 AWB 25-020, issued 7 September 2011, discussed concerns regarding the WAB-H18 batteries fitted to models of life jackets made by another manufacturer. CASA's Flight Safety Australia magazine reported concerns regarding WAB-H12 batteries (May–June 2002).

Emergency locator transmitters

Fixed emergency locator transmitter

In August 2009, VH-NGA was fitted with a fixed Artex ME406 emergency locator transmitter (ELT), capable of transmitting a digitally-encoded distress alert signal on 406 MHz and a local, lower power analogue homing sweep tone on 121.5 MHz. The ELT could be manually activated by a switch in the cockpit, and it would also activate automatically if the aircraft was subjected to g-forces consistent with an aircraft accident.

About 50 seconds after activation, the ELT would commence transmitting one half-second burst of digital data on 406 MHz every 50 seconds.[242] The sweep tone was continuously transmitted on 121.5 MHz while the ELT was operating. The latency delay between activation of the ELT and transmission of the first digital data burst was initially designed to provide a period for the ELT's oscillator to warm up and produce a signal on the correct frequency.

Digital data encoded with the 406 MHz distress alerts included the ELT's unique identification number and other pre-programmed information. The identification number was used to register the device and record additional information in a search and rescue database, including the name of the beacon owner, emergency contact information, specific identification data and the maximum number of persons that might be on board.

Some ELTs also had capability to transmit the distress position, using either a built-in GNSS receiver or by relaying a position derived from on-board navigation equipment. However, there could be a delay of several minutes between the initial activation of the device and acquisition/transmission of ELT distress position to the Cospas-Sarsat satellite network.[243] ELTs equipped with GNSS receiver/position reporting typically achieved distress location accuracy within 120 m.

The aircraft-mounted ELT in VH-NGA did not have a GNSS receiver and, consequently, could not transmit the distress position on activation. Although the Artex ME406 ELT could be interfaced with on-board navigation equipment to immediately provide a position (with the first burst of 406 MHz data) in the event of activation, the navigation interface module had only been recently released at the time the ELT was fitted to VH-NGA. There was no regulatory requirement for ELTs fitted to Australian aircraft to be able to transmit a distress position. [244]

The ELT on VH-NGA was installed behind the rear pressure bulkhead, on the right far-rear fuselage wall. The ELT mounting plate was attached to stringers, approximately halfway between the lower and upper fuselage surfaces. The body of the ELT was secured to the mounting plate by a hook-and-loop type fastener.[245] The ELT's antenna was concealed beneath the dorsal fairing.

The ELT on VH-NGA was recovered from the tail section of the wreckage at the same time as the CVR and FDR. The ELT was reported to have been secure in its mounting tray, restrained by its hook-and-loop fastener and with the coaxial antenna cable and wiring harness still connected. Although the hook-and-loop fastener was in two pieces, the buckle remained fastened and the damage was consistent with being sustained during the ELT's recovery from the wreckage.

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[242] To ensure two or more active transmitters would not have continuously coincident data bursts, the signal repetition period was randomised, so that the actual transmissions interval ranged between 47.5–52.5 seconds.

[243] Depending on installation, the delay could be due to the time required for the ELT's GNSS receiver to acquire its position.

[244] Similarly, ICAO standards and recommended practices did not require ELTs to be capable of transmitting a distress position.

[245] In February 2013, CASA issued Airworthiness Bulletin AWB 25-023, detailing the use of hook-and-loop style fasteners and their ability to retain their designed capability to restrain ELTs during accident impact. This information was consistent with similar safety communications, bulletins and recommendations issued by other agencies, including the United States' National Transportation Safety Board and Federal Aviation Administration, the European Safety Agency and Canadian Transport Safety Board.

Alert signal processing

Activation of 406 MHz distress alerts were detected by Cospas-Sarsat satellites. At the time of the accident, the satellite network included both geostationary and low-altitude Earth orbiting satellites.[246] The network transmitted any received distress alerts to the ground receiving stations, which processed the information to locate the signal and provide notification to mission control centres. The mission control centres in turn passed distress notification to search and rescue services.

In the Australian Search and Rescue (SAR) region, search and rescue services were provided by the Australian Maritime Safety Authority (AMSA). In the New Zealand SAR region, this service was provided by Maritime New Zealand. Although Norfolk Island was located within the New Zealand SAR region, AMSA operated the Cospas-Sarsat mission control centre responsible for alerting both the Australian and New Zealand SAR providers.

Most of the Earth's surface was within coverage of a Cospas-Sarsat equipped geostationary satellite. Providing an ELT antenna was in line of sight with a satellite, the geostationary satellite network could immediately process the distress alert signal and, if the ELT was GNSS equipped, also pass the distress position when acquired.

The position of a distress alert signal could also be calculated during passes of low-altitude Earth orbiting satellites. This technique utilised the slight Doppler-induced shift in 406 MHz signal frequency due to the relative motion between the satellite and the ELT. The low-altitude Earth orbiting satellites passed overhead any given location at irregular intervals. On average, a distress position could be calculated within 90 minutes to an accuracy of about 5 km. At least three digital bursts from an activated ELT were usually required to derive two potential locations for the beacon using the Doppler processing technique. A second low-altitude Earth orbiting satellite detection could similarly derive two potential locations, and thus the combination could resolve the actual location of the active ELT.

Under some circumstances, the processing of detections from a combination of Cospas-Sarsat equipped low-altitude Earth orbiting and geostationary satellites can provide a location from very limited beacon bursts.

Alert processing for the accident flight

On 18 November 2009, a Cospas-Sarsat equipped geostationary satellite received one 406 MHz distress alert signal from VH-NGA's ELT at 1026 UTC. The information communicated in this signal included the unique identification number and serial number of the ELT. The information associated with this transmission was received by AMSA's joint rescue coordination centre (JRCC) about 7 minutes after the aircraft ditched. This processing period was within normal Cospas-Sarsat operating parameters, which included initial signal detection and transmission of the distress alert signal to the local user terminal, the relevant mission control centre and rescue coordination centre. The JRCC used its beacon registration database to identify the owner of the ELT and aircraft involved and, at 1038, contacted the aircraft operator.

There were no distress alert signals detected by any of the Cospas-Sarsat equipped low-altitude Earth orbiting satellites. Due to their lower orbit altitude, each satellite has a smaller detection footprint compared to satellites orbiting at higher altitudes.

There were no further 406 MHz distress alert signals from the aircraft received by the Cospas-Sarsat equipped satellites. The receipt of a single 406 MHz distress alert was consistent with the ELT being rendered inoperable within about 50–100 seconds after the first impact, due to the submersion of either the ELT or its antenna.

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[246] More recently, 406 MHz signal detection has been included on medium-altitude Earth orbit GNSS satellites being deployed. Using these satellites, the MEOSAR system will provide near instantaneous global coverage and provide capability to independently locate the distress beacon location.

Even if the ELT had been within the coverage of a low-altitude Earth orbiting satellite at the time of activation, a single data burst would not have provided sufficient information to calculate a distress location using the Doppler processing technique.

Portable distress beacons

The operator's maintenance records indicated the aircraft was also equipped with four, manually-activated 406 MHz portable distress beacons that were waterproof. These included:

- Two emergency position indicating radio beacons (EPIRBs) located in life rafts carried on board the aircraft (one in each raft). Although not equipped with a GNSS receiver, these EPIRBs had the capability to transmit a homing sweep tone on 121.5 MHz.
- One personal locator beacon (PLB) was equipped with an internal GNSS receiver to transmit position with the 406 MHz distress alert and also a 121.5 MHz homing sweep tone. The operator reported this PLB was probably stored in the cockpit.
- One EPIRB had no internal GNSS receiver and no capability to transmit on 121.5 MHz. The operator reported this EPIRB was also probably stored in the cockpit.

None of the beacons were retrieved by any of the aircraft occupants before they exited the aircraft. The EPIRBS without a GNSS receiver would have helped locate the occupants with consecutive passes of satellites in the Cospas-Sarsat low Earth orbit network. The PLB with a GNSS receiver would have transmitted an accurate distress position within minutes of being activated.

Other search and rescue aspects

Search and rescue events

During the search for and rescue of VH-NGA's occupants, a significant number of personnel from many agencies were involved. Table 32 provides a chronology of the key events associated with the search and rescue. It is based on recorded radio transmissions and transcripts, various incident logs maintained by the responding agencies, investigation interviews and the post-accident report prepared by the Norfolk Island airport manager.

Table 32: Sequence of key search and rescue events

Time (UTC)	Event
1018	Unicom operator called the Norfolk Island emergency services coordinator (ESC), because of the deteriorating weather conditions and an apprehension that the aircraft would not be able to land.
1019:30	Captain advised the Unicom operator they had to ditch as they had no fuel.
1019:40	First officer informed the Unicom operator they would 'come around again' (for fourth approach). She did not specify which runway the crew would use.
1022	Airport manager was advised of the situation. He telephoned two local operators of fishing charter boats and requested they prepare their vessels for launch.
1023:05	Unicom operator asked the flight crew if they had enough fuel to reach Noumea, first officer replied 'negative'. The ESC was monitoring the Unicom frequency and heard this transmission, and called out the other members of the airport rescue and firefighting service.
1024:37	Unicom operator asked if the flight crew were able to talk yet, first officer replied 'no'.
1025:05	First officer broadcasted on the Unicom frequency 'we're going to proceed with the ditching'. She did not provide any further details. Unicom operator acknowledged the transmission, and stated he would 'put everyone on alert'.
1025:58	Aircraft ditched. At 1026:01 there was a brief (2-second) carrier wave transmission on the Unicom frequency.
1026	Single beacon burst detected from 406 MHz ELT by the geostationary satellite GOES-11. The New Zealand geostationary satellite tracking station (NZ GEOLUT) processed the signal. The GEOLUT waited 5 minutes for any subsequent transmissions to provide a better solution for the distress position. No subsequent signal was received and no distress position was resolved.

Time (UTC)	Event
1028	Unicom operator informed Auckland Oceanic controller the VH-NGA flight crew had declared an emergency, had no more fuel to continue, were going to conduct another approach and then ditch. Unicom operator advised he had initiated full emergency procedures. Controller advised he would inform the Rescue Coordination Centre New Zealand (RCCNZ).
1029	Unicom operator called the Norfolk Island police, advising a small jet aircraft was having difficulty landing and may have to ditch. Police called out the volunteer rescue association.
1030	Auckland Oceanic controller advised RCCNZ of the situation.
1031–1032	NZ GEOLUT sent beacon detection to the Australian Mission Control Centre (AUMCC), which was operated by the Australian Maritime Safety Authority (AMSA), and the detection was processed by the AUMCC.
1033	Because the beacon was registered to an Australian operator, the AUMCC sent notification of the beacon activation to the Australian Joint Rescue Coordination Centre (JRCC), which was operated by AMSA.
1036	JRCC created the incident record for the search and rescue response.
1037	Norfolk Island police arrived at the airport's emergency response centre (ERC). After a briefing by the Unicom operator, and in accordance with normal procedures, the police assumed responsibility for coordination of the local emergency response.
1038	JRCC advised the aircraft operator of an ELT activation involving one of its aircraft.
1038	Unicom operator attempted to contact the flight crew, with no response.
1038	Auckland Oceanic controller sent an AFTN message stating an alert phase (ALERFA) had been declared.[247]
1039	Unicom operator advised Auckland Oceanic controller they had lost contact with the flight crew. He asked Auckland to attempt to contact them on the HF frequency. Auckland air/ground operator attempted to contact the crew.
1041	Unicom operator advised RCCNZ they had lost contact with the flight crew, and asked if any alerts had been detected.
1042	Auckland Oceanic controller advised RCCNZ that communications with the flight crew were lost and that an ALERFA had been declared.
1045	RCCNZ contacted the JRCC to get advice on any alerts.
1046	RCCNZ informed the Norfolk Island police a signal had been detected from a distress beacon, but at that stage there was no distress location. They advised it would be about 18 minutes before the next pass of a low-earth orbit satellite, from which there could be a distress location derived.
1120	Firefighter contacted the ESC to advise he had sighted a light in the water to the west of Norfolk Island. The ESC relayed this information to the ERC.
1122	RCCNZ advised Norfolk Island police that the satellite had passed over again and no further signals were detected. Therefore no coordinates would be available. Local pilots had assembled at the ERC and had discussed possible ditching locations, including one pilot who lived west of the airport and had heard the aircraft but did not think it was climbing. The group consensus was that the most likely ditching location was to the west of the island and was passed to the police incident commander in charge of the ERC.
1125	Approximate time first search vessel departed Kingston Jetty to commence search. Initial plan was to search to the south-east of the island as it was thought the aircraft ditched after conducting an approach to runway 11. After receiving advice from the ERC that there were no coordinates from the ELT, that a light had been sighted to the west of the island and the consensus of the pilot group about the likely ditching location, the search vessel changed course to head to the west of island. The skipper of the search vessel plotted the vessel's position clear of the rocks off Bumbora Reserve before heading north-west.

[247] A number of situations will result in declaration of an ALERFA, including when apprehension exists as to the safety of the aircraft and its occupants. A distress phase (DETRESFA) was subsequently declared.

Time (UTC)	Event
1150	Personnel on the search vessel contacted the ERC to advise the occupants had been located and were being brought on board.

Search and rescue vessels and personnel

The two search vessels that were launched at Norfolk Island were shore-based trailer vessels, one a 7 m twin-hull catamaran and the other an 11 m cabin cruiser. The vessels were equipped with GPS satellite navigation and marine radar.

There was no permanent harbour at Norfolk Island and local vessels were launched from one of two locations, on opposite sides of the island. The selection of launch location depended on the prevailing weather conditions. The airport manager checked the launch conditions with the local charter boat operators and, in consultation with the police incident commander, confirmed the search vessels would respond from Kingston Jetty. After confirming the launch location, the airport manager left the airport's ERC to assist crewing one of the search vessels.

At Kingston Jetty, crews and equipment for the vessels were assembled. The crews included people with first aid qualifications and experience operating small surface vessels. The police incident commander approved the departure of the surface vessels as soon as they were ready, with initial planning being made to commence a search pattern to the south-east of Norfolk Island. At that time there was an understanding the aircraft's last approach had been to runway 11, and in the absence of more recent information, the belief was that the aircraft had ditched upwind from that runway and to the south-east of Norfolk Island. That search plan was subsequently amended with the sighting of a light to the south-west of the island and the consensus from local pilots about the most likely ditching location, and the first search vessel departed to search that location. For additional information about the search and rescue, see the relevant section in *The occurrence* (*Search and rescue*).

The airport manager recalled that the catamaran arrived back at Kingston Jetty with the evacuees rescued from the aircraft within an hour of being launched. At the time of rescue, the evacuees had been in the water for about 85 minutes. They were treated for symptoms of shock and hypothermia and transferred to Norfolk Island hospital.

The second search vessel got underway from Kingston Jetty about the same time that the aircraft occupants were rescued and it returned to the jetty a short time later.

In addition to the two vessels launched from Kingston Jetty, search and rescue personnel also initiated or planned a number of other actions:

- The general cargo vessel Norfolk Guardian had departed Norfolk Island earlier that afternoon for Auckland. During the initial stages of the response, the vessel was requested to return to Norfolk Island to potentially assist with the search.
- During the initial stages of the response, the RCCNZ commenced preparations to deploy a Royal New Zealand Air Force PC-3 long-range maritime surveillance aircraft to the search area.
- The RCCNZ coordinated with Maritime New Zealand to broadcast a MAYDAY relay for vessels within 100 NM of Norfolk Island to respond.
- Overflying aircraft were requested to monitor the aviation distress frequency 121.5 MHz for any distress beacon transmitting on that frequency.
- Preparations were initiated to use an airline passenger aircraft parked on the ground at Norfolk Island airport to conduct a visual search of the area, commencing at first light if the weather conditions improved.

Time frame for survival

Immersion hypothermia can be an issue after an aircraft ditching if either the water is cold or the survivors are in the water for a long time. Although often associated with the effects of cold water, as the human body loses heat 25 times faster in water than in air, very long exposure in warmer water can also result in hypothermia. Many factors besides water temperature affect heat loss, including age, body size, energy levels, life jackets and clothing.

The sea surface temperature at Norfolk Island at the time of the ditching was estimated to be about 21ºC. For a 21ºC water temperature and wearing life jackets and light clothing, it has been established that people will generally survive for at least 16 hours while motionless. Swimming, however, can accelerate the onset of hypothermia by 35 per cent (due to additional cold exposure from the increased circulation of warm blood to the arms and legs and colder water continuously moving across the body).[248]

Some of the evacuees reported that, by the time they were rescued, they were exhausted and distressed and probably could not have survived for much longer.

Airport emergency exercise

Licenced aerodrome operators were required to have an airport emergency plan. The purpose of the plan was to help aerodrome personnel and emergency services respond in a timely and effective manner to emergencies occurring in the vicinity of the airport. Those plans were required to be regularly reviewed, and a desktop exercise conducted at least annually and an actual exercise response at least every 2 years.

The Norfolk Island airport manager reported a desktop exercise was scheduled to be conducted on 19 November 2009 (the day after the ditching of VH-NGA) and that the scenario for that exercise was a ditching of a passenger aircraft, requiring a waterborne rescue response. As part of his preparation for the desktop exercise, the airport manager had considered the exercise scenario and formulated elements of the proposed response, including the identification of suitable vessels to respond to the exercise scenario.

The airport manager reported the preparations for the desktop exercise had helped with the ditching response for VH-NGA and that they had already thought through some of the issues involved.

Fatigue management

Overview of the operator’s fatigue risk management system

CAO 48.0 (Flight time limitations – general) outlined general requirements for flight crew flight and duty times for RPT, charter and aerial work operators, and CAO 48.1 (Flight time limitations – pilots) outlined more specific requirements. For many operators, the prescriptive requirements of CAO 48 were considered too restrictive, and CASA developed standard industry exemptions for different types of operations. However, some operators still found these standard exemptions too restrictive and had non-standard exemptions approved by CASA. Up until 2000, the operator had a non-standard exemption outlining prescriptive requirements associated with the operator’s night freight operations.

In 2000, CASA decided that it would no longer approve non-standard exemptions unless an operator developed a fatigue management system (FMS). The operator developed an FMS based on guidance material provided by CASA, and in March 2002 CASA approved the operator to conduct operations using its FMS.[249] The operator was one of the first in Australia to develop a CASA-approved FMS.

In late 2004, CASA requested the operator’s FMS manual be updated to include more risk management aspects and other improvements, in accordance with CASA’s understanding of the

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[248] Civil Aerospace Medical Institute, *Basic survival skills for Aviation*, Federal Aviation Administration. Available from www.faa.gov.

[249] Part of the rationale for developing an FMS approach was that following the prescriptive flight and duty requirements in CAO 48 could still result in fatigued flight crews (see McCullogh and others 2003).

latest developments in fatigue management. The operator's FRMS manual was subsequently approved by CASA in June 2007. This manual subsequently formed part G of the operator's OM.

The operator's FRMS contained many elements, including:

- roles and responsibilities
- rostering practices
- use of a bio-mathematical model of fatigue (BMMF) known as FAID (Fatigue Audit InterDyne)[250]
- standby
- extension of duty
- cockpit strategic napping
- fatigue management training.

There were also requirements for fatigue reporting, hazard identification and reviewing the effectiveness of the FRMS (see *Safety management*).

Roles and responsibilities

The policy statement in the FRMS manual stated:

> Flying activities present some inherent risks. These are not significantly more than other transport professions but the environment is very unforgiving. For this reason Pel-Air Aviation policy is never to fly fatigued aircrew.
>
> It is our policy that risk associated with fatigue is controllable…
>
> Pel-Air Aviation's system is based on a shared responsibility (management and employees) to apply the guidelines and strategies outlined in the Fatigue Risk Management System that will maximise performance and alertness during flight operations…

The manual stated the operator's obligations, which included ensuring:

- flight crew were aware of the risks associated with fatigue and their role in minimising the risk
- employment periods, work times, rosters and roster cycles were structured and managed in a manner that controlled and (where possible) minimised risk
- suitable sleeping accommodation facilities were provided when flight crew were on standby at work or when deployed.

In terms of flight crew obligations, the manual stated they were required to ensure:

- activities outside of working hours did not increase the risk associated with their work duties
- they got adequate sleep and were not in a fatigued state before commencing a duty period
- they contacted the relevant operations manager or the chief pilot if they suspected an increased fatigue-related risk.

Other specific duties and responsibilities were also included throughout the manual.

Rostering practices

The FRMS manual stated a number of factors were to be considered when rostering flight crew, including:

- the time of day
- the length of the work period
- the time available during a non-work period to maximise the opportunity to sleep
- the number of consecutive days worked
- minimising wherever possible rosters involving irregular operations.

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250 FAID was initially known as 'Fatigue Audit InterDyne'. It was subsequently renamed the Fatigue Analysis Tool by InterDynamics.

The manual also specified minimum roster requirements. These included:

- a maximum FAID score of 75 (see below)
- a minimum rostered work period of 4 hours
- a minimum 10-hour break after a flight duty period of 6 hours or more (unless a shorter break was ‘agreed to by both parties’)
- if a split shift was used within a duty period, a minimum of 4 hours rest at suitable sleeping accommodation
- a maximum of 90 hours rostered work over 14 days.

From April 2009, Westwind flight crew only conducted ad hoc air ambulance and charter tasks. The Westwind operations manager was responsible for maintaining the fleet’s roster and ensuring any assigned ad hoc tasks met the requirements of the FRMS. When a new task was being planned, she entered the likely duty times into FAID to get the FAID score. She reported she would generally enter conservative duty times to allow for potential delays.

If a pilot’s FAID score exceeded 75, the operations manager stated the operator could not use that pilot for that task. Management would then select another pilot, delay the trip or add additional time off duty to reduce the pilot’s FAID score, or decline the task. Similarly, if the score was approaching 75 they would review the proposed trip and add additional time off duty.

The FRMS manual did not require rostering personnel to ask the flight crew about their level of alertness or recent sleep when assigning them a new task. The operations manager said that, if the pilot’s FAID score was below 75, it was assumed they were able to complete the assigned duty. She said pilots always had the right to say they were fatigued, and it was the pilots’ responsibility to say whether they were able to complete the assigned task.

The operator reported that, on occasion, it did not commence an air ambulance trip, or it delayed the start of an air ambulance trip, due to factors such as the retrieval airport’s location, the time of day or night and the remoteness of the retrieval airport. In some cases it provided additional crew at intermediate airports to ensure flight crew had adequate rest, and on other occasions it provided extended rest periods at intermediate airports to reduce fatigue.

The Westwind operations manager and Westwind standards manager both reported there were several occasions were the operator delayed starting times or had to decline tasks because of a pilot’s FAID scores or a pilot had declined the task due to feeling fatigued. However, these events were never formally recorded.

Westwind pilots reported the rostering of their duty periods appeared to be heavily based on the FAID score. They were never asked about their level of alertness or recent sleep when tasks were assigned, or during the progress of a trip. However, many pilots reported that on some occasions they had suggested changes to an assigned task to better manage potential fatigue, such as delaying a start time. These suggestions were usually able to be accommodated.

The operations manager stated the length of most air ambulance tasks was such that there was no requirement for a period of time off duty during the task. Westwind pilots also reported trips involving a rest break away from their home base were relatively uncommon. Pilots also noted that where rest breaks were required, they were usually the minimum length possible until the patient had been transported to their destination. Several pilots noted there was an expectation that once a task started it would be completed as soon as practicable, at least until the patient had been transported to their required destination.

When a rest period away from home base was required, the operations manager reported the operator used 4-star hotels or accommodation. She stated they had used the hotel in Apia near the airport (used by the accident flight crew) on a few previous occasions and there had been no concerns reported by flight crew. Westwind pilots who had stayed in the same hotel reported they had no concerns with the hotel.

The operator's FRMS had no specific requirements for trips involving multiple time zone changes. Almost all of the operator's trips with rest periods involved at most a 2-hour time zone change, and such changes are generally not considered to have a significant influence on sleep and fatigue. The operator occasionally conducted trips with longer time zone changes. However, these were usually planned with significant advance notice.

Background information on bio-mathematical models of fatigue

A BMMF uses mathematical algorithms to predict the effect of different patterns of work on measures such as subjective fatigue, sleep or the effectiveness of performing work. Most of the models are applied using computer software. Each model uses different types of inputs and produces different types of outputs, and each model is based on many assumptions and has limitations.

In particular, the models are based on group-averaged data that do not apply to every individual, and none of the models consider all of the factors than can influence fatigue. Most of the models used by industry are designed to be one element of a system for evaluating and comparing work rosters, and it is widely agreed that the models are not well suited for predicting a specific individual's level of fatigue (CASA 2010, CASA 2014, Dawson and others 2011, Independent Transport Safety Regulator 2010).

The operator's FRMS required that flight crew duty periods be assessed with FAID. FAID is a BMMF that has been widely used in the Australian aviation and rail industries since the early 2000s. It was also a key part of a CASA-recommended FMS framework for operators in the early 2000s.

FAID uses hours of work (start time and end time) as its inputs, and it produces a score based on an algorithm that considers the effects of the length of the duty periods, time of day of the duty periods and the amount of work over the previous 7 days (Roach and others 2004). The more recent the duty period, the more effect the duty period has on the resulting score. The higher the FAID score, the higher the potential for fatigue.

FAID documentation stated scores of 40–80 were broadly consistent with a safe system of work. However, the threshold for deciding the acceptability of a roster needed to be set by the operator based on an assessment of the safety-criticality and nature of the tasks. However, it was common practice for operators to use the default threshold of 80 for the peak or highest FAID score. The operator's FRMS used a threshold of 75, which was proposed by CASA in 2002 for operators that used an FMS.

As noted above, there are limitations with all BMMF that reduce the extent to which they should be relied on as a basis for evaluating rosters. With regard to FAID in particular:

- The Independent Transport Safety Regulator (ITSR) of New South Wales (2010) noted a FAID score helps to assess some aspects of the accumulation of fatigue because it places a higher value on the hours worked that are important for recovery sleep (that is, working during the normal hours of sleep will lead to a higher FAID score than working during the day). It also noted FAID assumes every hour of rest or time away from work has the same recuperative value, regardless of the time of day. Consequently, ITSR stated the FAID score is 'limited in its ability assess the adequacy of recovery provided by a particular break between shifts'. Due to this and some other aspects, ITSR stated 'a FAID score of less than 80 does not mean that a work schedule is acceptable or that a person is not impaired at a level that could affect safety'.
- The US Federal Railroad Administration (FRA 2010) compared FAID with another BMMF model, the Fatigue Avoidance Scheduling Tool (FAST), which the FRA had previously validated for use in the rail industry. Based on this comparison, it concluded FAID scores between 70 and 80 can be associated with 'extreme fatigue'.
- A key feature of FAID is that it only considers the duty periods over the past 7 days, with the influence of a period of duty time on the FAID score decaying in a linear fashion over the 7 days. If there has been no duty periods in the previous 7 days, then there is a lag as the score in the

next duty period(s) accumulates. For example, if there has been no duty periods in the past 7 days and then a person commences a duty time at 0800 in the morning, it will take about 42 hours of continuous work before the FAID score rises to 75. In other words, if there has been very little duty time in the previous 7 days, FAID will underestimate the potential fatigue level associated with the next duty period, and at times this level of underestimation can be significant.

Publicly-available guidance material regarding FAID issued by the FAID provider during the period up to 2009 included general advice about how to use the model. It discussed several potential problems with using the model and provided guidance for how to approach these problems. However, as far as could be determined, no guidance was provided about the potential to underestimate the fatigue level of long duty periods if there had been no or minimal duty time in the previous 7 days.[251]

The FAID provider advised the ATSB it is difficult to provide all the appropriate cautions to cover all situations in guidance material. However, this problem with no duty time in the previous 7 days, and the related issue of how to consider standby periods, had been discussed individually with organisations over the years. They were also complex issues for which it was difficult to provide simple guidance that was adequate.[252]

ITSR (2010) also noted 'Instructions supporting the use of [BMMF] are often unclear and need to be supplemented in order to provide better guidance to users'.

Operator's use of FAID

The operator purchased FAID in 2001. Based on the available information, it appears that the operator did not ask the FAID provider to provide any specialist support or advice regarding the use of the model. The FAID provider reported the operator's approach was not uncommon for operators who started using FAID as part of an FMS in the early 2000's.

CASA personnel reported that, after the introduction of FMSs that used FAID by some Australian aviation operators in 2002, CASA recognised these systems relied too heavily on the use of FAID (see also McCulloch and others 2003). It then worked with these operators to improve the quality of the FMSs and make them less reliant on a BMMF. For example, the report from a November 2004 CASA audit of the operator's FMS stated:

> It was also determined that the current document needed updating to reflect current scientific opinion detailing the limitations of sole reliance on the FAID modelling tool and the need to involve hazard identification within the organisation's activities and subsequent risk mitigation…
>
> The system was evolved with CASA guidance and is dated January 2002. At that time the methodology was acceptable to CASA as a mechanism of achieving fatigue management. Since then advancements in the understanding of the limitations of total reliance on a mathematical model have emerged. This was explained to company representatives and as a result of these discussions the operator has elected, with CASA facilitation, to re-write sections of the system, to include risk management….

Subsequent correspondence between CASA and the operator indicated the operator's management were aware there were limitations with FAID and there was a need to enhance other aspects of the FMS.

During the process of enhancing the operator's FMS to an FRMS from late 2004 to mid-2007, the operator's compliance manager became familiar with the nature of FAID and many aspects of fatigue management. The compliance manager left the operator in August 2008. As far as could

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251 Roach and others (2004) reported that, when using FAID to evaluate various rosters where no information was provided in the previous 7 days, they assumed that the previous 7 days consisted of a standard work week (5 days of 0900-1700 work) and then a weekend off.

252 The FAID provider noted FAID software by default will only publish a FAID score if there was 7 days of previous work schedule data. This 'work history' period was explained in supporting documentation as necessary to 'warm up' the model. The provider noted that, although the work history period is sufficient for most work schedule environments, it does not account for aspects such as standby or returning from a long leave period during the previous 7 days.

be determined, none of the operator's other personnel developed a detailed knowledge of FAID or FRMS aspects.

The operator's personnel who used FAID to evaluate rosters, including the Westwind operations manager, were provided with in-house training on how to apply the model according to the operator's FMS/FRMS. However, these rostering personnel did not have specialist training in fatigue management and did not receive specialist guidance or training regarding the assumptions and limitations associated with the model.

As noted above, the operator used FAID to assess the suitability of proposed duty periods. After tasks were completed, the flight crew provided actual duty times to rostering personnel, who checked the actual duty periods with FAID. Any instances where the FAID scores based on actual duty periods exceeded 75 were reported and reviewed (see *Fatigue occurrence reports*).

Standby

The operator's FRMS stated standby was:

> A period during which a flight crew member is required to be available for a duty period. Standby is neither duty, nor time free of duty.

The manual also stated standby undertaken in suitable accommodation (as defined by the FRMS manual) was 'non-work' for the purposes of fatigue management. The FRMS included no restriction on the amount of standby that could be rostered. In addition, because it was not considered to be duty time, standby time was not input into FAID as part of the fatigue modelling.

The operator's definition of standby and associated conditions were consistent with the guidance provided by CASA to operators for setting up an FMS in 2001. The standby definition was also consistent with CASA's standard industry exemption to CAO 48. However, the exemption, and the CAO 48 requirements for operators who were not using an approved FRMS or the exemption, restricted standby to a maximum continuous period of 16 hours.

The default roster cycle for Westwind pilots based in Sydney and Darwin consisted of:

- 3 days standby
- 1 'grey' day
- 2 days off duty.

A grey day (see also *Personnel information*) was effectively another standby day, but if an assigned task was likely to extend beyond 2200 local time then the flight crew could refuse to take the task without providing a reason.

The two flight crew based in Perth were rostered for longer periods of standby, reported to be up to several weeks at a time. Pilots from Sydney or Darwin took turns to be based in Perth to provide relief. Pilots from Sydney and Darwin also took turns to be based in Cairns for periods of 3 weeks (or longer by agreement).

Standby was either done from home, or for pilots operating temporarily at remote bases it was done at company-provided accommodation. Pilots were able to conduct non-work and recreational activities away from their home or accommodation, provided they met the requirement of being ready to depart within 2 hours of being contacted for an air ambulance task.

Most Westwind pilots reported that being on standby had little if any effect on their overall amount or quality sleep. Some pilots reported they would take afternoon naps in order to minimise the potential effects of fatigue if called out for an overnight duty period, whereas other pilots reported they did not take preparatory naps.

However, some pilots reported conducting extended periods (many days in succession) of 24-hour standby was quite restrictive and led to stress or frustration. Some of these pilots also stated extended periods of standby had a negative impact on the duration and quality of their sleep.

Management personnel reported standby was an integral part of their Westwind air ambulance operation, and managing the operation without extended periods of standby at some bases was very difficult to resolve. It was noted each pilot did a relatively low amount of actual flying each year, and that pilots were paid while on standby.

Extension of duty

The FRMS manual stated that if an assigned duty period exceeded 15 hours, an 'extension of duty' process was required.[253] The manual also required this process to be followed if a pilot was currently undertaking a duty period and an additional duty period was then assigned. However, the process was not required to be followed if a pilot was on standby and then was assigned a new task.

The extension of duty process required the relevant operations manager to calculate the flight crew's FAID scores to ensure the additional duty would not result in a score greater than 75. In addition, the process required the manager to ask both pilots a series of questions to assess:

- their alertness
- their perception of the other pilot's alertness
- recent meals, snacks and drinks
- recent sleep history.

The process required the recent sleep data and time awake to be analysed using an algorithm to calculate an individual fatigue likelihood score (IFLS). The FRMS manual included a table that listed IFLS scores, their potential fatigue-related symptoms and approved mandatory and optional management responses.

The IFLS was based on the prior-sleep wake rule (PSWR) (Dawson and McCulloch 2005). In simple terms, this rule states that fatigue risk is increased if the amount of sleep in the last 24 hours is less than 5 hours, the amount of sleep in the last 48 hours is less than 12 hours, or the time awake is more than the hours of sleep in the last 48 hours.

The Westwind operations manager stated she had been shown how to use the extension of duty checklist and calculate an IFLS during her training. However, she had never applied it when assigning duties for the Westwind fleet. She noted it was used more by the turboprop fleet where crews already had rosters with assigned duty periods, whereas the Westwind fleet's duties were ad hoc and duty periods were rarely assigned in advance.

Cockpit strategic napping

The FRMS manual stated that, even though the FRMS was intended to ensure flight crew were well rested:

> … the nature of Pel-Air operations can present unique challenges to crew alertness, despite meeting crew rest requirements. Pel-Air scheduled and ad-hoc charter operations tend to involve lengthy sectors at critically fatiguing periods of the night as well as fatiguing tasks in demanding flight scenarios, as such deliberate crew napping is seen as a suitable means of improving crew alertness during more critical portions of the flight.

Accordingly, the manual stated 'cockpit strategic napping' was permitted subject to specified conditions. These conditions included:

- only one pilot was able to nap at a time
- napping could only be done during low workload parts of a flight

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[253] The flights on 18-19 November were considered two duty periods (see *Rostering processes for the 17–18 November 2009 flights*).

- naps were limited to 30 minutes maximum (to prevent problems associated with sleep inertia[254])
- pilots should be woken 30 minutes before any anticipated high workload event
- the autopilot was engaged
- pilots were not permitted to disconnect their headset or turn down the volume of their radio.

Many Westwind pilots reported cockpit napping was regularly used as a risk mitigator on long flights at night.

Fatigue management training

As a part of the FRMS (and the previous FMS), the operator required its flight crew to complete an annual training course on fatigue management. When the operator initially introduced its FMS in 2002, flight crew were provided with classroom-based training on fatigue and the FMS.

In March 2008, CASA identified during an audit that the operator had not been conducting annual FRMS training of its flight crew. Soon after, the operator re-commenced the training, and it was then conducted every 12 months.

As with the CRM training, the operator provided FRMS training via a CBT package. Each pilot viewed a presentation at their own pace and then completed a short exam. If a score of less than 100 per cent was achieved on the exam the first time, the candidate answered the questions they answered incorrectly again until they obtained the correct answers. No classroom training was involved.

The training content covered the material in the FRMS manual. It also provided information on fatigue, factors affecting fatigue, symptoms of fatigue, strategies for minimising fatigue and maximising sleep and the PSWR. The content also included three scenarios to help explain the FRMS and its provisions.

CASA reviewed the CBT training material and exam in March 2008 when it was first introduced (see also *Oversight of flight crew training and checking*), and again during a special audit conducted in late 2009 (see *Special audit conducted after the accident*). On both occasions it found the training content met the syllabus requirements stated in the approved FRMS manual.

Westwind pilots reported the training material had limited effectiveness. In particular, some pilots indicated they were provided with insufficient information about the FAID program and they did not understand how it produced its scores or why its scores seemed to be inconsistent with their perceptions of their own fatigue levels.

Rostering processes for the 17–18 November 2009 flights

The air ambulance provider kept a log of significant events and decisions for each air ambulance task. For the task on 17–18 November 2009, the log indicated the Westwind operations manager provided approximate flight times for the task, and also stated the flight crew required a rest period in Apia of 8 hours. The air ambulance provider’s log also indicated its personnel were expecting that the departure out of Apia would occur about 9 hours after landing.

The Westwind flight crew roster indicated the following duty periods were entered for the trip:

- 17 November 2009: 2200–0630 AEDT (8.50 hours)
- 18 November 2009: 1400–0330 AEDT (13.50 hours).

These times included a rest period of 7.50 hours in Apia. The aircraft landed in Apia at 0602 AEDT, which was also consistent with these times.

As noted in *Recent history*, the flight crew experienced delays in checking into their hotel rooms at Apia. Because of this delay, they pushed back their meeting time at the hotel to 1500 AEDT. The

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[254] Sleep inertia: a short period of time immediately after awakening associated with poorer task performance and a feeling of mental sluggishness.

actual rest periods were about 7.75 hours for the captain and about 8.25 hours for the first officer.[255]

The operations manager reported the time off duty should have been 10 hours, which would normally allow for 8 hours rest at a hotel. She could not explain why there was only an indicated time off duty of 7.50 hours on this occasion in the roster, and it was not possible to determine if the duty times were last updated before or after the second duty period started.

Neither of the flight crew had any other duty periods in the previous 7 days. The resulting peak FAID scores for both crew using the duty periods listed above were 28 for the first duty period and 51 for the second duty period.

Given the length of the duty periods, there was no requirement under the FRMS for the extension of duty process to be followed, and there was no requirement for the operations manager to assess the pilots' alertness in any way other than using FAID.

Phone records confirmed the captain and the operations manager were in regular contact during the time the aircraft was on the ground in Apia.[256] The operations manager stated she received no advice from the captain regarding the crew being delayed access to a hotel room, the captain having a disrupted sleep or the difficulties he experienced when flight planning.

In addition to the scheduled roster, the ATSB examined alternative roster scenarios using FAID:

- updated roster with captain's actual duty periods up until returning to Norfolk Island and expected duty period continuing the trip to Melbourne then Sydney (2200–0645 and 1430–0400 AEDT)
- initial scheduled roster with 10 hours time off duty between the duty periods (2200–0630 and 1630–0500 AEDT).

Using FAID, neither of the alternate scenarios resulted in a meaningful difference to the FAID scores of the scheduled duty periods.

The ATSB conducted additional evaluations using two other BMMFs that take into account additional factors which have been shown to affect fatigue and are widely used internationally by air transport operators: the System for Aircrew Fatigue Evaluation (SAFE) and FAST. Both models produced similar results for the scheduled roster and the updated roster. More specifically:

- at the end of the first duty period (when landing in Apia) scores were just better than the nominal threshold levels
- for the initial part of the second duty period (prior to and during the flight from Apia to Norfolk Island) scores were significantly better than nominal threshold levels
- for the middle part of the second duty period (during the expected flight from Norfolk Island to Melbourne) scores gradually deteriorated to just better than nominal threshold levels
- for the last part of the second duty period (during the expected flight from Melbourne to Sydney) scores deteriorated to worse than nominal threshold levels.

For the scheduled roster with a 10-hour period of time off duty, the scores were worse during the second half of the second duty period, such that the scores would have been worse than the nominal threshold levels for the expected flight from Norfolk Island to Melbourne and significantly worse than the threshold levels for the expected flight from Melbourne to Sydney. This deterioration in fatigue-related scores was associated with the extra rest time extending the second duty period to 0600 AEDT, which meant that the flight crew would have been operating through the circadian low.[257]

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255 A captain and a first officer normally recorded the same duty times for each trip. Flight crew could not recall their practice for when a duty period started and there was likely to be variations across pilots. For the purpose of the investigation, the most accurate estimate of each pilot's duty times was used.

256 There was no indication the Westwind operations manager's messages or call interrupted the captain's sleep.

257 Circadian low: the period of time in a circadian cycle when body temperature, mental performance and alertness are generally at their lowest. For most people it typically occurs from about 0200 to 0500.

As noted in *Background information on bio-mathematical models of fatigue*, BMMFs are based on group-averaged data. It is widely agreed they should not be used to make specific decisions regarding a specific individual's fatigue level, and any attempt to do so should be interpreted with great caution. Both SAFE and FAST enable the user to enter actual or estimated sleep times. Using the updated roster and the estimated sleep times of the captain (see *Personnel information*), the resulting scores were slightly worse than using the updated roster with the default estimated amounts of sleep. However, the scores during the period just prior to and during the accident flight were notably better than the nominal threshold levels.

Review of other duty periods

As noted above, the FRMS did not specify a maximum length for a duty period, or state different requirements for the length of duty periods depending on the time of day. The ATSB reviewed the Westwind fleet's rosters for the 6 months prior to 18 November 2009. There were at least six occasions when a duty period was more than 15 hours, and several other duty periods that were 14–15 hours. A significant proportion of the longer duty periods included late night hours (between 2200 and 0600). The extent to which the longer duty periods were scheduled or due to unanticipated delays could not be determined.

In terms of time off duty, there was a relatively small number of occasions were time off duty was required during a trip and many occasions when two trips were rostered in close succession. The requirement to have 10 hours time off duty following a duty period of at least 6 hours was generally followed. Five exceptions included:

- A 15-hour duty period ending at 0100 local time followed by 5 hours time off duty and then a 13-hour duty period.
- A 14-hour duty period ending at 1000 local time followed by 6.75 hours time off duty and then a 13.5-hour duty period. This occurred during the 29–30 September 2009 trip to Apia. As noted in *30 September 2009 flight from Apia to Norfolk Island*, this trip required a diversion to Nadi due to a tsunami warning in Apia, before returning to pick up the patient. The scheduled roster included shorter duty periods and 10 hours time off duty.[258]
- Three occasions where the time off duty was just under 10 hours. All three cases occurred overnight at the pilot's home base.

The ATSB examined several roster periods over the previous 6 months where a Westwind pilot's FAID score had exceeded 50. The duty times were analysed using SAFE and FAST. For most of the cases, the FAID scores remained well below the default threshold of 75, but the SAFE and/or FAST scores exceeded those programs' default thresholds. These rosters generally involved a pilot undertaking limited duty time in the previous 7 days and then conducting one or two long duty periods, with a significant proportion of the duty periods occurring at night.

The 29–30 September 2009 trip to Apia was the only occasion when a pilot's FAID scores exceeded the threshold of 75, with both pilots' scores just exceeding the threshold. The SAFE and FAST scores for this roster pattern significantly exceeded default thresholds.

The ATSB also examined the duty periods for other air ambulance trips from Sydney to Apia (or nearby Pago Pago) and return that involved transporting a patient to either Sydney or Melbourne. These included:

- Four trips in 2004–2005 prior to the upgrading of the operator's FMS to FRMS (when there was no specific requirements for periods of time off duty and limited processes for an extension to duty). The time off duty periods in Apia were about 2 hours (commencing at 1600 AEDT),[259]

[258] The air ambulance provider's log for the 29-30 September 2009 flights indicated that on that occasion the Westwind operations manager advised the provider the flight crew required a 10-hour break on the ground.

[259] This trip was the only trip that involved transporting a patient to Melbourne. The crew had a 7-hour rest period in Melbourne before returning to Sydney.

5 hours (commencing at 2300 AEDT), 9 hours (commencing 0400 AEDT), and 10 hours (commencing 0130 AEDT).

- One trip in 2008, for which the time off duty period was 12 hours (commencing at 0300 AEDT).
- One trip in 2009, for which the time off duty was several days (due to the charter client's requirements).

Safety management and management oversight

General requirements and guidance

International requirements and guidance

In 2006, ICAO introduced a standard, in Annex 6 (Operation of Aircraft) Part I, for each State to require commercial air transport operators to have a safety management system (SMS). An SMS was defined as:

> A systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures.

The standard stated the SMS, as a minimum:

> a) identifies safety hazards;
>
> b) ensures the implementation of remedial action necessary to maintain agreed safety performance;
>
> c) provides for continuous monitoring and regular assessment of the safety performance; and
>
> d) aims at a continuous improvement of the overall performance of the safety management system.

The annex stated these requirements were to apply from January 2009, and prior to that they were included as recommendations.

ICAO provided detailed guidance for the development of an SMS, with the first edition of its Safety Management Manual (SMM) published in 2006. A second edition was published in 2009. In 2009, Annex 6 Part I also included an appendix describing a framework for an SMS.

Australian requirements and guidance

The *Civil Aviation Act 1988* outlined general requirements for AOC holders. These included:

> [Section 28BD] The holder of an AOC must comply with all requirements of this Act, the regulations and the Civil Aviation Orders that apply to the holder.
>
> [Section 28BE (1)] The holder of an AOC must at all times take all reasonable steps to ensure that every activity covered by the AOC, and everything done in connection with such an activity, is done with a reasonable degree of care and diligence...
>
> [Section 28BF (1)] The holder of an AOC must at all times maintain an appropriate organisation, with a sufficient number of appropriately qualified personnel and a sound and effective management structure, having regard to the nature of the operations covered by the AOC…

CAOs outlined additional general requirements for operators, with CAO 82.1 applicable to charter and aerial work operators, CAO 82.3 applicable to low-capacity RPT operators and CAO 82.5 applicable to high-capacity RPT operators.[260]

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[260] Low-capacity operators use aircraft with a certified seating capacity of 38 seats or less, or a maximum payload of 4,200 kg or less. High-capacity operators use aircraft with a certified seating capacity of more than 38 seats, or a maximum payload of more than 4,200 kg.

CASA provided guidance material to operators about safety management from 1998. In 2002, it published an NPRM for CASR Part 119,[261] which proposed detailed requirements and guidance for an SMS.

CASA subsequently encountered delays with the implementation of Part 119. To implement ICAO's SMS requirements, CASA introduced changes to CAO 82.3 (for low-capacity RPT operators) and CAO 82.5 (for high-capacity RPT operators). The CAO 82 requirements for an SMS for RPT operators took effect on 31 January 2009. At the same time, CASA issued guidance material to operators in CAAP SMS-1(0) (Safety management systems for regular public transport operators).[262]

Based on the ICAO SMM, the CAOs and the CAAP outlined an SMS framework with four major components:

- safety policy, objectives and planning
- safety risk management
- safety assurance
- safety training and promotion.

Each of these components included multiple elements. More specifically, CAO 82.3 and 82.5 included:

> An SMS must, as a minimum, include the following:
>
> (a) a statement of the operator's safety policy and objectives, including documented details of the following:
>
> (i) the management commitment to, and responsibility for, safety risk management;
>
> (ii) the safety accountabilities of managers;
>
> (iii) the appointment of key safety personnel;
>
> (iv) the SMS implementation plan;
>
> (v) the relevant third party relationships and interactions;
>
> (vi) the coordination of the emergency response plan;
>
> (b) a safety risk management plan, including documented details of the following:
>
> (i) hazard identification processes;
>
> (ii) risk assessment and mitigation processes;
>
> (c) a safety assurance system, including documented details of the following:
>
> (i) safety performance monitoring and measurement;
>
> (ii) management of change;
>
> (iii) continuous improvement of the SMS:[263]
>
> (d) a safety promotion system, including documented details of the following:
>
> (i) training and education;
>
> (ii) safety communication…

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[261] NPRM 0201OS, April 2002, Air Operator Certification - Air Transport, Proposed Civil Aviation Safety Regulation (CASR) – Part 119.

[262] A draft version of the CAO 82 requirements and the CAAP were distributed to the industry in an NPRM in November 2008.

[263] CAAP SMS-1(0) included a fourth element under safety assurance titled 'internal safety investigation'.

CASA permitted operators to introduce an SMS in a phased approach, and CAO 82.3 required operators submit their SMS implementation plan by 1 July 2009. CAAP SMS-1 recommended that the SMS for low-capacity RPT operators be implemented in three phases:[264]

- phase 1 (complete by 1 February 2010), including management commitment and responsibility, safety accountabilities of managers, appointment of key personnel, reactive risk assessment and mitigation process, reactive safety performance monitoring and measurement, training and education of key personnel
- phase 2 (complete by 1 July 2010), including third party interfaces, coordination of the emergency response plan, proactive/predictive hazard identification, proactive/predictive risk assessment and mitigation, training and education of all safety critical personnel and safety communication
- phase 3 (complete by 1 February 2011), including change management, continuous improvement, and additional training, education and safety communication.

In broad terms, the SMS elements and recommended phases in CAO 82.3 and CAAP SMS-1(0) were similar to those proposed by ICAO in its SMM.

To ensure low-capacity RPT operators' had their SMS approved by 1 February 2010, CASA advised operators to submit their proposed SMS manual by 2 November 2009.

Further information regarding CASA's implementation of the SMS approach for operators is provided by the Australian National Audit Office.[265]

Operator requirements

Prior to April 2009, the operator had many elements of an SMS, which were distributed across several manuals. These included:

- Hazard and Incident Reporting System (latest version 2004)
- Audit Manual (latest version 2003)
- Operations manual part A – Policy and Organisation (last amended July 2008)
- Operations manual part G – Fatigue Risk Management System Manual (last amended December 2007).

A CASA audit of the operator in October 2007 identified the SMS processes as defined in the Hazard and Incident Reporting System manual were out of date and inconsistent with the FRMS manual (see *Oversight of safety management and management oversight*). Similarly, the operator identified in an internal audit in March 2009 that the SMS processes as defined in its manuals were out of date. In response, it developed its Safety Management System (SMS) manual in April 2009.

As the operator's AOC included approval for RPT operations (for freight operations in Westwind aircraft), it was required to comply with the CAO 82.3 SMS requirements for low-capacity RPT operators introduced in 2009. It submitted an SMS implementation plan to CASA in June 2009, which was approved by CASA in October 2009. The operator subsequently submitted version 1.1 of the SMS manual (September 2009), which CASA approved in January 2010. The SMS applied to all aspects of the operator's operations.

The following sections provide information on some elements of the operator's safety management and related processes. Prior to discussing these elements, the report provides additional background information regarding the operator's organisation in the period leading up to the 18 November 2009 accident involving VH-NGA.

[264] The phases for high-capacity RPT operators were the same, though less time was provided for compliance.

[265] Australian National Audit Office, Implementation and administration of the Civil Aviation Safety Authority's safety management system approach for aircraft operators, Audit Report No. 13 2010-1011, October 2010.

Safety policy

The operator's SMS manual specified its safety policy. The policy required senior management demonstrate a commitment to safety and risk management in operational decisions, and provide adequate resources to maintain an effective SMS. The policy also emphasised that all staff were responsible and accountable for maintaining safety standards, and that free and honest reporting of safety issues was to be encouraged and fostered in accordance with 'just culture' principles.

Prior to the SMS manual being released in April 2009, the Hazard and Incident Reporting System manual outlined the operator's safety policy. It was similar in nature to the 2009 safety policy.

Roles and responsibilities

Senior management

As noted in *Operator information*, the operator (Pel-Air Aviation) was fully owned by another airline (REX). The operator's activities were overseen by a board whose role was to provide strategic direction. The board had three directors.

One of the directors was the AOC Holder. The AOC holder was also the chief operating officer, chair of the operator's management committee, and a member of the operator's safety management group (SMG). He had over 15 years experience in senior management roles within the operator.

The operator's SMS manual stated the AOC holder had overall responsibility for the performance and supervision of the operator's SMS. It also stated his roles and responsibilities included:

- ensuring compliance with all relevant regulatory requirements
- giving direction and providing facilities and resources adequate for managing the SMS
- developing and maintaining the safety policy.

The OM listed similar roles and responsibilities for the chief operating officer.

In addition to the AOC holder, one of the other board directors was also member of the management committee and a member of the SMG.

Chief pilot

CAO 82.0 Appendix 1 outlined the responsibilities of a chief pilot. These included:

- ensuring operations were conducted in compliance with the legislation
- arranging flight crew rosters
- maintaining records of flight and duty times
- maintain records of flight crew licences and qualifications
- monitoring operational standards
- maintaining training records and supervising the training and checking of flight crew.

The CAO also stated:

> A Chief Pilot, in exercising any responsibility, may delegate duties to other members of the operator's staff, but may not delegate training and checking duties without the written approval of CASA.

The operator's OM specified a more detailed list of responsibilities and duties, which was consistent with the requirements of CAO 82.0. The chief pilot reported to the AOC holder and the board. He was also a member of the operator's management committee and the SMG.

Following an internal review in March–April 2008 (see *Review of the training and checking organisation*), the board decided to replace the operator's chief pilot. Senior management advised the ATSB that, during 2008, the operator's board wanted to transition the operator's flight operations standards and safety culture from a general aviation approach to an airline approach. The operator was also in the process of introducing the Saab 340 into its operations. Accordingly, the board selected as the new chief pilot a Saab 340 pilot from the parent airline with training, checking and management experience. The new chief pilot was approved by CASA in November 2008.

When he was approved by CASA, the chief pilot also became the operator's HOTC, as at that time the operator could not find a suitable person to undertake the role. The OM stated the HOTC was responsible overall for monitoring operational standards and supervising the training and checking of all flight crew.

Senior management and the chief pilot reported that, after he was approved by CASA in November 2008, the chief pilot's initial priority was to improve the flight standards and safety culture of the operator's turboprop fleet, as that was considered to be the fleet with the highest potential risk at that time. Areas of concern included the experience levels of the flight crew and the introduction of the Saab 340 operation. After the turboprop fleet was being managed more effectively, the chief pilot would then direct his attention to the Westwind and military jet fleets. These fleets were mature operations, and were being managed by experienced pilots who were very familiar with their operations and had significant management experience as well as training and checking experience with those fleets. Therefore, senior management and the chief pilot considered them to be a lower priority for the chief pilot's attention than the turboprop fleet.

The chief pilot also noted that turboprop operations was his area of expertise, so it was easier to focus his attention on that fleet first. In addition, he reported there was some resistance to his efforts to improve the operator's procedures and practices to an airline standard, particularly from some flight crew and other personnel in the Westwind and military fleets. Accordingly, he adopted an incremental approach to making changes.

The chief pilot reported his major tasks during his first year with the operator included the introduction of Flight Crew Operating Manuals (FCOMs)[266] for the turboprop fleet, the introduction of the Saab 340 operation,[267] the introduction of simulator training for the Metro fleet, improving the process of controlling flight crew records across all fleets and introducing a formal Notice to Aircrew (NOTAC) communication process.[268] He also advised he developed improved and more transparent communications with CASA than had been the case in the past.

The chief pilot stated that, up until the time of the accident, he had minimal involvement with the day-to-day operation of the Westwind or military fleets, except dealing with some matters that had come to his attention (for example, see *Operator's practices*). His involvement with training and checking was limited to reviewing the paperwork that was submitted to him and ensuring records were kept up to date, as there had been ongoing problems with that in the past. His intention was to introduce FCOMs for the Westwind and Learjet aircraft, but this project had not commenced at the time of the accident.

The chief pilot did not hold a command endorsement on the Westwind, Learjet or EMB-120. His chief pilot instrument stated he did not need to hold an endorsement on these aircraft types as long as specified pilots continued to be employed by the operator and acted as senior pilots for these aircraft types.[269]

Westwind standards manager

The operator's organisational chart listed a 'standards manager' for each aircraft type, all of which reported to the chief pilot (as HOTC). The former chief pilot was listed as the standards manager

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266 An FCOM is a fleet-specific operations manual. It also generally includes more detailed information about aircraft systems than a typical operations manual.

267 Saab 340 maintenance was managed by the parent airline.

268 Commencing in July 2009, the operator's NOTACs advised flight crew of important information about their aircraft, systems or operations that were not contained in the OM, NOTAMs or other operational information. The information was generally of a temporary nature, and most of the NOTACs were directed at the operator's turboprop flight crew.

269 The former chief pilot's chief pilot approval also had a similar condition requiring a specified person to be employed and act as a senior pilot for the Metro and EMB 120. The Saab 340 was added to the operator's AOC in late November 2008.

for the Westwind fleet, and other experienced check pilots were listed as standards managers for the other fleets.

The organisational chart also included the role of General Manager Flying Operations (Medivac Charter), which was filled by the Westwind standards manager. In this general manager role, he reported direct to the AOC holder and the board. He was also a member of the operator's management committee and the SMG. The General Manager Flying Operations position was depicted at the same level in the organisational chart as the chief pilot. None of the other standards managers was a member of either of these committees.

The new chief pilot's instrument stated the senior pilot specified for the Westwind aircraft was the former chief pilot.[270] However, there was no definition of 'senior pilot' in the CARs, CAOs or CASA manuals. Similarly, the operator's OM did not define the role, responsibilities or duties of the 'senior pilot', 'standards manager' or General Manager Flying Operations (Medivac Charter).

The Westwind standards manager advised the ATSB that, after he was no longer chief pilot, he still in effect managed the Westwind fleet's activities. However, in April 2009, he had a disagreement with the chief pilot regarding their respective roles. From that time he undertook more of a background role, providing advice to the chief pilot as and when required. In particular, he had less involvement with training and checking activities, and had no involvement in developing or maintaining the operator's manuals. However, he was still closely involved in liaising with the air ambulance provider on air ambulance tasks, making management decisions regarding the submission of quotes for complex air ambulance tasks, providing flight planning and operational support to Westwind pilots, and being the point of contact for Westwind pilots regarding any concerns or questions they had regarding the aircraft or their tasks (see also *Assistance with obtaining information and completing flight plans*). He noted there was no formal announcement or documentation regarding his change of role, and he could understand why other people were not aware of the change.

Senior management, the chief pilot and safety personnel all recalled the Westwind standards manager was still managing the Westwind fleet's operations throughout 2009 up until the time of the accident. Senior management and the chief pilot noted the intention was for the chief pilot to take a more hands-on role with the Westwind fleet in the future, but this had not occurred by the time of the accident, and they were still relying on the standards manager to manage the fleet's operations. They also noted the standards manager had an important role in the organisation as he had substantially more knowledge and experience of the Westwind aircraft and the operator's Westwind operations than other management personnel. In addition, he had an important role in developing and maintaining commercial relationships with clients.

Most Westwind pilots recalled the standards manager was still in effect managing the Westwind fleet's operations up until the time of the accident. They generally stated they had a very high regard for the standards manager and his level of knowledge and experience of their operations, and they would seek advice from him and report any concerns to him regarding their tasks and day-to-day operations.

Most Westwind pilots also stated they had minimal interaction with the chief pilot. Some pilots reported they had some interaction with the chief pilot on specific matters he had taken an interest in, but the chief pilot was not involved in their day-to-day operations. Some pilots noted they were aware of tensions between the chief pilot and the Westwind standards manager, and they preferred to interact with the standards manager as he had a better understanding of the aircraft and their tasks.

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270 The former chief pilot's chief pilot approval also had a similar condition requiring a specified person to be employed and act as a senior pilot for each of the operator's turboprop aircraft.

The Westwind operations manager stated she reported to the Westwind standards manager and had minimal interaction with the chief pilot. She also understood that the standards manager was managing the Westwind fleet's operations up until the time of the accident.

A Westwind check pilot reported there was a lack of clarity regarding the role of the standards manager. Although he generally liaised with the standards manager on most issues, he noted the standards manager referred him to the chief pilot on some issues. Some other personnel noted there was a degree of confusion regarding the role of general manager relative to the role of chief pilot.

Safety management personnel

Up to August 2008, the operator's safety management functions were managed by the compliance manager. The OM stated this manager's responsibilities included developing and managing:

- regulatory systems compliance
- a system of auditing and site inspections for company operations
- a system of document control, amendment and distribution for the controlled company manuals
- the operator's SMS
- the operator's transport security program
- the operator's quality management system.

During 2004– 2008, the compliance manager also played a key role in managing various projects, such as the merger of the two AOC's in October 2006, the upgrading of the operator's FMS to an FRMS between 2004 and 2007 and the introduction of new aircraft types. He reported to the AOC holder.

Following the compliance manager's resignation in August 2008, senior management decided to have the parent airline group take over responsibility of several functions. The group compliance department took over management of the operator's compliance functions (in addition to those of the parent airline and a general aviation operator in the group). In November 2008 the group safety department took over management of the operator's safety management functions (in addition to those of the parent airline and the general aviation operator).

The operator's SMS manual outlined the roles and responsibilities of the safety manager and the compliance and quality assurance manager. These descriptions were broadly similar to those outlined in the OM for the previous compliance manager position. With regard to the operator's operations, the group safety manager reported to the AOC holder and the operator's board, and the compliance and quality assurance manager reported to the AOC holder.

In addition to the managers, the group safety and group compliance departments had several other officers. Prior to August 2008, the operator's compliance manager had some additional resources.

Safety management group

The SMG was chaired by the group safety manager. Its members included the AOC holder, another director, the chief pilot, the Westwind standards manager (in his general manager role), the group compliance and quality assurance manager, the engineering manager and the general manager of freight operations. The group met monthly, commencing in March 2009.

The SMS manual stated the SMG:

> …will provide overall control and management of day-to-day SMS issues and provide feedback to all staff on high and significant risk safety issues and safety policy as determined through both incident reporting analysis and auditing functions…

The manual stated the primary functions of the SMG were:

> - Act as a source of expertise and advise on all matters relating to safety.

- Review the status of high and significant hazard/risk reports and actions taken.
- Identify hazards and provide recommendations and or policy to provide defences to hazards.
- Review safety related audit report findings.
- Review and approve appropriate safety related audit responses and actions taken.

Prior to the group safety department assuming control the operator's safety management functions, there was a safety management committee (SMC). This committee was chaired by the compliance manager and had a similar membership as the SMG. Its role was primarily to review reported hazards and events and provide recommendations for improvement. It met several times a year, although it only met four times in 2008.

Management committee

The operator's management committee was chaired by the AOC holder, and its membership was similar to the SMG (or SMC). The committee met monthly, and reviewed progress of the activities of each of the operator's departments and made key decisions in relation to the operator's day-to-day activities.

Overview of hazard identification processes

A fundamental component of safety management is the identification of hazards with the potential to adversely influence flight operations. CAAP SMS-1 stated:

> Hazards can be identified from a range of sources including, but not limited to:
>
> • brain-storming using experienced operational personnel;
>
> • development of risk scenarios;
>
> • trend analysis;
>
> • feedback from training;
>
> • flight data analysis programs;
>
> • safety surveys and operational oversight safety audits;
>
> • monitoring of normal operations;
>
> • state investigation of accidents and serious incidents; and
>
> • information exchange systems (similar operators, regulators, etc.).

The ICAO SMM (second edition) provided a similar list of sources. It also noted hazard identification processes could be classified as:

- reactive or associated with events that have already occurred (such as accident and incident reporting)
- proactive or actively looking for hazards before they result in accidents or incidents (such as voluntary reporting systems, safety audits, and safety surveys)
- predictive or actively reviewing normal operations to identify future problems (such as hazard reporting, flight data analysis programs and structured monitoring of normal operations).

The SMM stated mature safety management required the integration of all three types of hazard identification processes. The use of purely reactive safety data was insufficient for safety management.

The operator's SMS manual stated:

> Both formal and informal processes are used to gather information from staff about hazards at Pel-Air, including:
>
> - Electronic reports submitted via the Safety Management System;
> - confidential surveys or questionnaires of staff;
> - audit results;

- informal communication; and
- observations of work practices and workflow.

The following sections provide information on the operator's various hazard identification processes. They then outline other SMS aspects.

Formal incident, hazard and fatigue occurrence reporting

Reporting processes

The operator's requirements for reporting incidents and hazards were outlined in the SMS manual and previously in other manuals. Personnel were required to submit formal reports to the group safety department (previously the compliance manager) to be reviewed by safety personnel and then the SMG (previously the SMC). Personnel had the option of submitting a report confidentially. The process for submitting a fatigue occurrence report was effectively the same, and this process was outlined in the FRMS manual.

All hazard, incident and fatigue occurrence reports were entered into a database for tracking and trend monitoring purposes. Prior to 2009, reports were submitted on paper and then tracked in a spreadsheet. At the beginning of 2009, the operator started using the group's electronic reporting system.

Safety personnel reported that, with the start of the parent airline group safety taking over the safety function, the reporting rate significantly increased in 2009 compared to previous years. This was particularly the case for the turboprop fleet.

A review of the available SMS data for the operator indicated:

- The total number of reports per 1,000 flights across all the operator's fleets was several times higher in 2009 than in 2007 or 2008.
- The total number of reports per 1,000 flights in 2009 (up to the end of November) for the turboprop fleet was at least two times the rate for the Westwind and military fleets. The available data was provided by aircraft type, and therefore it did not enable the rate for the Westwind fleet to be easily distinguished from the military fleet as both fleets flew Westwind aircraft.

Incident reports

The ATSB reviewed the operator's incident and hazard reports for 2009.[271] For the Westwind fleet, there were 12 incident reports:

- 7 failure to comply with external instructions/procedures events (all reported by external parties such as an ATS provider or an airport operator)[272]
- 4 technical failures (all of which resulted in diversions or a return to the departure airport)
- 1 airport lighting failure (which resulted in a diversion).

Safety personnel stated the reports from previous years would have been similar in nature. The reported incidents for the turboprop and military fleets generally involved similar types of events. However, they also included some incidents reported by pilots that were not externally reported and did not result in a diversion.

During interviews, the ATSB became aware of one 2009 incident that should have been reported in accordance with the operator's safety system, but was not formally reported (a high speed rejected take-off during a freight flight). There was also one flight to Norfolk Island that diverted to

[271] The operator used a different safety report database from the beginning of 2009. Its ability to search and identify incidents for years prior to 2009 was limited.

[272] In each case, the operator received a notification of these events from an external party. The operator then obtained a report from the captain of the flight.

Auckland in early 2009 due to low cloud at Norfolk Island.[273] This event was not formally reported as an incident, although it was known to management personnel.

As far as could be determined, all incidents during 2009 that were required to be reported to the ATSB in accordance with the *Transport Safety Investigation Act 2003* were reported.

The ATSB requested from the operator details of any incidents from 1 January 2002 to 18 November 2009 associated with fuel management or fuel planning involving a Westwind aircraft. No such incidents were identified. Similarly, none were identified in the ATSB occurrence database. Only one of the 12 reported incidents (of all types) in 2009 appeared to involve problems with flight planning or pre-flight preparation.[274]

A review of Westwind flight records from 1 January 2002 to 18 November 2009 identified no flights that landed with less than the fixed fuel reserve of 600 lb. Further details of fuel planning aspects of previous flights are provided in appendix M.

As noted in *Previous occurrences involving unforecast adverse weather conditions*, from interviews with Westwind pilots, three previous events were identified where a flight departed with the forecast conditions at the destination aerodrome being above the alternate minima, but the conditions then deteriorated to below the landing minima prior to arrival without the flight crew being made aware of the problem. One of these occurred in 2009 and the other two events occurred several years previously. As far as could be determined, none of these events were formally reported.

Hazard reports

During 2009 (and prior to 18 November 2009), there were two formal hazard reports associated with Westwind operations. They involved a pilot's qualifications not being updated before conducting a flight or being rostered for a flight. Both events were reported by support personnel.

During 2009 there were several hazards reports associated with the turboprop and military fleets, including hazards reported by flight crew members.

Fatigue occurrence reports

The FRMS manual stated that pilots' responsibilities included:

> Fly only when they consider themselves to be free from fatigue which may affect judgement and performance…
>
> Report all occurrences arising from hazards related to irregular working hours…
>
> Report to management, via the appropriate procedure for consultation, the circumstances in which fatigue and lack of sleep are impacting on their well being and workplace safety.

The FRMS manual also required pilots to submit a fatigue occurrence report form in various circumstances. These included when:

- a pilot's FAID score exceeded 75
- the extension of duty process had been applied and the resulting IFLS score exceeded the prescribed level
- a pilot considered that they were unable to complete an assigned duty due to insufficient rest or fatigue.

In the first two cases, the event would be identified by rostering personnel. In all cases the relevant pilot(s) were required to submit a report. The reporting form included a series of questions

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273 In both of these events the weather conditions encountered at Norfolk Island had been included on the aerodrome forecasts.

274 The flight crew were using an old navigation log for the flight, which included some waypoints that were different to those on the submitted flight plan. Consequently, the aircraft's flight path diverted from the submitted flight plan, which was detected by ATS.

to record what happened, the circumstances, the pilot's recommendations, and recent sleep and duty times.

During 2008, there were five fatigue occurrence reports associated with the Westwind fleet. All were reported due to a FAID score exceeding 75. Four of the events were attributed to the duty periods for ad hoc air ambulance and charter tasks not being updated in the roster and entered into FAID prior to new duty periods being assigned. These events resulted in changes to the operator's processes for submitting duty hours for completed tasks, and ensuring it had accounted for all duty periods prior to assessing a pilot's FAID score for a new task. The fifth event was attributed to unexpected delays in rostered freight tasks, with the operator's recorded response being to discuss the freight schedule with the client.

During 2009, there were two fatigue reports associated with the Westwind fleet:

- In January 2009 a pilot submitted a report when he was asked to conduct an overnight duty period with a start time about 9 hours after his previous overnight duty period ended. The pilot declined the duty, and the operator selected another pilot for the task. The operator's response to the report noted the processes of the FRMS were followed and no further action was required.
- On 29–30 September 2009, the captain of the accident flight and another pilot conducted an air ambulance task from Sydney to Apia (see *30 September 2009 flight from Apia to Norfolk Island*). Due to a tsunami warning at Apia, the aircraft had to depart to Nadi before picking up the patient, and the crew had a short rest period in Nadi before returning to pick up the patient and flying back to Sydney. The FAID scores of the planned duty periods were well below 75, but the scores for the actual duty periods were just over 75. Further information includes:
    - The resulting duty periods included 14 hours starting at 2000 AEDT on 29 September, a 6.75-hour period off duty and then 13.5-hour duty period starting at 1645 AEDT.
    - On 15 October 2009, the operator's SMG noted the crew's FAID scores on 30 September 2009 were 77 and 78, and in accordance with the FRMS the captain was requested to submit a report.
    - The captain subsequently submitted a safety report on 15 November 2009, which provided an explanation for the task's delays. He indicated fatigue was not involved, and he did not complete the fatigue questions.
    - During the reopened investigation, both pilots advised the ATSB they had limited sleep in Nadi and they were fatigued during the return flights.

During 2008–2009, there were six fatigue occurrence reports submitted by pilots in the operator's turboprop and military:

- three reports were associated with FAID scores over 75
- three reports were associated with a pilot not being able to obtain sufficient sleep.[275]

Reporting culture

Management and safety personnel stated the reporting culture within the operator had been problematic for many years. A CASA audit of the operator's turboprop AOC in 2006 noted the operator had experienced difficulty establishing an open and honest reporting system, and this had been associated with past events that had reduced pilot confidence. CASA and the operator's management personnel advised these concerns related to a 2003 incident involving a turboprop freight flight. The flight crew had reported the incident to the operator, who reported the incident to CASA, and subsequently CASA conducted an investigation and interviewed the flight crew. According to management personnel, aspects of this CASA investigation significantly reduced the willingness of flight crew across all its fleets to report incidents to the operator.

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[275] In addition to fatigue occurrence reports, there were two incident reports in 2009 involving the turboprop fleet where a flight crew member also reported they were fatigued.

Safety personnel advised another problem with the reporting culture had been the frequent change of reporting forms and processes over the years, which made it harder to motivate personnel to report matters. They also noted some management personnel had not actively supported the formal hazard and reporting processes. However, safety personnel noted there was a significant change in management support with the appointment of the new chief pilot in November 2008, with the new chief pilot actively supporting the operation of the SMS. The SMG minutes in May 2009 noted the chief pilot expressed concern with cultural issues within the operator's flight operations and not using the SMS system to report all safety events.

Safety personnel advised there were significant improvements in the reporting culture within the turboprop fleet during 2009. They also noted the military fleet had tended to report problems internally within their base in Nowra and it took some effort to encourage them to use the operator's formal SMS, but improvements were noted during 2009. However, safety personnel stated they had not identified any significant change in the reporting practices of the Westwind fleet. They believed that, if Westwind pilots were reporting incidents and hazards, they appeared to be reporting them to the Westwind standards manager rather than through the formal reporting system. The pilots would typically only submit a formal report when directly requested to do so.

Westwind pilots provided a range of responses regarding incident and hazard reporting. Some pilots noted they had no problems reporting matters that had to be reported, and others noted they would have been reluctant to voluntarily report incidents or hazards using the formal reporting system. Many Westwind pilots indicated that if they had reported any concerns or hazards, they would have reported them verbally to the standards manager rather than submit a hazard report.

In terms of fatigue occurrence reporting, some Westwind pilots stated they had declined to accept a task due to tiredness or fatigue, but that they had not submitted or been required to submit a fatigue occurrence report. Other pilots stated they had never declined a duty, and some of these pilots stated they would have been reluctant to report they were fatigued.

Several Westwind pilots stated that at times during flights they had been tired or fatigued, and some pilots indicated that on occasions they had been fatigued. However, most of these events did not result in a fatigue occurrence report. None of the pilots could recall completing a fatigue occurrence report unless it was required because the FAID score was over 75.

Informal reporting of hazards or concerns

Some Westwind pilots reported they had expressed concern to the Westwind standards manager and/or the chief pilot concerns regarding the adequacy of the flight planning tools and resources available to them. Although a flight planning software tool was introduced in late 2008 on computers at each base, the pilots reported this tool had limited functionality and/or was cumbersome to use (see *Availability of flight planning tools*).

Management personnel reported the most common concern they had received from Westwind pilots was related to 24-hour standby practices. Several pilots also noted concerns had been expressed regarding standby, and in one case a pilot reported concerns to CASA (see *Oversight of fatigue management*).

Darwin-based pilots reported a manager would occasionally visit Darwin and there would be informal discussions regarding various matters with the available pilots. However, Sydney-based pilots stated there were no pilot meetings where they could raise issues of concern. No line pilots were represented on the SMG (or the previous SMC).

As noted in *Operator's CRM training*, the operator provided recurrent CRM and FRMS training via CBT. As such, there were no classroom-based courses where line pilots had the opportunity to discuss safety-related matters.

Internal auditing

The operator had an internal auditing program, which included coverage of flight operations, engineering and other organisational functions and activities.

With regard to topics examined as part of the ATSB investigation (discussed in previous sections), the operator's internal audits included the following:

- In May 2007, an audit was conducted of the FRMS. The audit involved observing the processes used for managing and updating flight crew rosters, as well as interviewing rostering personnel and flight crew. The audit identified post-flight updating of the roster for Westwind pilots could be delayed because completed flight records with actual duty times were not always promptly passed to rostering personnel. The audit also identified some fatigue occurrence reports had been passed to the chief pilot and the compliance manager but not entered into the incident and hazard database. In addition, the audit found rostering personnel had not undertaken the operator's FRMS training. Finally, the audit report noted some pilots had limited understanding of the FAID scores.
- In August 2007, an audit was conducted of several flight operations and engineering aspects in preparation for an upcoming CASA audit. The 2-day audit focussed on already-identified areas of concern and was not a full organisational review. It included reviewing a sample of flight crew training and checking records and the spreadsheet used for tracking flight crew currency, with the report noting that there was no record of many pilots having conducted some types of training, including FRMS or CRM training. This problem was also subsequently identified by CASA (see *Oversight of flight crew training and checking*). The audit also reviewed the operations manual, focussing on areas of concern raised in recent CASA audits. It identified several minor issues that needed to be clarified.
- In January 2008, a brief audit was conducted of flight crew training and checking records, following the problems identified in the August 2007 internal audit. The audit note stated the records had improved, however some training records from prior to the AOC merger in October 2006 had been removed but were still relevant and should be replaced.
- In July 2008, a brief audit was conducted to examine the accuracy of duty time data that had been entered by rostering personnel into the FAID program to calculate FAID scores. No problems were identified. Safety personnel subsequently reported these checks were done on multiple occasions. However, there were no formal records of subsequent checks after July 2008.
- In March 2009, an audit was conducted on the operator's SMS. The audit identified many staff where unaware of the SMS policy and where it was located, the SMC had not been meeting regularly (and had not met since the compliance manager left in August 2008), and staff had not been receiving feedback regarding closed investigations. Following the audit and the development of the new SMS manual, the operator's personnel were provided with training in the operator's SMS processes, and the SMG started conducting monthly meetings. In addition, the safety department noted the use of the group's on-line reporting system meant that anyone reporting an incident or hazard would receive feedback.
- In May 2009, an audit was conducted of flight crew training and checking records. The audit identified that some flight crew folders were not up to date and the crew history spreadsheet was not up to date for some pilots.

As far as could be determined, none of the operator's internal audits examined flight planning or fuel management aspects.

During 2005–2009, CASA identified some problems associated with the operator's internal auditing processes (see *Oversight of safety management and management oversight*).

External audits

In addition to external surveillance by CASA (see *Regulatory oversight*), the operator was subject to a number of audits by external organisations, usually conducted on behalf of clients. The ATSB obtained and reviewed several of these audit reports.

The most detailed external audit of the operator was conducted on behalf of the air ambulance provider in November 2002, soon after the start of joint air ambulance operations involving the operator and the provider. The audit report made several recommendations regarding fatigue management, flight crew training and checking, safety management and cabin safety aspects. Most of these matters were addressed over subsequent years.

Subsequent external audits examined topics at a relatively general level and they did not conduct detailed examinations of flight planning, flight crew training and checking, fatigue management or cabin safety matters. These audits did not identify any significant problems.

None of the external audits specifically examined fuel planning or management aspects.

Observation and monitoring of operations

Observation and monitoring of line flights

Safety and compliance personnel reported they did not conduct any in-flight observation flights, and none of the operator's internal or external audits involved an auditor conducting a line observation flight. The chief pilot stated he observed a proficiency check on the Westwind fleet but he could not recall if he ever conducted a line observation flight with the Westwind fleet.

Safety personnel reported that during 2009 they conducted several ramp checks on the operator's aircraft. These were conducted on the turboprop fleet, and they identified several problems. They did not recall conducting any ramp checks on the Westwind fleet, and noted such checks would be difficult to organise given the ad hoc nature of the Westwind fleet's activities.

As noted in *Operator's practices*, flight crew proficiency checks for the Westwind fleet rarely included a normal line flight. In addition, many of the Westwind pilots conducted little if any flying with a check or supervisory pilot on international flights or flights to a remote aerodrome prior to becoming a captain. In addition, after a Westwind pilot was cleared to line as a captain, they rarely conducted line operations with a check or supervisory pilot. This was particularly the case for pilots based in Sydney where, after the departure of the then HOTC in August 2008, there were no other check or supervisory pilots other than the Westwind standards manager. As of November 2009, there were three captains and three first officers based in the operator's Sydney Westwind base, in addition to the standards manager. Two of the captains had 12 months experience and one had 6 months experience as a captain.

A review of flight records showed that, prior to May 2009, the Westwind standards manager regularly conducted charter and air ambulance flights, as well as proficiency check flights of other flight crew. From late May to August 2009 he did not conduct any flights. He stated that during this period he was busy working on contract submissions as part of his general manager role. He also had 6 weeks of leave during this period. From September to November 2009, he conducted several air ambulance and charter flights. However, he conducted limited check pilot duties, which were being primarily conducted by the operator's other approved Westwind check pilot (based in Darwin). Although the Westwind standards manager regularly conducted line flights, these were almost always conducted with first officers rather than captains.

Review of flight documentation

CAR 220 (Fuel instructions and records date) included:

> An operator shall maintain a record of the fuel remaining in the tanks at the end of each scheduled flight and shall review continuously the adequacy of the instructions in respect of the fuel to be carried in the light of that record...

The operator's OM also stated the chief pilot shall monitor the average consumption rate for each aircraft by reviewing the fuel records to compare the actual consumption rate with the fuel planning figures in the operations manual.

When interviewed during the reopened investigation, the chief pilot reported that he could not recall how the operator was monitoring aircraft fuel burns. He noted the Westwind standards manager had the relevant expertise to be conducting that type of task for the Westwind fleet.

The Westwind standards manager reported that, when he was chief pilot, he had developed a database that included all the details from flight record sheets submitted by the operator's pilots. This database allowed fuel consumption figures and other matters to be easily reviewed. However, the operator transitioned to a different database in mid-2008, and after that time he did not have ready access to the data from flight records and therefore did not review them. He also noted the fuel burn figures in the OM had been based on many years experience and were known to be quite accurate.

The OM required that flight crew submit their flight records, navigation logs, international flight preparation forms and passenger manifests at the end of each flight. Westwind pilots reported they regularly submitted all the required documentation. Soon after the accident, CASA reviewed the documentation the operator retained for a sample of recent international flights and noted for most of the flights only the flight record was available.

CAR 220 and the OM did not specifically require the operator to review flight planning or fuel planning documentation. Westwind pilots reported they rarely if ever received feedback from the Westwind standards manager or other personnel regarding aspects of fuel planning or fuel usage on their flights. The captain of the accident flight also reported he was never provided with statistics showing normal fuel loads for different flight distances or flight times.

Review of flight crew training and checking records

The chief pilot reported that, in his role as HOTC, his activities for the Westwind and military jet fleets were generally limited to reviewing documentation regarding training and checking activities w were submitted to him. He relied on the standards managers in the fleets to manage the training and checking functions for their fleets.

During 2009, the chief pilot became aware of various problems with the conduct of some training and checking activities across the fleets (for example, see *Operator's practices*). As a result, he required a number of the operator's check pilots to attend a CASA Professional Development Program in June 2009. He subsequently held a series of standardisation meetings with check pilots.

The chief pilot reported several problems were identified during 2009 with the currency of flight crew records. As a result, the operator applied significant effort to improve the processes for recording each pilot's training and checking activities and related qualifications, and improve the system to alert rostering personnel if a pilot's qualifications or currency were not valid.

Safety surveys, studies and reviews

Fatigue management

When the operator initially developed its FMS in 2001, an external specialist reviewed a sample of flight crew rosters using FAID. The review focussed on the operator's Westwind night freight activities between Darwin and Melbourne, and made recommendations to regarding these rosters and fatigue management.

CASA's first audit of the operator's FMS was conducted in March 2002. The audit report noted the operator had not effectively consulted with pilots, and it had not conducted an assessment of the fatigue risks associated with its operations. In response, the operator conducted a survey of all flight crew regarding their rosters and fatigue-related aspects. The results were reviewed by a management committee. A senior manager issued a memorandum to flight crew that provided feedback from the survey and clarified some issues. The memorandum also outlined some proposed changes to the FMS, including the introduction of the requirement for a 10-hour period of time off duty following a duty period of at least 6 hours. The memorandum also noted pilots had expressed concern about 24-hour standby not being included in FAID scores. As a result, 24-hour standby was to be abolished and future standby would be on the basis of 12 hours on and 12 hours off.

As far as could be determined, the operator conducted no other formal process of surveying flight crew to identify fatigue hazards and concerns. However, the compliance manager who upgraded the FMS to an FRMS during 2004–2007 reported he had many informal conversations with pilots when developing the FRMS.

The operator's FMS manual (January 2002) and FRMS manual (July 2007) both included a requirement for an annual system review of the FMS/FRMS. The review was required to obtain flight crew input regarding how the system was operating and any perceived problems. It was also required to consider results from audits, status of corrective actions from fatigue occurrence reports and various other items. Other than the activities conducted in 2001–2002, and the development work involved in upgrading the FMS to an FRMS, there was no evidence that a formal system review as described in the manual had been conducted prior to the accident in November 2009.

The operator's FRMS manual also stated:

> Risk assessments of operational processes enable the presence or suitability of fatigue management related controls to be assessed and where necessary instituted, amended or replaced.

However, the manual provided no detail on when or how risk assessments were required to be conducted. As far as could be determined, no such assessments were conducted.

As noted in *Background information on bio-mathematical models of fatigue*, FAID guidance material stated operators needed to assess their personnel's tasks to determine their criticality and the appropriate FAID scores to be used. As far as could be determined, the operator never conducted a study or analysis to review the suitability of using a default FAID score of 75 for its operations. According to the FAID provider, this was not unusual for organisations using a BMMF.

Review of the training and checking organisation

In March 2008, a CASA audit of the operator's flight crew training and checking system identified the operator had not provided its flight crew with annual FRMS training, as required by its OM, since 2002. The regulator issued a safety alert regarding this issue and requests for corrective action (RCAs) regarding other flight crew training issues (see *Oversight of flight crew training and checking*). In response to the safety alert, the board chairman requested another director conduct a review of the circumstances that led to the issue of the safety alert, as well as related aspects of the operator's management of flight crew training and checking.

The detailed review involved interviewing a number of personnel and reviewing a range of documentation. Completed in April 2008, the review identified a number of problems. These included the then chief pilot spending too much time on commercial and operational matters rather than regulatory responsibilities, and the training and checking system suffering from the chief pilot and HOTC often being called out on flying duty. In addition, there were limitations in the communications between key personnel. The report noted the problems identified by CASA with the conduct of some types of training in March 2008 had previously been identified in both internal and CASA audits but not addressed.

The review made several recommendations to improve the training and checking system's organisation, record keeping and review processes. It also recommended the chief pilot position be more focussed on regulatory functions and less confused with commercial functions, and a new person be assigned to the role of chief pilot (see also *Overall assessment of the operator*). In addition, it recommended changes to the compliance manager's role, so it focussed on monitoring compliance and was not associated with developing training programs.

Other surveys, studies and reviews

Since the commencement of air ambulance operations in 2002, there were no surveys, studies or reviews of the operator's conduct of these operations. Similarly, the ATSB found no indication of any other studies, surveys or reviews undertaken into the flight operations activities of the Westwind fleet during the period from 1 January 2002 to 18 November 2009.

Risk assessment and mitigation

After an incident, hazard or occurrence report was received, it was assessed by safety personnel. This involved using a risk matrix to classify the report's risk level, with the risk level determining the depth of investigation and priority for action. An investigator was then assigned, and the investigator's findings and recommendations were reviewed by the SMG (or previously the SMC).

Internal audits, CASA audits and other documents indicated that during 2006 and 2008 there was often a backlog with the processing of incident, hazard and fatigue occurrence reports. More specifically:

- In an internal report for the management committee in June 2006, the compliance manager noted the functionality of the FRMS was 'at a standstill' due to insufficient resources for 'report processing and administration, risk assessment and corrective actions'. The report indicated similar problems with the SMS.
- An internal audit of the FRMS in May 2007 noted several submitted fatigue occurrence reports had not been processed.
- A CASA audit in October 2007 noted there had been a breakdown in the processing of SMS reports due to insufficient resources (see *Oversight of safety management and management oversight*). It also noted that, following the full takeover of the operator by the parent airline, management had committed more resources to the compliance and safety sections to help address this and related issues. In its response to the CASA observation, the operator stated the 'root cause' of the problem had been the availability of resources and that a compliance officer had been employed to assist.
- The SMC minutes of a brief meeting in August 2008 indicated there were many outstanding reports in the system.

Safety personnel stated they would not close a report unless they received evidence that corrective action had been implemented. This resulted in difficulties at times with some managers and the ability to obtain evidence of corrective action from them.

An internal audit of the SMS in March 2009 noted the SMC had not been meeting regularly and the SMS was not operating effectively. From March 2009, the SMG met monthly. The SMG meeting minutes showed incident, hazard and fatigue occurrence reports and audit findings were regularly reviewed. Key issues arising from the reports or audits, and or other matters raised, resulted in action items assigned to a manager or safety officer. The progress against action items was regularly monitored and tracked.

Resourcing and commitment

As indicated in the previous section, a number of CASA audits and other documents indicated safety and compliance personnel had insufficient resources to conduct all of their required tasks at times during 2005–2008 (see also *Oversight of safety management and management oversight*). Safety personnel confirmed there was often insufficient resources to conduct all of their required tasks during this period. Although additional resources were employed at times, these resources were not always maintained and the mismatch between the resources required and resources available was not fully addressed.

Safety personnel also reported that prior to 2009 there was limited support or involvement from some key management personnel with regard to the operator's safety and compliance activities.

Safety personnel recalled there were no apparent problems with their level of resourcing during 2009. They also noted there was active support and involvement from the new chief pilot in SMS activities during 2009. However, they noted there was still difficulty in implementing SMS activities within the Westwind fleet.

Regulatory oversight

The function of the Civil Aviation Safety Authority

CASA was responsible, under the provisions of Section 9 of the Civil Aviation Act 1988, for the safety regulation of civil aviation in Australia and of Australian aircraft outside of Australia. Section 9(1) stated the means of conducting the regulation included:

> (c) developing and promulgating appropriate, clear and concise aviation safety standards;
>
> (d) developing effective enforcement strategies to secure compliance with aviation safety standards;
>
> (da) administering Part IV (about drug and alcohol management plans and testing);
>
> (e) issuing certificates, licences, registrations and permits;
>
> (f) conducting comprehensive aviation industry surveillance, including assessment of safety-related decisions taken by industry management at all levels for their impact on aviation safety;
>
> (g) conducting regular reviews of the system of civil aviation safety in order to monitor the safety performance of the aviation industry, to identify safety-related trends and risk factors and to promote the development and improvement of the system;
>
> (h) conducting regular and timely assessment of international safety developments.

The two primary means of oversighting a specific operator's aviation activities were:

- assessing applications for the issue of or variations to its AOC and associated approvals (including key personnel and the training and checking organisation)
- conducting surveillance of its activities on a regular basis.

Up until 2004, CASA oversight of the operator's jet AOC was conducted by the Bankstown general aviation (GA) field office[276] and oversight for the operator's turboprop operation was conducted by the Brisbane air transport office. In August 2004, responsibility for oversighting the turboprop AOC was transferred to the Bankstown office. The Bankstown office retained oversight responsibility for the operator when the two AOCs were merged in October 2006.

This section briefly overviews the processes involved in assessing variations and conducting surveillance, and then discusses CASA's oversight of specific aspects of the operator's activities. The section focusses on CASA's oversight of flight operations activities conducted under the operator's AOC during 2005–2009, with some events prior to 2005 discussed when relevant.

Processes for assessing variations to approvals

CASA was required by the Civil Aviation Act 1988 to satisfy itself about various matters when processing an application for the issue of, or variation to, an AOC. Section 28(1) of the Act stated:

> (1) If a person applies to CASA for an AOC, CASA must issue the AOC if, and only if:
>
> (a) CASA is satisfied that the applicant has complied with, or is capable of complying with, the provisions of this Act, the regulations and the Civil Aviation Orders, that relate to safety, including provisions about the competence of persons to do anything that would be covered by the AOC; and
>
> (b) CASA is satisfied about the following matters in relation to the applicant's organisation:

[276] Up to 2006, the Bankstown field office was located within the Sydney Basin Area Office. After 2006 it was located within the Sydney Region Office.

> (i) the organisation is suitable to ensure that the AOC operations can be conducted or carried out safely, having regard to the nature of the AOC operations;
>
> (ii) the organisation's chain of command is appropriate to ensure that the AOC operations can be conducted or carried out safely;
>
> (iii) the organisation has a sufficient number of suitably qualified and competent employees to conduct or carry out the AOC operations safely;
>
> (iv) key personnel in the organisation have appropriate experience in air operations to conduct or to carry out the AOC operations safely;
>
> (v) the facilities of the organisation are sufficient to enable the AOC operations to be conducted or carried out safely;
>
> (vi) the organisation has suitable procedures and practices to control the organisation and ensure that the AOC operations can be conducted or carried out safely…

The procedures for assessing an application for the issue of, or variation to, an AOC were contained in the CASA *Air Operator Certification Manual* (AOCM). It contained checklists and explanatory notes to assist CASA inspectors during the assessment process. Separate guidance material was provided for high-capacity RPT operations and 'other than' high-capacity RPT operations (such as the operator of VH-NGA).

For the initial issue of an AOC, the assessment process was divided into a series of phases that required CASA flying operations and airworthiness inspectors to carry out a number of tasks, including:

- evaluation of the operator's manuals and other documents required by the legislation
- inspection of the operator's organisational structure and staffing, and the proposed operations, facilities, aircraft and aerodromes, including the conduct of proving flights (if required)
- certification of various personnel, and the approval of the training and checking organisation.

When an operator sought to change its AOC, it was required to submit an application with relevant information to CASA. The AOCM noted it was administratively easier to process changes as a new AOC rather than a variation to an existing AOC. Regardless of how it was processed administratively, the manual stated:

> … CASA must still be satisfied that an applicant can comply with the provisions of the Act Regulations [sic] and Orders that relate to safety (section 28).
>
> This means the applicant must supply CASA with all relevant information about a proposed variation and CASA must assess the information, conduct appropriate inspections and satisfy itself that the applicant can properly undertake the new activities.

The manual indicated that changes to an AOC did not require a full assessment of the operator's existing manuals and processes that were not affected by the change. For example, in terms of an operations manual, the AOCM stated:

> … if the information is already with CASA as a result of the existing AOC there is no need for the applicant to repeat the information, nor is it appropriate for CASA to reassess the information.

CASA assigned each AOC a flying operations inspector (FOI). This assigned FOI was the main point of contact between the operator and CASA regarding regulatory approvals and CASA surveillance activities. Depending on the nature of the activity, a range of other CASA personnel could be involved.

Processes for conducting surveillance

Approach to surveillance

In order to fulfil the function prescribed in Section 9 of the *Civil Aviation Act 1988*, CASA developed a surveillance program to determine whether aircraft operators, maintenance organisations and other organisations were meeting the regulatory requirements. The CASA *Surveillance Procedures Manual* (SPM) defined surveillance as:

> … the mechanism by which CASA monitors the on-going safety health and maturity of permission holders undertaking aviation endeavours. Surveillance comprises scheduled audits, special audits and spot checks. It is the examination and testing of systems including sampling of products, and gathering of evidence, data, information and intelligence.

The surveillance program was documented in various CASA manuals. From 1994 until 1999, the program was known as the Aviation Safety Surveillance Program (ASSP), and the ASSP Manual was issued to staff with responsibilities for planning and conducting surveillance activities. During 2000–2001, the ASSP Manual was progressively replaced by Compliance Management Instructions (CMIs) as CASA reviewed its surveillance planning activities and changed the focus of its surveillance activities for airline and larger non-airline operators from product-based to systems-based auditing.[277]

In November 2001, CASA commenced a project to replace the ASSP, which resulted in the development of the SPM, which was released in November 2003.[278] The SPM contained procedures and checklists to assist CASA staff in the planning, preparation, conduct, and reporting of surveillance activities. In a section on surveillance philosophy, the manual stated:

> CASA will discharge the obligations accepted by Australia, under the Chicago Convention and the Civil Aviation Act, by deploying appropriately experienced and trained teams of Auditors to conduct comprehensive surveillance.
>
> The minimum compliance standards required to be met and continually maintained by Certificate/Permission holders are those that exist during the issuance of the authorisation at entry and any subsequent authorised changes or variations to the authorisation. These are articulated in the relevant entry control manuals. Where civil aviation authorisation holders' manuals and operational plans are submitted to CASA for acceptance or processing an approval then those accepted standards are the standards against which compliance is measured, subject to legislative requirements requiring the authorisation holder to update their manuals as the result of changes in the Certificate/Permission holder's operations, aircraft or equipment, or in the light of experience.
>
> CASA will encourage the aviation industry to take on standards higher than the minimum required by regulations and those standards will be assessed during surveillance.

The SPM outlined the following types of surveillance:

- scheduled audits
- spot checks
- safety trend indicator (STI)
- special audits.

Scheduled audits

The SPM defined an audit as:

> The objective examination of evidence to determine that the Auditee has documented and implemented appropriate systems to ensure compliance with relevant Legislative requirements and other accepted safety standards such as those outlined in Civil Aviation Advisory Publications (CAAPs) or Advisory Circulars (ACs).

The SPM outlined a systems audit approach. It stated:

> A Systems Audit seeks to assess an Auditee's management system and its ability to keep operational risks as low as reasonably practicable. To achieve this, safety-related processes are audited to

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277 Product-based surveillance focusses on the end products of a system, whereas systems-based surveillance focusses on the systems an organisation uses to produce the products (or safe outcomes). Product-based surveillance activities were also known as 'spot checks'.

278 The SPM was also developed in response to recommendations from the Australian National Audit Office (ANAO) issued in its Audit Report No. 19 1999–2000, Aviation Safety Compliance, Civil Aviation Safety Authority, and Audit Report no. 66 2001–2002, Aviation Safety Compliance Follow-up Audit, Civil Aviation Safety Authority.

assess if they are operating in accordance with the Auditee's documentation and Civil Aviation Legislation.

The manual also stated:

CASA's Systems Audit Approach aims to encourage and guide the aviation industry to assume higher levels of responsibility for safety. This is achieved by highlighting the following to industry management:

- deficiencies in existing safety systems with regard to applicable Civil Aviation Legislation, and
- The management's responsibility for safety as required by legislation.

CASA should not dictate how an Auditee should resolve deficiencies. CASA may provide assistance to the Auditee by highlighting the appropriate guidance material with necessary explanation. The Auditee should be responsible for identifying the cause of the system deficiency (identified during the audit) and making the necessary changes. The Auditee should internally verify changes implemented and CASA may verify the effectiveness of these changes in future audits…

An organisation's management of safety-related systems provides a means to keep operational risk as low as reasonably practicable.

This means the Auditee must have:

- Documented procedures;
- Adequate, trained personnel;
- Adequate resources;
- Monitoring and improvement systems appropriate to their activities; and
- A committed management team prepared to fulfil their obligations, as defined in Legislation.

CASA's audit approach was based on its management system model. The model consisted of four system attributes, which were summarised in the SPM:

Management Responsibility

Management Responsibility ensures responsibilities and authority are defined for the processes and that management have ensured the processes, those for organisational functioning and also those for monitoring and improving them, are adequately designed and implemented.

Infrastructure

Infrastructure must be in place to support the operation, including the various controls to continuously ensure their updating and suitability.

Process in Practice

Process in Practice assesses: the legislative compliance, the effectiveness of policies and procedures in supporting the processes, the level of implementation of the policies and procedures, the adequacy of infrastructure and their effective use in supporting the processes; and the clear identification and workings of the interrelationships and interdependencies between various processes.

Monitoring and Improvement

This focuses on finding problems within the system through internal audits, provides system feedback including latent conditions through internal reporting, finds causal factors through investigation and takes action to remedy the problems, eradicate the causes and remove latent conditions through remedial, corrective and preventive actions. As a result of auditing a number of processes, an overall assessment of the Monitoring and Improvement systems can be made.

Note: Given organisation size, these attributes may not be documented formally. However, the principles will apply in the management of any organisation.

The SPM stated these four attributes could be examined for each system element. Guidance on system elements for different types of operations was provided in separate documents. For a general aviation (or non-airline) operator, the system elements were classified in four groups, as indicated in Figure 43.[279]

Figure 43: Matrix of CASA's management system model attributes and system elements for a non-airline operator

Why / What	Attribute	Management Responsibility			Infrastructure				Process	Monitoring and Improvement			
System	Component (Why) / Element (What)	Management Commitment	Management Planning	Management Review	Facilities	Tools Equipment Materials	Data, Information and Records	Personnel	Processes in practice	Internal Audit	Internal Reporting	Investigation	Remedial Corrective preventative action
Operational Personnel	Crew Scheduling												
	Operational standards												
Aircraft	Airworthiness Control												
	Maintenance System												
	Line Servicing												
	Airworthiness Assurance												
Cargo and Passengers	Passenger Control												
	Non-DG Cargo/Baggage system												
	DG-Cargo control system												
	Fuel Load control system												
	Aircraft Load control												
Flight Operations	AOC Operations												
	Operational support systems												
	Flight System												
	Operating ports												
	Air-routes												

Source: Civil Aviation Safety Authority's Surveillance Procedures Manual

Explanatory material in the SPM or in associated documents indicated:

- for the operational personnel system:
  - the crew scheduling element included ensuring rostered operational personnel had appropriate qualifications, certification and recency as well as flight and duty times (or fatigue management)
  - the operational standards element included initial training, proficiency checking, remedial training and upgrade training of flight crew and other relevant personnel
- the aircraft system elements considered aspects from the perspective of an AOC holder[280]
- the cargo and passengers system elements considered aspects relating to the loading of the aircraft and the safety of personnel on the ground[281]
- for the flight operations system:
  - the AOC operations element included systems to contain operations to that authorised in the AOC and to control operations

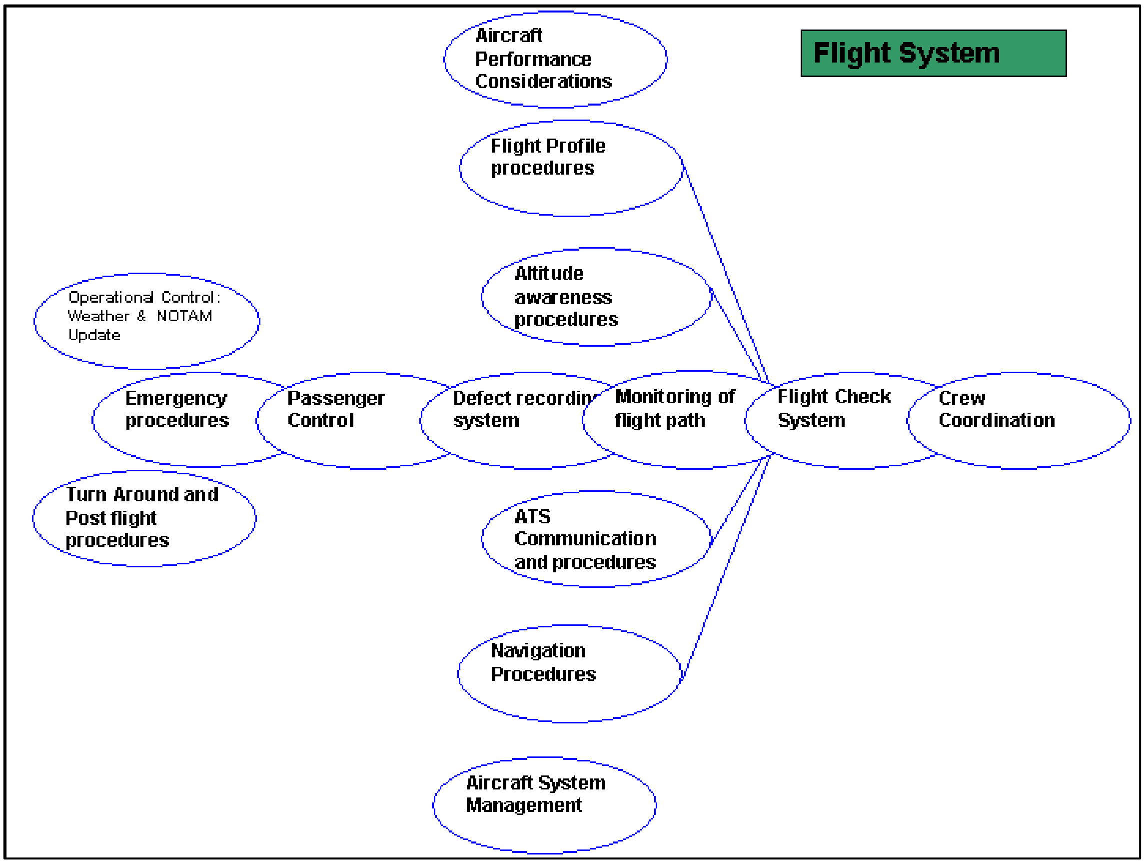
279 For airline operators, CASA used a different list of elements based on a list developed by the US Federal Aviation Administration.

280 Different elements were specified for auditing an organisation's maintenance certificate of approval (COA), and COAs were generally audited separately to AOCs.

281 For example, the fuel load control element referred to the processes involved in ensuring that refuelling was done safely, and the fuel uploaded was the right quality and the same amount as that ordered.

- the operational support systems element included elements such as the provision of performance data and flight plan preparation services
- the flight system elements included information, procedures and instructions regarding 14 sub-elements (as shown in Figure 44)
- fuel planning was not specifically listed as an element or sub-element (other than in terms of the provision of flight plan preparation services)
- in-flight fuel management was associated with the flight system sub-elements 'operational control procedures – weather and NOTAM updates' and aircraft systems (in terms of procedures for operating the fuel system, including maintaining a fuel log and fuel quantity cross-checks)
- the safety of passengers during flight was included as a sub-element under the 'flight systems' element (whereas the passenger control element under the 'cargo and passengers' system referred to the processes associated with ensuring passengers were allocated appropriate seats and the safety of passengers as they got on and off the aircraft).

Figure 44: Components of the 'flight system' element



Source: Civil Aviation Safety Authority's Surveillance Procedures Manual

The SPM and associated documents outlined some general concepts and questions that could be used for assessing each attribute and some of the system elements. Guidance was also provided for conducting the different stages of an audit.

Depending on its scope, audits were conducted by one or more CASA inspectors. The lead auditor for an AOC audit was often but not always the assigned FOI for the AOC.

Spot checks

The SPM defined a spot check as:

> Spot Checks are product inspections, and include Ramp Checks, En Route Inspections, Port Inspections, ATO [approved testing officer] Inspections, etc.[282] Spot Checks are designed to gather information on particular facets of the aviation industry and are usually carried out independently of an audit.

It also stated:

> Spot Checks are planned on an "as required" basis for certificate and permission holders. Plan for a spot check to take up to a half-day audit time to complete. If a spot check is likely to take more than half a day, then a Special Audit should be considered.
>
> Spot Checks are random checks carried out to observe processes, and/or inspect aircraft, documents, and records. They may also be undertaken for monitoring compliance with special airspace/operating procedures introduced for special events where a higher than normal air activity takes place. Spot checks may be undertaken independently of scheduled or special audits, or used for product verification or verification of the end result of a process in support of audits.

Safety trend indicator (STI)

In October 2000, CASA introduced the STI as an assessment tool for monitoring safety and targeting surveillance resources. The SPM described the STI as a questionnaire:

> … that provides a profile of an organisation, to assist with decisions regarding the scheduling of Special Audits. An STI also functions as a limited audit, providing an opportunity to review an organisation's performance.

The STI form was divided into two main sections (see also appendix P), the first seeking general information about the operator, including details of the operator's aircraft fleet (number and age), types of operations (primary type and percentage of operations that carried passengers) and overall judgement of the performance (compared with 12 months prior and relative to other organisations carrying out similar work). Responses were selected from a predetermined list.

The second section of the AOC STI contained 30 safety indicator questions, which rated aspects of the organisation's operation during the preceding 12 months. The questions covered a number of aspects including:

- changes in organisational structure, key personnel or operations
- compliance, accident/incident history or other concerns
- the extent of some general types of operational hazards
- the maturity and effectiveness of the organisation's safety management processes.

For each question, the available responses were 'yes', 'no' or 'don't know'. Inspectors could add additional comments to clarify or explain their responses. Based on the responses to the 30 items, an overall AOC safety indicator score was calculated. This involved summing the non-favourable responses to get a raw score, and then considering other factors to get a weighted score.[283]

Although the SPM stated the STI could function as a 'limited audit', CASA stated it was primarily a means of prioritising organisations requiring additional surveillance. It also noted the STI was not designed to identify specific types of hazards.

When the STI was initially introduced, there were concerns about the relatively high number of 'don't know' responses and inconsistency of responses across inspectors. CASA made minor changes to the form in 2002 (version 1.1), and made it easier for inspectors to complete the form using an online version.

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[282] The SPM defined a ramp inspection as 'Inspection of an aircraft, including documentation, equipment and procedures associated with that operation.' ATO inspections also included checks of CAR 217 check captains, which often involved an assessment of them conducting an instrument rating renewal and proficiency check.

[283] The weighted score took account of varying operational factors, such as the size of the operation and whether it involved the carriage of passengers, the raw score, and the number of items marked as 'don't know'.

The STI was initially intended to be used for all types of operators. In 2003, CASA inspectors in airline offices ceased conducting STI assessments for airline operators, as those operators were already being audited twice a year and it was thought the tool did not provide any additional information to those audits. However, STIs continued to be used in for non-airline operators, who were subject to less frequent auditing.

CASA Bankstown FOIs reported the STI could be a useful tool for planning surveillance activities but it had limitations. One positive aspect was that, if there had not been any recent surveillance activity or other interaction with the operator, it forced the inspector to contact one of the operator's key personnel to help answer some of the STI questions. However, due to the limited amount of surveillance conducted for most operators, it was difficult to evaluate the accuracy of the information provided by the key personnel.

Inspectors also noted some of the terms in the questions were subjective and led to different interpretations across inspectors. In addition, inspectors noted some questions about recent organisational changes (such as a change in key personnel) could get recorded as a high risk response, whereas such changes could sometimes be positive for the operator.

In 2002, CASA advised it intended issuing a second version of the STI, requiring graded responses rather than 'yes', 'no' or 'don't know' responses. In addition, the second version of the tool was intended to include a form for the operator to complete in order to gather factual information about the operator and its activities prior to a CASA inspector completing the other parts of the STI.[284] However, the second version and operator information form were not implemented, and CASA personnel continued using the 2002 version of the STI. During the reopened investigation, CASA could not identify from its records why version 2 of the STI was not implemented.

Special audits

Special audits were an additional method of evaluating an operator and were conducted in response to an assessment of an operator's risk profile using the STI and other safety intelligence, such as incident reports. The SPM stated:

> A Special Audit may be planned for the following reasons:
>
> • STI score indicates certificate holder to be a high risk. Certificate holders rise to the top of the priority list according to their STI score and other information gained;
>
> • Follow-up of RCAs [requests for corrective action] and Safety Alerts, where there is potentially a high impact on safety if the corrective action is not implemented effectively within the time given;
>
> • To address information received from any source that points to an increased risk…

The manual also stated special audits did not necessarily mean that the operator was 'unfit to remain in the aviation industry: however, there may be reasons for the additional scrutiny'.

Other surveillance activities

In addition to the formally specified surveillance activities, CASA personnel also received other types of information such as:

- incident reports associated with the operator's operations (either submitted by Airservices Australia, the operator or another party)[285]

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[284] Australian National Audit Office, Aviation Safety Compliance Follow-up Audit, Civil Aviation Safety Authority, Audit Report no. 66 2001-2002, June 2002.

[285] In accordance with the *Transport Safety Investigation Act 2003*, occurrences were required to be reported to the ATSB. However, Airservices Australia, who reported about 60 per cent of all the submitted occurrences to the ATSB in the 2002-2009 period, also submitted its notifications to CASA. In addition, some other parties also submitted some notifications to CASA in addition to the ATSB. The ATSB also provided CASA with limited details of reported occurrences on a weekly basis.

- complaints or concerns raised by one of the operator's personnel or external parties (either directly to CASA or through an external party or agency).

On receipt of such information, CASA personnel would review the submitted documentation and, if required, request additional details and/or an explanation from the operator. Such information could also lead to additional surveillance activity, such as a special audit.

After the implementation of the SPM, CASA identified that the use of systems-based audits, based on its management systems model, for small operators was not an efficient use of resources. Consequently, in 2005 it implemented a 'functional surveillance' approach for such operators. This focused on using simpler surveillance activities, such as site inspections and spot checks.

Use of questionnaires to obtain information

At times, CASA utilised questionnaires or forms to obtain general information about an existing operator's organisation and activities. The SPM noted that, for an AOC, CASA inspectors could send an 'auditee profile' form to the AOC organisation prior to an audit to request information about the organisation. The auditee profile form requested details about:

- company directors, management personnel and CAR 217 approved persons (names and duties)
- operating, maintenance and training bases (location and aircraft types)
- operations manual, training and checking manual and flight manuals (amendment status)
- aircraft operated (including registration, maintenance release, operational category)
- flight crew employed (including name, licence number, currency of various certificates and checks, base and position).

Associated with the functional surveillance approach, CASA also introduced an organisation annual return (OAR) form. Guidance material for inspectors stated:

> The OAR is used by CASA to correlate industry activity in the assessment of safety from the statistical data. The OAR will contain information relevant to the 12 months to 30 June each year and be submitted by a date nominated by CASA. This information will enable CASA to update its database on certificate holder profile information and cross check aspects such as aircraft and pilot employment.

The OAR form for an AOC organisation requested details about:

- management personnel
- facilities (operating bases, type of activity and aircraft types)
- procedures manuals (type and last amendment number and date)
- current permits, approvals, exemptions and delegations
- flight crew employed (including names, licence numbers, currency of various certificates and checks, base and position)
- aircraft operated (including type, registration, total time in service and maintenance organisation)
- accidents and incidents reported to the ATSB.

Neither the auditee profile form nor the OAR requested any information on the types or nature of the operations being conducted by the operator, or any recent changes to those operations.

In October 2007, CASA amended CAO 82 (for charter, aerial work and RPT operators) to include a requirement for operators to complete an AOC holder safety questionnaire (AHSQ) if they were asked to do so by CASA. The AHSQ issued in 2008 asked questions about:

- types of operations conducted (such as passenger RPT, passenger charter, aero medical, flying training)
- maintenance arrangements
- number of pilots
- staff continuity (or starting date of key personnel)
- recent reorganisation (or any significant reorganisation or restructure in the previous 6 months)

- aircraft activity details (including operation type, hours flown and number of landings for each aircraft)
- other aerial work and freight questions (namely, the proportion of flights that involved carrying passengers)
- passenger charter and RPT operations questions (such as the extent of multi-crew operations and IFR operations)
- perceptions of CASA's safety contribution.

The AHSQ issued in 2009 contained a smaller and more general set of questions.

Bankstown office personnel stated the AHSQs were collated and analysed across industry sectors by another section within CASA and the field offices were not provided with the specific results for each operator.

Frequency of surveillance activities

The CSM outlined an audit schedule for different types of AOCs. These included:

- high-capacity RPT airline – every 6 months
- low-capacity RPT airline – every 6 months
- large charter – every 12 months[286]
- small charter – every 3 years.

In early 2005, CASA recognised that the systems auditing approach was resource intensive and it was not able to meet its surveillance schedule requirements. Accordingly for non-airline AOCs, it introduced the general aviation (GA) surveillance planning matrix. From late 2005 to mid-2009, the matrix provided the following schedule for system audits:

- low-capacity RPT (passenger transport) – 1 systems audit per year
- large (passenger) charter and specific large EMS aerial work – 1 systems audit per 3 years
- large flying training school – 1 systems audit per 3 years.

Smaller and less complex GA operators were subject to the 'functional surveillance' approach which did not require systems-based audits. For example, small (passenger) charter and specific EMS aerial work did not have a scheduled audit frequency but required one site visit every 3 years.

Bankstown personnel reported that, consistent with CASA policy guidance regarding sector priorities (see *Classification of operations*), passenger charter operators would generally receive more scheduled surveillance activity than aerial work operators (including air ambulance operations). However, given the operator of VH-NGA conducted passenger charter operations, it was classified as a 'large charter' operator and therefore according to the matrix it would receive a scheduled systems audit every 3 years.

The GA surveillance planning matrix also specified additional surveillance requirements. For a 'large charter' operator, such as the operator of VH-NGA, these included:

- site inspection – not required
- OAR – completed once per year
- in-flight surveillance – opportunity basis only
- industry contact record – opportunity basis only
- STI – 2 per year (one on-site and one desktop)
- ramp check – opportunity basis only

[286] Large charter was defined as a charter operator using aircraft with a maximum take-off weight greater than 5,700 kg (excluding some types of aircraft such as Metro II, EMB-110 and DHC-6).

- CAR 217 personnel inspections – 5 per cent of operator's proficiency checks or 1 per year (whichever is greater).[287]

In June 2009, the OAR requirement was removed, but other details remained the same.

As noted above, special audits or additional surveillance activity could be planned if there were indications of elevated risk associated with the operator from an STI or other sources.

Surveillance planning

Each office developed an annual surveillance plan, based on the operators being oversighted by the office and considering the type of operator and the required frequency of surveillance activities.

Each month the office managers reviewed the progress and needs for surveillance of each operator. The meeting considered:

- the latest weighted STI scores for each operator
- results of recent audits and/or surveillance activities
- unacquitted RCAs
- recent reported incidents
- other known intelligence about operators
- available resources.

Based on this information, the surveillance priorities for future months would be determined. This included any decisions regarding the need for special audits or additional surveillance of an operator based on indicators of risk.

CASA Bankstown office personnel reported that during 2005–2009, they were responsible for the oversight of about 170–180 AOCs. Each flying operations inspector (FOI) was designated as the assigned FOI for 25–30 AOCs. The assigned FOI was the main point of contact for the AOC, but did not necessarily conduct each surveillance activity depending on their availability and the qualifications or skills required.

Of the 170–180 AOCs, CASA personnel reported the operator of VH-NGA was one of the larger and more complex AOCs that they oversighted. However, they also dealt with several other large and/or complex AOCs, including some low-capacity RPT operators. During 2005–2009, some of the other operators required a significant amount of time and resources. In addition, a large component of the FOIs' time was spent on regulatory service work for AOCs (such as approvals of new training and checking personnel).

Audit scoping

In an explanatory section, CASA audit reports stated:

> The audit is a sampling exercise and does not purport to be a total systems review. The sampling provides a snapshot of the system and any deficiencies detected could point to a systemic problem, requiring a total systems review by the operator. The operator/certificate holder… must address deficiencies and problems identified in the audit findings.

The SPM stated an audit's scope played a vital role in the development and conduct of a successful audit. It provided guidance for scoping an audit, which involved inspectors reviewing:

- the operator's previous surveillance and entry-control history (such as RCAs and observations)

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[287] The matrix stated the schedule for a low-capacity RPT operator included one system audit, one in-flight surveillance activity and two ramp checks per year, and two CAR 217 personnel inspections (or 10 per cent of checks, whichever was greater). Otherwise it was the same. Prior to the introduction of the SPM in 2003, the surveillance schedule required more frequent spot checks. For example, an email in 2000 indicated the required surveillance activity of the operator's jet AOC for that year included three ramp checks, one en route inspection and six check pilot inspections. The email also noted there had been significant difficulties achieving this schedule the previous year.

- other safety information (such as incident reports or comments from the assigned auditors)
- organisational changes (such as changes or expansion to operations, introduction of new aircraft or equipment, introduction of new procedures, growth or decline in resources, introduction of new staff, changes in key personnel, change in operating environment and introduction of new routes).

Inspectors were provided with a 'surveillance planning and scoping form' and guidance for completing the form. The form included sections for:

- previous surveillance / entry control history (including the date of the last audit, elements from the scope of the last audit and matters to note)
- other safety information (including date, source and details)
- organisational changes (including type of change, effective date and how it affects the scope).

The guidance indicated the first section should include significant findings from previous audits that require follow-up and issues from entry-control activities that needed resolution. The final section of the form listed a series of elements to be examined and matters requiring attention.

The SPM stated:

> For organisations subject to 6 monthly or annual audits (i.e. organisations where all applicable audit elements are covered by several audits over a three-year period), and when specific problem areas from previous audits are identified, it may be necessary to include some elements already audited. In such a case these elements should take precedence when selecting elements for this audit.

For organisations where an audit was required once every 3 years, there was no requirement for audits to cover all system elements over a set period of time.

The assigned lead auditor developed the draft audit scope. The relevant team leader (flying operations or airworthiness) reviewed the scope and the area/regional manager approved the scope.

Reporting of surveillance activities to operators

The results of audits were recorded in a formal report, which included an executive summary, details of the aspects audited and findings. The potential types of findings included:

- Request for corrective action (RCA): issued when there was a failure to comply with the regulatory requirements, and necessitated the operator to take corrective or preventive action to address deficiencies in its policy and/or procedures. If an RCA was issued, the operator had to address the deficiency and provide CASA with details of the remedial action, 'root cause' and corrective action by an agreed date.[288] The SPM stated 'The aim of issuing an RCA is to highlight process or system deficiencies and not to provide consultancy and tell the Auditee what to do. It is the Auditee's responsibility to investigate and identify the root cause and take corrective action to address the root cause.'
- Safety alert: a type of RCA issued to an operator to raise a safety concern of a serious breach of the regulatory requirements. A safety alert required immediate action by the operator to rectify the problem.
- Aircraft survey report (ASR): used to advise of non-compliance of regulatory requirements relating to an aircraft or its maintenance documentation.
- Audit observation (AO): issued to draw the operator's attention to latent conditions or minor deficiencies in the operator's systems or processes that could not be attributed to current regulatory requirements. The intention of the AO was to raise awareness with a view to avoiding problems in the future. An operator was not required to submit a response to an audit

[288] In an explanatory section, CASA's audit reports stated that if the identified deficiency was 'cabin crew not currently trained in emergency procedures' the remedial action would be 'conduct training for all affected staff' and the corrective action would be 'document and implement a system for training, recording and warning of pending expiry dates for all initial and recurrent training'.

observation. However, the SPM stated that if the operator provided a response, this may be an indicator it had a mature safety system.

The lead auditor was responsible for collating the audit information and preparing the audit report. The relevant team leader (flying operations or airworthiness) reviewed the report and the area/regional manager approved the report.

Training and guidance for inspectors

Most of the FOIs who were significantly involved in oversighting the operator's AOCs during 2002–2009 had been at CASA since 2001 or earlier (or were at CASA for several years prior to being involved in surveillance of the operator). During their time at CASA they had undertaken a number of training courses, in addition to on-the-job training with more experienced inspectors.

CASA inspectors received a 5-day introductory training course on human factors, which included some content on system safety concepts. CASA also provided its inspectors with a 5-day course in auditing processes. Although this auditing course was designed to be tailored to the requirements of CASA personnel, CASA inspectors reported it was still generic in nature. They also reported it did not provide detailed guidance on conducting audits of system safety issues. A review of the course notes provided during the training found these notes were consistent with the inspectors' impressions.

With the introduction of the SPM, inspectors were provided with a 2-day course on material associated with the manual (November 2003–May 2004), although some inspectors only received 1 day of training. An internal review of the introduction of the SPM noted there were some difficulties with the initial training courses in 2003 before the material was finalised. Subsequent training courses were evaluated as being much more successful.

During 2004 and early 2005, CASA conducted internal audits of the implementation of the SPM approach in some of its offices. These audits included reviews of CASA surveillance files on some operators, with the results of the audits provided to CASA senior management and the relevant office manager in order to provide feedback and guidance to inspectors. An audit of the Bankstown office's use of the SPM approach was completed in January 2005. A number of items were raised regarding deviations in practice from the requirements of the SPM, primarily concerning the drafting of audit reports and what information was placed on file. The issues appeared to be similar to those raised in other office reviews.

CASA personnel advised the ATSB that, as far as they could recall, there were no other audits or internal reviews of CASA surveillance activities at CASA general aviation offices such as the Bankstown office prior to the 18 November 2009 accident.

Overview of CASA oversight of the operator (up to 18 November 2009)

Overview of AOC assessment processes

Significant assessment activities in the period prior to 2005 included:

- In late 2001, an external contractor prepared a new version of the operator's operations manual (OM), used by both its turboprop and jet AOCs, which was submitted to the Brisbane air transport office for approval. The manual was also reviewed by the Bankstown office.
- In January 2002, the operator applied to CASA to have 'aerial work – ambulance functions' added to its AOC in order to facilitate operations into Noumea (see *History of the operator's air ambulance activities*). The operator's submission included an OM supplement with procedures related to air ambulance operations. CASA approved the application in early February 2002.
- In March 2002, CASA issued the operator an exemption from CAO 48 that allowed the operator to conduct operations using its fatigue management system (FMS) (see *Overview of the operator's fatigue risk management system*).

With regard to the addition of air ambulance operations to the AOC, the operator had already been approved to conduct passenger and freight charter operations internationally for many years.[289] Accordingly, CASA's 2002 assessment process involved reviewing the operator's proposed new procedures for air ambulance operations.[290] The operator informed CASA that the approval request was 'urgent'. Given the workload in the Bankstown office at the time, and the perceived limited nature of the task, the assessment was conducted by personnel within CASA's Regulatory Services Division. The assessment stated the operator's proposed procedures were satisfactory, and noted the operator had a CASA-approved, removable stretcher, oxygen bottle installation and stretcher loading system for the Westwind.

During 2005–2009, a significant AOC assessment activity was the issue of a combined AOC for the operator's jet and turboprop operations, which was finalised in October 2006. During the approval process, CASA did not review all aspects of the OM in detail, instead focussing on areas where the operator had submitted changes to what had been previously approved. This primarily included assessing the suitability of proposed procedures for the Metro 23 to conduct passenger charter operations, which the operator was introducing alongside its current Metro III aircraft (which were being used for freight operations).

Other notable approval activities that occurred during 2005–2009 included:

- approval of a Westwind check pilot as head of training and checking (HOTC) for the jet AOC (May 2005)
- addition of the EMB-120 to the turboprop AOC (completed August 2005)
- addition of the Saab 340 to the combined AOC (completed November 2008)
- acceptance of the operator's revised FRMS manual (June 2007)
- approval of the new chief pilot (November 2008)
- approval of the operator's SMS implementation plan (October 2009).

In addition, there were many other instances of approvals of check pilots and reissue of existing instruments, and some approvals of minor changes to the OM.

The operator's AOCs were generally reissued every 3 years. When the combined AOC was initially issued in October 2006, CASA specified an expiry date of June 2009 in order to align the certificate with various instruments of delegation. The AOC was subsequently reissued in June 2009.

Overview of audits

Table 33 provides an overview of the CASA AOC audits conducted on the operator's jet or combined AOC, or by Bankstown office inspectors on the turboprop AOC, from 2002 to November 2009 (prior to the accident).[291] The table also includes the type of audit, elements examined and number of findings. Further details are provided where applicable later in this section.

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[289] In September 1999, during the process to reissue the operator's AOC, a letter from the then chief pilot to CASA noted the operator had been conducting international charter operations to regular destinations and on-demand for about 20 years, and these operations included VIP transport, medical flights for the retrieval of organs for transplant, United Nations related operations and military-related flights associated with the operator's defence contract.

[290] The procedures were primarily administrative in nature, but included some discussion of passenger briefings and roles of flight crew and medical personnel. There was minimal discussion of flight planning aspects (as these were effectively the same as covered by other sections of the manual).

[291] The last audit conducted on the turboprop AOC by the Brisbane airline office was in March 2004. It focussed on load control and a review of some parts of the OM, and resulted in 3 AOs.

Table 33: Overview of CASA audits of the operator's AOCs, including the number of requests for corrective action (RCAs), audit observations (AOs) and aircraft survey reports (ASRs)

Date	Type	Systems / elements examined	RCAs	AOs	ASRs
Mar 2002	Special (jet AOC)	Fatigue management		7	
Mar 2002	Scheduled	Flight operations: miscellaneous	1	1	
	(jet AOC)	Aircraft performance / load control	4	7	
		Aircraft airworthiness / maintenance	4		2
		Total	9	8	2
May 2003	Scheduled	Flight operations: miscellaneous	1		
		Flight crew training and checking		1	
	(jet AOC)	Aircraft performance / load control		2	
		Dangerous goods	2	4	
		Total	3	7	
Oct 2003	Special (jet AOC)	Fatigue management			
Jun 2004	Scheduled	Flight crew training and checking			
	(jet AOC)	Fatigue management		2	
		Flight operations: miscellaneous		1	
		Aircraft airworthiness / maintenance			
		Total		3	
Nov 2004	Special (jet AOC)	Fatigue management		1	
Jun 2005	Scheduled	Organisational structure	1		
	(jet AOC)	Flight crew training and checking	4		
		Aircraft performance / load control	5	2	
		Aircraft airworthiness / maintenance	1	2	
		Total	11	4	
May 2006	Scheduled	Flight crew training and checking	6		
	(turboprop AOC)	Fatigue management	1	1	
		Aircraft airworthiness / maintenance	5	6	1
		Total	12	7	1
Oct 2007	Scheduled	Flight crew training and checking	3	1	
		Fatigue management		1	
		Safety management / internal audit		1	
		Total	3	3	
Mar 2008	Special	Flight crew training and checking	4	1	

Note: The classification of the systems and elements in this table has been modified from the original audit reports and documentation to provide consistency across the audits. Similarly, RCAs issued about specific aircraft in 2002 were reclassified as ASRs. Most of the 'miscellaneous' items in 2002–2004 arose from an FOI inspecting an aircraft and the documentation on board. One of the RCAs in the 2008 audit was issued as a safety alert (see Table 34).

Prior to 2005, both the operator's jet AOC and turboprop AOC were subject to annual CASA audits. From 2005, there were less frequent audits, consistent with the change in CASA's surveillance schedule for large charter operators. However, the frequency of audits during 2005–2009 (prior to the accident) exceeded the requirements of the GA surveillance planning matrix.[292]

Although the audits of the FMS in 2002, 2003 and 2004 are listed as 'special' audits in the table, they were conducted in order to review the progress of the operator's FMS rather than on the basis of any specific indicators of risk. The March 2008 audit was a continuation of the October

292 As the AOC issued in October 2006 was to a new entity, there should have been one scheduled systems audit every 3 years after this date. The first audit of the new entity was conducted in October 2007.

2007 audit, which was not able to be completed because insufficient information was available to complete the examination of the flight crew training and checking records (see *Oversight of flight crew training and checking*).

The scheduled audits from 2002–2006 were generally conducted with multidisciplinary teams of four to five inspectors, including FOIs, airworthiness inspectors (when airworthiness elements were examined), airworthiness engineers (when aircraft performance or load control elements were examined), a dangerous goods specialist (in the May 2003 audit) and a fatigue management specialist (in the June 2004 and May 2006 audits). The original scope of the 2007 audit was meant to include airworthiness, aircraft performance and dangerous goods aspects, but relevant specialists were unavailable. As a result, the 2007 audit was conducted by four FOIs and the 2008 audit was conducted by three FOIs from the same team. The 2002 and 2004 special audits of the operator's FMS were conducted by a team including a fatigue management specialist and an FOI, and the 2003 special audit was conducted by a single FOI.

A review of the CASA surveillance files noted the following regarding the audits conducted during 2005–2008:

- The audits appeared to be scoped using the processes outlined in the SPM.[293] The audits also appeared to have been conducted using the processes and guidance in the SPM and associated documents.
- None of the audits focussed on air ambulance operations, although the content of most of the audits applied to air ambulance operations as much as any of the operator's other types of operations.
- The audits primarily involved reviews of documentation and interviews with key management personnel (such as the chief pilot or compliance manager). There were no interviews or discussions with line personnel except in some audits in relation to fatigue management issues. The audits conducted from 2002–2004 were similar.
- Ramp checks or aircraft inspections examining flight operations aspects were conducted during the 2003, 2004 and just prior to the 2008 audits, each of which resulted in an RCA or AO about an element not included in the audit's scope.
- The RCAs and AOs varied significantly in terms of their breadth and potential severity, with many of the RCAs referring to a specific example of a breach of regulatory requirements.
- The operator assertively disputed CASA's findings in the May 2006 audit report and requested most of the RCAs be withdrawn. CASA meeting notes indicated the operator believed it could 'suffer a commercial disadvantage' when issued with CASA RCAs. CASA ultimately cancelled three airworthiness RCAs and replaced them with observations (resulting in the total as shown in Table 33). Information on CASA files indicated the operator also disputed some comments in the June 2004 audit report, but there were no indications of disagreement associated with the other audit reports.
- The operator's responses to RCAs included information about remedial action, root cause and corrective action. However, in some cases there was limited information about corrective action, and in most of those cases further corrective action did not appear to be warranted.[294] In most cases, it appeared that CASA inspectors did not acquit an RCA until they had sighted or received evidence of the proposed remedial and corrective action.[295]

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[293] In comparison, the scheduled audits conducted in 2002-2003 appeared to involve an examination of more elements, though each element was examined in less depth.

[294] For example, if a typographical error was identified in a manual or a check captain had not completed or signed a form, the extent to which corrective action was warranted or could be applied was limited.

[295] Following the May 2006 audit, there were a series of communications between the operator and CASA regarding the audit findings and what CASA would regard as appropriate action to address the RCAs. Ultimately, the operator agreed to do what CASA requested, but from the documentation on CASA files it was unclear for some RCAs whether the operator provided documentation to show they had conducted some of the proposed corrective actions.

- The operator generally responded to all AOs in the same manner as it responded to RCAs.

Overview of spot checks

In terms of spot checks conducted by CASA on the operator's AOC activities during 2005–2009 (prior to the accident):

- There were several ramp checks, with the last recorded check conducted in February 2008 (on a Metro). Ramp checks were conducted on Westwind aircraft in August 2005, August 2006 and April 2007. Problems were noted on some ramp checks, although no significant problems were noted on the Westwind checks (each of which was conducted prior to a freight or charter flight).
- There was one en route inspection recorded on CASA files, and this was conducted on a Metro freight flight from Sydney to Brisbane in November 2007. No problems were noted. Up until 2006, CASA had a Westwind type specialist based in the Bankstown field office. The operator's flight records indicated this FOI conducted one trip each year (from 2003–2006) on one of the operator's Westwind aircraft with one of the operator's check pilots to help maintain recency on the aircraft type. Other than a freight trip in November 2005, these flights did not involve normal line operations. The initial scope of the 2005 audit included an en route inspection of a Westwind flight by the type specialist, but this was changed prior to the audit to an observation of a check flight as part of the process of approving a Westwind check pilot as the operator's HOTC. The last observation of a Westwind line flight indicated on CASA files was in November 2003, which was conducted by the FOI type specialist on a freight trip as part of the November 2003 audit of the operator's fatigue management system.
- There were about two observations per year by a CASA FOI of an instrument rating renewal and/or CAR 217 proficiency check being conducted by already-approved check pilot (with the pilot being checked often being another check pilot). The last observation of a Westwind check captain was conducted in February 2007. No significant problems were noted with any of the Westwind check pilot observations.
- CASA conducted additional observations each year of check pilot candidates prior to their initial approval. The last observation of a Westwind check pilot candidate was conducted in September 2008, when two check pilot candidates were assessed.
- None of the FOIs assigned to the operator's AOCs during 2005–2009 were Westwind type specialists. There were notes on CASA files file indicating the assigned FOIs attempted to schedule additional observations of Westwind proficiency checks but were unsuccessful due to the limited availability of a Westwind type specialist. The September 2008 observation of two Westwind check pilot candidates was conducted by an FOI that was not a Westwind type specialist (but was a type specialist on the Learjet). At that time, CASA's only Westwind type specialist was based in Darwin and was not current on the aircraft.[296]

Overview of STIs

CASA completed four STIs on the operator's AOCs in 2005 (two for the jet AOC and two for the turboprop AOC), none in 2006, two in 2007, one in 2008 and two in 2009 (January and November). Table 34 summarises selected responses from the STIs completed on the jet AOC (in 2005) and the combined AOC from 2007–2009, including the questions that resulted in a high-risk response. Regarding these STIs:

- Three different FOIs completed the STIs. There were some minor differences in responses to the same question between the FOIs, however they all consistently rated the operator as 'about the same' as or 'somewhat better' than similar organisations.
- Two of the STIs (in 2005) were recorded as being completed after a site visit, although a comment on the November 2009 STI also indicated it was completed after a meeting with the

[296] The use of a non type specialist to observe (and not participate) in the check flights was formally approved by the regional manager.

chief pilot. Some of the other STIs were completed within 6 months of an audit or meeting with the operator.

- In most of the STIs, the operator was classified as carrying passengers on less than 25 per cent of its operations (with passengers defined on the form as anyone on board other than flight crew). The November 2009 STI stated 25–50 per cent of operations involved the carriage of passengers (consistent with the increase in turboprop passenger-charter flights). This STI also noted the operator's primary type of activity was aerial work operations (with flight crew only).
- None of the total STI scores (based on the 30 questions) indicated the operator was high risk, with the number of 'high risk' responses ranging from 2 to 6 (average 3.9).[297] Common high risk responses included:
    - Changes in the organisation's key personnel or ownership that occurred during 2005–2008.
    - Aircraft being used to the limit of their performance. Comments on the forms indicated this was generally associated with freight aircraft being at operated at maximum weight.
    - Reported incident/s where the organisation was at least partially responsible. There was insufficient evidence on CASA files to indicate what incidents were associated with these responses.
- Both of the 2009 STIs indicated the operator conducted 'operations under more difficult conditions than other operators'. The November 2009 STI included a comment, indicating this was associated with 'international medivac and target towing'.
- There were only two 'don't know' responses, both included on the July 2007 STI (relating to staff morale and levels of fatigue or overtime).

Overview of other surveillance activities

In terms of occurrences and concerns reported by external parties during 2005–2009:

- There were a number of incident reports involving the operator's aircraft placed on CASA files, all of which had been submitted by Airservices Australia. In many cases CASA had requested additional information from the operator, which had been provided. The reports generally involved aircraft technical failures or flight crew not complying with ATS instructions or procedures (similar to the types of incidents discussed in *Incident reports*). There was no indication CASA had any concerns regarding the operator's responses to these occurrences. Some of the reported occurrences were associated with air ambulance flights, but as far as could be determined none of the incident reports involved flights to Norfolk Island or Christmas Island.
- There was correspondence from the French DGAC regarding problems identified during ramp checks the DGAC had conducted on the operator's Westwind aircraft in Noumea in November 2005 (regarding the currency of a pilot's medical certificate), July 2006 (regarding the absence of an alternate airport on a flight plan, see *Oversight of fuel planning and in-flight fuel monitoring*) and February 2009 (regarding the aircraft not having an EGPWS and an ACAS when conducting air transport operations in New Caledonian airspace, see *Suitable alternate aerodromes for flights to Norfolk Island*).[298] In each case, CASA requested additional information from the operator, and it was satisfied with the operator's response. During the reopened investigation, CASA advised the ATSB it had no record of any other ramp checks conducted by overseas authorities on the operator's aircraft.

[297] STIs completed by the Bankstown office for the turboprop AOC during 2005 were similar (average of 4), and STIs completed for the jet AOC from 2002-2004 had lower scores (average of 2).

[298] In 2006 and 2009, the DGACs correspondence to CASA indicated problems had also been identified during a ramp checks of another Australian operator.

- There was one reported complaint recorded on CASA files, associated with a Westwind pilot's concerns in March 2009 regarding FAID scores and the operator's standby provisions (see *Oversight of fatigue management*).
- A review of the ATSB database identified only one confidential report associated with the operator. This report, submitted in November 2008, was associated with a concern about the type of GPS system fitted on one of the operator's Metro aircraft.
- The September 2008 STI indicated a complaint had been received about the operator. A comment on the STI indicated this was associated with a Westwind pilot(s) not meeting medical standards, and that this concern could not be confirmed. There was no other information regarding this concern included on CASA files.
- Other than the matters identified above, CASA advised the ATSB it had no record of receiving any other complaints or concerns about the operator.

On CASA's files for the operator, there was a copy of completed auditee profile for the turboprop AOC prior to the June 2006 audit and copies of OAR forms for the jet AOC and turboprop AOC completed in September 2006 (just prior to the merger of the two AOCs). The operator completed the AHSQ in 2008 and 2009 and submitted them to CASA. Copies of the completed questionnaires were not included on CASA's files for the operator.

Table 34: Summary of selected responses for STIs completed on the operator's jet AOC or combined AOC from 2005–2009

	Date STI completed						
Information about the operator	**Jun 05**	**Dec 05**	**Mar 07**	**Jul 07**	**Sep 08**	**Jan 09**	**Nov 09**
STI completed after on-site visit	Yes	Yes	No	No	No	No	No
Passenger carrying work as percentage of total operations	< 25%	< 25%	< 25%	< 25%	< 25%	< 25%	26–50%
Primary type of operations undertaken	Low capacity	General transport	Low capacity	Closed transport	Cargo	Cargo	Aerial work (flight crew
Compared to others	Somewhat better	Somewhat better	Somewhat better	About average	About average	About average	About average
Compared to 12 months ago	About the same	Somewhat better	About the same	About the same	Somewhat better	Somewhat better	Somewhat better
Questions with high risk responses							
2. organisation subject to takeover or change of ownership		Yes	Yes	Yes			
3. any key people had less than 12 months experience with organisation		Yes				Yes	Yes
4. significant change to organisational structure or areas of responsibility			Yes	Yes	Yes	Yes	Yes
6. new aircraft, new routes or significant changes to procedures or processes				Yes			
8. any safety alerts issued					Yes	Yes	
9. failed to satisfactorily acquit RCAs by required date		Yes					
12. subject to adverse safety comment warranting further investigation					Yes		
14. reported incident where organisation was at least partially responsible	Yes	Yes		Yes		Yes	
16. operate under more difficult conditions that other operators						Yes	Yes
19. aircraft regularly utilised to limit of their performance			Yes	Yes	Yes	Yes	
23. organisation's documented procedures generally applied in practice	No						
Total high risk responses	2	4	3	5	4	6	3

CASA oversight of specific system elements (prior to 18 November 2009)

Oversight of fuel planning and in-flight fuel monitoring

With regard to CASA AOC assessment activities associated with flight/fuel planning and in-flight fuel management, a review of CASA files noted:

- There was one instance of the operator requesting CASA approval to conduct a passenger-carrying charter flight (with one passenger and freight) from Darwin to Christmas Island in August 2001 (see also *Operator requirements for flights to remote aerodromes*). The application included fuel planning documentation showing the flight would carry alternate fuel, and CASA approved the flight. As of August 2001, there was no requirement under CAO 82.0 for the operator to seek specific approval or for CASA to provide approval for flights to Christmas Island (or Norfolk Island).
- There was no indication fuel planning or in-flight fuel management aspects were examined in detail when the operator was approved to conduct air ambulance operations (including international operations) in January 2002. At that time, the operator already had approval to conduct international charter operations.
- During the introduction of the EMB-120, CASA reviewed the operator’s proposed fuel policy and procedures for that aircraft type. After some correspondence between CASA and the operator regarding appropriate fuel burn rates, the policy was approved.
- During the approval process to merge the two AOCs in 2006, CASA did not review the operator’s fuel policy in detail. A CASA FOI completed the CASA checklist for the ‘assessment of proposed fuel policy’ for a non-high capacity RPT operator. This checklist included items based on CAAP 234, but it included no reference to remote islands or isolated aerodromes or the requirements of CAO 82.0.[299] The completed checklist noted the proposed changes for the Metro 23 were considered acceptable, and the policy for other aircraft (including the Westwind) was considered acceptable as no changes had been made.

In terms of surveillance activities regarding fuel planning and in-flight fuel management, a review of CASA files noted:

- None of the audits conducted from 2002 to 2008 focussed on flight planning, fuel planning or in-flight fuel management aspects. The audit reports for the 2002 and 2003 scheduled audits indicated samples of flight records and fuel records were reviewed and no problems found. However the types of flights for which records were reviewed and the extent to which they were reviewed could not be determined. No reviews of such documents were noted for any of the audits conducted during 2004–2008.
- CASA inspectors may have examined flight planning and fuel planning aspects during some of their other oversight activities, such as ramp checks, check flights observations, and the approval of key personnel such as the HOTC and the chief pilot. However, none of these activities were conducted for air ambulance or international flights.
- In July 2006, the French DGAC conducted a ramp check of a Westwind aircraft in Noumea that was being operated on an air ambulance task from Sydney to Noumea and return. The final ramp check report identified several problems, including that the flight crew’s flight plan did not include ‘fuel calculated for alternate airport’.[300] CASA contacted the operator for a response, and

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299 This checklist was developed in June 1999. A separate checklist for high-capacity RPT operations was more detailed but also did not refer to remote islands or isolated aerodromes.

300 An initial ramp check report provided to the flight crew indicated the DGAC had found no problems with ‘flight data’. Other concerns raised on the ramp check report included some types of documentation (such as the aircraft’s certificate of airworthiness, aircraft noise certificate, aircraft radio licence and the operator’s AOC) not being carried on board.

the operator provided documents to CASA that showed both the chief pilot and the captain had prepared fuel plans for the flight. The chief pilot's fuel plan included a specific amount of fuel for 1 hour holding, but neither flight plan included a specific amount for alternate fuel.[301] However, the flight record showed the aircraft departed from Sydney with full fuel (8,700 lb) and had 4,400 lb remaining after engine shutdown at Noumea. This was more than sufficient fuel to conduct a missed approach at Noumea and divert to an alternate aerodrome or to have held for more than 2 hours at Noumea. CASA was satisfied with the operator's response.

Oversight of flight crew training and checking

During the approval process to merge the two AOCs in 2006, CASA identified some problems with the OM content on training and checking. Although none of these were considered to be a significant safety concern, it wanted them addressed. Accordingly, when the initial combined AOC was issued on 23 October 2006 with an expiry date of 30 June 2009, CASA issued the approval instrument for 'Training and Checking Organisation, Tests and Checks' with an expiry date of 22 December 2006 until the identified problems were addressed. After 2006, the main changes to the training and checking system that required approval were associated with the introduction of the Saab fleet and the use of simulators for training and checking on the Metro fleet.

An assessment of flight crew training and checking activities formed a significant part of the scope of each of the CASA scheduled audits during 2004–2007 and the special audit in 2008. With regard to these audits:

- The assessments primarily involved reviewing pilot log books and the operator's training and checking records. The 2004 audit report indicated a relatively small sample of records, and no problems were noted. The audits during 2005–2008 reviewed a larger sample of records, and in each audit multiple RCAs were issued.
- The June 2006 audit of the turboprop AOC noted 'flight training records were of a high standard and most contained all the required certificates of pilot training and pilot qualifications' and that there were 'well structured practices and procedures in relation to the training and checking organisation'. However, it identified a problem with the way the operator had conducted some command endorsements[302]. Because this issue had been previously identified in the June 2005 audit of the jet AOC, and the operator had introduced corrective action to address the situation at that time that was not successful, the 2006 audit included a broad RCA that noted the operator's management needed to accept responsibility for this ongoing situation. The operator initially disputed CASA's interpretation of command endorsement requirements and this RCA, but ultimately accepted CASA's position.
- Most of the other RCAs during 2004–2007 were related to administrative aspects or technical problems with the manner in which a small number of endorsements, instrument rating renewals or proficiency checks had been conducted or recorded.[303]

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301 Although not included on the CASA files, the TAF for Noumea included a TEMPO for the period that applied to the flight. Therefore, 1 hour of holding fuel was required. There were no weather-related problems at the likely alternate aerodrome (Port Vila), and the captain reported to the operator he had obtained weather forecasts for both Noumea and Port Vila.

302 The operator believed it was appropriate that if a pilot had a co-pilot endorsement (which required 3 hours flight time and a specified list of requirements) and then subsequently undertook a command endorsement (which required at least 5 hours flight time and a specified list of requirements), the subsequent command endorsement could use the completed co-pilot endorsement to provide credit towards common elements in the command endorsement. CASA disagreed and stated there was no provision in CAO 40.1.0 to permit this to occur.

303 In addition to problems with command endorsements, examples included results of instrument rating renewal tests not being submitted to CASA (2005), a check pilot conducting a proficiency check without a current CASA delegation (2005), base proficiency checks not being conducted on new pilots who already had an endorsement before commencing line training (2007), and two pilots command instrument rating renewal being issued including one type of approach without that approach being examined during the flight test (2008). Two other RCAs (in 2006) dealt with pilots completing a small number of flights without current qualifications (in one case a current medical certificate and in another case a CAO 20.11 proficiency check, which was subsequently found to have occurred).

- The remaining RCAs and one AO were associated with flight crew not receiving (or appearing to not receive) a particular type of training. Examples included fatigue management training (June 2006, October 2007 and March 2008), wet drills demonstrations (June 2005 and March 2008), CRM training (March 2008) and EGPWS training (March 2008). Table 35 provides further details.
- Prior to the October 2007 audit, CASA was considering a request from the operator to approve two Westwind captains as check pilots. Given that CASA did not have a Westwind specialist it could use at the time, and the perceived maturity of the operator's training and checking system, the Bankstown office recommended to CASA senior management that CASA provide the operator with an exemption from the requirement for a CASA FOI to observe the performance of check pilot candidates. To support this recommendation, the 2007 audit scope included a review of the training and checking organisation. As part of the audit, CASA requested copies of all pilot log books through the operator's compliance manager. Initially there was a poor response to this request from check pilots and other pilots. Due to the poor response, the audit team withdrew the recommendation for the operator to be able to approve check pilots without CASA observation.
- The 2007 audit included an RCA that stated most of the flight crew training records were not up to date and did not contain appropriate records. CASA elected to finalise the 2007 audit report with the information it had, and then conduct a further audit of the operator's flight crew training and checking processes within 3 months after the remaining log books became available and flight crew records had been better organised.
- The March 2008 audit was conducted to complete the 2007 audit's examination of flight crew training and checking. As indicated above, it identified several types of training had not been conducted. During the audit, CASA also issued a safety alert associated with fatigue management training not being conducted as required by the operator's FRMS manual. The operator provided an extensive response, outlining root causes and corrective actions, including that a review of the operator's training and checking system was being conducted by one of its directors (see *Review of the training and checking organisation*). It also advised CASA it had introduced a new process for monitoring the currency of required flight crew training, checks and certificates.

CASA conducted a significant amount of regulatory services work associated with the operator to assess and approve check, training and supervisory pilot candidates. In addition, it observed several instrument rating renewals / proficiency checks conducted by check pilots. In almost all cases, no significant problems were identified, including during the period after the March 2008 audit.

Table 35: CASA findings regarding flight crew training not completed (2005–2008)

Audit	Finding	Response
Jun 2005	RCA: initial wet drills demonstration as required by CAO 20.11 not conducted	Sep 2005: operator acknowledged its 'oversight', advised it had sought a quote from an external provider and the training would be completed within 90 days. It also reported it was considering other options, such as obtaining approval to do the training internally. Sep 2005: CASA acquitted the RCA. [The audit report advised the operator CASA would audit this matter again after the RCA was acquitted.] Subsequent records indicated existing flight crew completed the training in January 2007.
Jun 2006	RCA: annual fatigue management training not conducted as required by operator's FMS manual, and a safety committee was not established as required by the manual	Oct 2006: operator's response addressed the safety committee aspect but not the recurrent training of the RCA. Oct 2006: CASA acquitted the RCA. However, CASA documents from early 2007 indicated it was aware it needed to verify both elements of the RCA in future surveillance.
Oct 2007	AO: interviews with three pilots identified two had not completed fatigue management training as required by the operator's FRMS manual	Feb 2008: operator stated the new training package for FRMS training was still being finalised, and the root cause of the problem was insufficient resources. Audit observations were not required to be acquitted by CASA, and CASA conducted its next audit soon after receiving the operator's response.
Mar 2008	Safety alert and RCA: fatigue management training as required by the operator's FRMS manual not conducted	Mar 2008: as directed by CASA, the operator conducted operations under CAO 48 until the required training was provided. The operator provided all flight crew with training by 17 March. It also provided an extensive response to CASA, outlining root causes and corrective actions, including a review of the operator's training and checking system by one of its directors. Mar 2008: CASA approved the operator to recommence operations under its FRMS on 18 March. The RCA was acquitted by CASA on 25 April.
Mar 2008	RCA: EGPWS training as required by the operator's OM for flight crew on relevant aircraft not conducted	Jun 2008: operator advised relevant pilots had been provided with the training. It provided a copy of the operator's 'crew currency record' showing the training was completed in March 2008. The record also showed all flight crew had completed annual CFIT training in March 2008. Oct 2008: CASA acquitted the RCA.
Mar 2008	RCA: CRM training as required by the operator's OM not conducted	Jun 2008: operator advised all relevant pilots had been provided with the training. It provided a copy of the operator's 'crew currency record' showing the training was completed in March 2008. Oct 2008: CASA acquitted the RCA.
Mar 2008	RCA: initial and recurrent wet drills demonstrations as required by CAO 20.11 not conducted	Jun 2008: operator advised all pilots had been provided with the training. It provided a copy of the operator's 'crew currency record' showing when the training 'Wet Drills – Perpetual' was done. Sep 2008: CASA advised chief pilot by email of requirements for 12-monthly wet drills training, and the chief pilot advised he would inform the external training provider. Oct 2008: operator requested the external training provider be issued an approval to conduct CAO 20.11 tests and checks in accordance with the operator's OM. CASA issued the approval in Nov 2008. Oct 2008: CASA acquitted the RCA.

During 2009, CASA identified or was made aware of some problems associated with the operator's flight crew training and checking activities. These included:

- In February 2009, during an observation of an instrument rating renewal and proficiency check of a Metro captain conducted by a Metro check captain, a CASA FOI identified problems with the captain's performance. Although the check pilot had rated the check as a pass, the FOI believed the check should have been rated as a fail. He advised the chief pilot, who investigated the circumstances and subsequently advised the FOI that the proficiency check would be rated as a fail and that he (the chief pilot) would observe the subsequent check flight.
- In April 2009, CASA became aware that a Westwind check pilot conducted an instrument rating renewal, base check and line check on another check captain (the Westwind standards manager) in 0.7 flight hours. CASA advised the operator that this was inadequate (see *Operator's practices*).
- In June 2009, the chief pilot advised CASA he had identified that one of the military fleet's check captains had been conducting CAO 20.11 proficiency checks on the Westwind as well as Learjet when he had only received CASA delegation to conduct them on the Learjet.[304] The chief pilot advised CASA an internal hazard report had been raised, with remedial and corrective actions undertaken to address the problem (including revising procedures for developing the crew recency record).

In each case, CASA was satisfied with the way the new chief pilot (and HOTC) was addressing the problem.

Oversight of cabin safety and emergency procedures

With regard to CASA's consideration of cabin safety and emergency procedures during 2002–2009, a review of CASA files noted the following:

- During an aircraft inspection conducted on a Westwind as part of the May 2003 audit, CASA identified problems with the passenger safety briefing card on board and issued an RCA. The RCA stated the briefing card did not meet the requirements of CAO 20.11 as it did not indicate the location and use of life jackets, the location of fire extinguishers or the brace position. The operator submitted a revised briefing card to CASA using diagrams sourced from a major Australian airline's briefing card, and CASA acquitted the RCA (see also *Safety briefing card*).
- When CASA evaluated sections of the OM during the process to approve the merged AOC in 2006, it identified some minor issues with passenger briefing procedures, which were addressed by the operator.
- None of the audits conducted from 2002 to 2008 focussed on emergency procedures or cabin safety aspects, and none of the audit teams included a cabin safety specialist.
- As noted in *Oversight of flight crew training and checking*, CASA audits in 2005 and 2008 identified problems with the absence of wet drills training.
- During a ramp check of a Metro (used for freight operations) in February 2008, CASA identified some life jackets had just passed their 5-year inspection date.[305] As far as could be determined, no problems were identified with cabin safety or emergency procedures aspects on other ramp checks.

Oversight of fatigue management

As noted in *Overview of the operator's fatigue risk management system*, the operator was one of the first in Australia to be approved to operate under an FMS. During 2001, there was a series of meetings and correspondence between the operator and CASA regarding the appropriate format

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304 The check captain had the appropriate delegations to conduct instrument rating renewals and base checks on both aircraft types.

305 This aspect and some other problems were included in an AO, but it is unclear from CASA files whether it was ever sent to the operator. Another AO from the same ramp check (and check pilot assessment done at the same time) dealing with flight operations issues was included in the March 2008 audit.

of an FMS. Ultimately, this resulted in the operator submitting an FMS manual based on CASA guidance material in January 2002.[306]

Subsequent events during 2002–2008 included:

- CASA conducted a post-implementation audit of the operator's FMS in March 2002. This involved reviewing the manual and relevant records (such as rosters and fatigue reports), and interviewing key personnel and one pilot (as no others were available at the time). The audit report stated that overall the audit team was satisfied with the functioning of the FMS, but several areas needed improvement. Two of the seven AOs stated the operator had not effectively consulted with pilots, and it had not conducted an assessment of the fatigue risks associated with its operations. In response, the operator conducted a survey of flight crew and proposed some changes to its system (see *Safety surveys, studies and reviews*). The audit report also recommended the operator consider including additional work practice limits. Following the audit, CASA approved the operator to conduct operations in accordance with its FMS manual until August 2002.[307]
- Following a pilot complaint to CASA about the FMS,[308] CASA conducted a site inspection in July 2002 to review aspects of the FMS. No findings were issued, and the report noted the operator was about to commence a review of its system. Following the inspection, CASA reapproved the operator to conduct operations in accordance with its FMS manual until August 2003.
- CASA investigated further complaints in December 2002 (from pilots in the turboprop AOC), and no problems were found. During the scheduled audit of the jet AOC in May 2003, FMS training records were examined and no problems were identified. CASA reapproved the operator to conduct operations in accordance with its FMS manual until August 2005.
- A CASA FOI conducted a short audit of the FMS in November 2003. This involved reviewing the manual, attending the FMS training and conducting a series of freight flights as an observer. No findings were issued.
- During the May 2004 scheduled audit, CASA identified the military fleet were still operating under CAO 48, which was contrary to the operator's FMS, and an AO was issued.
- In November 2004, CASA conducted another audit of the FMS. This involved reviewing the manual and relevant records, and interviewing key personnel and two pilots. The audit report concluded the operator was compliant with its current system. However, it included a detailed AO with suggestions for improving the FMS. The report stated:

  > The [operator's] system was evolved with CASA guidance and is dated January 2002. At that time the methodology was acceptable to CASA as mechanism of achieving fatigue management. Since then advancements in the understanding of the limitations of total reliance on a mathematical model have emerged. This was explained to company representatives and as a result of these discussions the operator has elected, with CASA facilitation, to re-write sections of the system to include risk management.

- During the scoping of the June 2005 scheduled audit, CASA considered examining fatigue management aspects. However, the fatigue management specialist involved in the November 2004 audit stated it would be more useful to wait until the operator's revised system was introduced.
- During 2005 and 2006, there were various meetings and correspondence involving the CASA fatigue management specialist and the operator's compliance manager regarding the

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306 Initially CASA used a dedicated project team involving human factors specialists and trained FOIs for assessing FMSs. CASA added formal guidance for evaluating an FRMS to its AOCM, including a detailed checklist, in 2004.

307 This approval, and subsequent approvals, were in the form of an exemption from the requirements of CAO 48, as long as the operator conducted its operations in accordance with its approved FMS/FRMS manual

308 The complaint in July 2002 stated the time incurred during fatigue training (in 2001) had not been considered as duty time, and that 'deadhead' travel (or a pilot travelling on a flight as a passenger before commencing a flight as flight crew) had not been included in duty time. The December 2002 complaint also referred to deadhead travel.

development of the revised system, and the operator submitted revised versions of the new manual for CASA review.[309] CASA reapproved the operator to continue using its existing system in August 2005 for 6 months to allow the operator further time to develop the new system. It then issued another approval in January 2006 for 12 months. At that time, CASA stated the operator's progress had been delayed due to the merger of the operator's two AOCs.

- During the May 2006 scheduled audit of the turboprop AOC, CASA included fatigue management as part of the audit scope. It reviewed relevant records and interviewed key personnel, and reviewed the operator's progress with the new manual. The audit resulted in an RCA that stated two aspects of the currently-approved FMS were not being conducted as required: (a) a safety committee was not established and (b) fatigue management training was not being conducted (see Table 35). CASA also issued a detailed AO that outlined other areas for improvement when the operator was developing its new system. Although the audit team (including the fatigue management specialist) intended to interview some pilots, this was not conducted given the advice of the (turboprop) chief pilot that this would not be productive given the current 'lack of faith that exists with an open and honest reporting system'.
- During the May 2006 audit, the operator advised it would complete the revised manual within 6 weeks. In January 2007, the operator again requested an extension to its approval to conduct operations under its existing FMS (as the revised manual had not been completed to CASA's satisfaction). CASA considered not approving the request due to the slow progress to date. After considering various factors, it elected to approve the extension for 3 months, and during this period it would conduct further surveillance of the FMS.
- In April 2007, the fatigue management specialist conducted a site inspection and met with the operator to review progress with the new system. He reviewed the revised manual and assessed various processes and forms associated with the new system. In addition, he reviewed the training material for the new system, which was nearly complete. Some minor problems were found with the system, but the CASA fatigue management specialist was satisfied with the operator's progress. Consequently, CASA reapproved the operator to conduct operations according to its approved FMS for another 12 months, with the understanding that the new manual would be finalised and submitted to CASA in May 2007.
- The operator submitted the revised FRMS manual in May 2007 and, after further communications, submitted another version in early June 2007. CASA formally notified the operator on 7 June 2007 it could operate using its new FRMS manual.
- During the October 2007 scheduled audit, CASA included fatigue management as part of the audit scope. The fatigue management specialist did not participate but provided advice to the audit team. Over a 3-day period, an FOI reviewed the new FRMS manual and relevant records and interviewed the compliance manager to assess how various processes operated. The FOI also interviewed three pilots.[310] Notes on file indicated the pilots reported no significant concerns with the FRMS, and did not feel obliged to extend duty periods. However, some pilots indicated some concern regarding 3–4 days of continuous standby. As noted in *Oversight of flight crew training and checking*, two of the pilots reported they had not undertaken fatigue management training, which resulted in an AO. The audit also resulted in an AO regarding the FRMS not having a process to compare pilot log books with recorded flight and duty times. The audit report noted the compliance manager was regularly reviewing and evaluating the effectiveness of the system. It also stated:

309 Some of the issues that took time to resolve were the operator's request to be able to roster pilots for 5 days in a row with late night duty, and the operation of the IFLS.

310 It was unclear from the audit files whether three or four pilots were interviewed. The notes on file indicated the pilots were randomly selected. However, they included some Darwin-based pilots, as the operator suggested these pilots may have more concerns regarding the FRMS.

> Based upon the size and complexity of the company operations and the sampling process used in the audit of the system, the FRMS appears to be achieving the desired outcomes with flight times less than 20 hours per week and not exceeding 80 hours per month.

- As noted in *Oversight of flight crew training and checking*, the March 2008 audit resulted in a safety alert due to FRMS training not being conducted. After the operator promptly addressed the problem, and satisfied CASA it had processes in place to prevent reoccurrence, it reapproved the operator to conduct operations according to its approved FRMS for another 12 months.
- In May 2008, the operator provided CASA with an investigation report into the circumstances which resulted in a Westwind first officer having a FAID score of 102.[311] The situation arose primarily because the pilot was rostered for a new task before duty time records for a previous task had been received and entered into FAID (and another pilot on standby declining the task). The operator's report outlined a series of corrective actions to prevent reoccurrence (see *Fatigue occurrence reports*).

In February 2009, a Westwind pilot sent an email to the CASA fatigue management specialist who had been involved in oversighting the operator's FRMS since 2004. The pilot asked for information to help him understand why, given his roster and extensive standby hours, his FAID score was relatively low. He noted he had undertaken the operator's FRMS training and asked the operator's management but had not been able to get a satisfactory answer. He also expressed concern about other aspects of the FRMS, including being scheduled for 3 weeks of continuous standby. In response, the CASA specialist provided some general advice to the pilot about FAID. He also noted standby was not captured by FAID as it was time available to sleep.

As a result of the complaint, and because the operator's current approval to operate according to its FRMS was about to expire, CASA personnel (including the fatigue management specialist) met with the operator's chief pilot, the Westwind standards manager and safety personnel (including the parent airline's safety manager) in March 2009. Notes of the meeting on CASA files indicated the operator was able to satisfy CASA it had taken the pilot's concerns seriously, and that CASA was satisfied with the operator's explanation of how it used standby.[312] During the reopened investigation, the CASA fatigue management specialist noted that, as of 2009, CASA did not have any formal position or guidance regarding standby, and it had a limited understanding of the stress associated with continuous standby at that time.

The March 2009 meeting notes also indicated CASA and the operator discussed the current functioning of the operator's FRMS and SMS, and that CASA had identified some weaknesses in the current FRMS, which included:

- Since the compliance manager resigned in 2008, the operator had no 'central knowledge' person (or subject matter expert) who could answer questions from pilots about the FRMS. It recommended that a safety officer obtain formal FRMS training.
- The operator had not trained personnel to investigate incidents with fatigue as a perspective, and the CASA specialist would provide the safety manager with relevant information.
- The operator needed to provide additional information to pilots regarding standby and FAID, and the operator agreed to do this.

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311 According to the operator's FMS/FRMS manual, the occurrence of a score greater than 85 was required to be reported to CASA. The May 2008 correspondence and report was not on CASA files and was identified from documents provided to the ATSB by the operator. Information about FAID is provided in *Fatigue management.*

312 During the reopened investigation, the ATSB interviewed all of the attendees at the meeting, and although they could recall the meeting none could recall any significant details about what was discussed. The ATSB also interviewed the pilot who made the complaint. The available evidence indicates there were individual aspects associated with the pilot which increased the likelihood he would experience difficulties with an ad hoc charter / air ambulance operation.

There was no evidence these actions were communicated in writing to the operator, and no indication the operator formally responded. As far as could be determined, the nominated safety officer did not undertake FRMS training and no additional information was provided to pilots.[313]

Following the March 2009 meeting, CASA were satisfied the operator's FRMS was operating satisfactorily and it reapproved the operator to conduct operations according to its approved FRMS for another 24 months.

Oversight of safety management and management oversight

CASA's 2002 and 2003 scheduled audits noted the operator had a safety management system (based on hazard/incident reporting) and that an internal audit system was being developed. However, the audits did not examine these systems in detail.

CASA specifically examined the operator's safety management processes in the October 2007 audit. In addition, through the application of the management systems model, the auditors could examine organisational aspects when auditing system elements such as flight crew training and checking and fatigue management. One of the Bankstown FOIs who was significantly involved in the 2005–2008 audits stated inspectors found the management systems model to be more academic than practical. However, each of the audit reports contained comments regarding the four attributes of the management systems model, including regarding management responsibility and monitoring and improvement.

Aspects of the 2005–2008 audits relating to safety management and related matters included:

- Prior to the June 2005 audit of the jet AOC, the operator advised CASA it had undertaken a review of key operational positions and introduced changes to reduce the workload of the jet AOC's chief pilot.[314] These changes included the appointment of a Westwind check pilot as the HOTC (subject to CASA approval) and the compliance manager to take on new roles, including administrative resources for the OM, audit processes and compliance aspects that had previously been the role of the chief pilot. During the 2005 audit, CASA reviewed the organisation's structure, and issued an RCA associated with the new positions' roles not being adequately defined in the OM. The operator submitted amendments to the manual and CASA acquitted the RCA.
- As a result of its assessment of aircraft airworthiness aspects, the June 2005 audit identified internal audits were not being conducted in accordance with the operator's audit schedule. The June 2005 audit report also included comments suggesting the operator consider internal auditing of some training and checking activities. In its response to the RCA, the operator stated the problem was due to 'insufficient resources available to facilitate the required audit schedule' and that additional resources had been employed to assist the compliance manager. It also stated an audit schedule had been developed, and it subsequently provided evidence audits were being conducted to the schedule.
- The June 2006 audit of the turboprop AOC stated 'While the audit did not consider all aspects of the company's operations, the findings indicate the company is well managed at all levels, by appropriately qualified persons, and displays a healthy safety ethic.' The audit's examination of aircraft airworthiness aspects indicated the compliance manager had established a comprehensive internal audit system. Relating to the problems identified with flight crew training and checking, one of the RCAs recommended 'a program of internal audit should be established to audit the training and checking activities of check pilots/delegates'. In addition, in regard to

[313] The SMG minutes in September 2009 discussed FRMS changes required to make the FRMS manual consistent with the SMS manual. Associated with this discussion, the chief pilot noted CASA had suggested safety personnel attended FRMS training. No action item was developed.

[314] Personnel from CASA and the operator advised during the reopened investigation that these changes were initiated by concerns held by CASA about the chief pilot's workload.

fatigue management, an AO included a comment that there appeared to be problems with the reporting culture (see *Oversight of fatigue management*).

- The October 2007 audit included a detailed assessment of the operator's safety management system and internal auditing. This assessment included interviews with the compliance manager and the internal auditor, and a review of the operator's relevant manuals (including the OM, FRMS manual, Hazard and Incident Reporting System manual and the Audit Manual), a sample of incident and hazard reports, internal audit reports and related documentation. The audit resulted in a detailed AO, which noted the manuals contained inconsistent content, the formal processing of incident and hazard reports and responses to internal audits was not up to date, and the processes for amending manuals needed improvement. In its response, the operator stated the root cause was the availability of suitable resources. Its corrective action included the employment of a compliance officer and that work had commenced to remedy the backlog of tasks.
- In addition, the 2007 audit report's section on flight crew training and checking noted internal auditing did not appear to be an integral part of the day-to-day flying operations and that it did not extend to a review of operational documents such as flight crew training records. The report's section on safety management and internal auditing noted the internal audit plan did not encompass all aspects of flight operations, and the operator's audit program for that year was only 60 per cent complete. It also stated the parent airline had committed funds and resources to the compliance section, and that an additional resource was recently employed to help facilitate further internal auditing. In addition, the report stated that, despite the findings in the report, 'the audit team consider the company is managed at all levels, by appropriately qualified people', and that management took an active part in all operational and safety matters.
- As noted in *Oversight of flight crew training and checking*, the March 2008 audit identified several types of training had not been conducted as required. The audit report reiterated the comment from the previous audit report that internal auditing was not an integral part of the operator's day-to-day flying operations, and it recommended a review of the workload of the chief pilot and HOTC. The report also stated:

  > The findings of the system audit and the product surveillance conducted since the issue of the AOC in October 2006 had demonstrated that while senior management and staff have appropriate documented procedures available, the failure to detect the deficiencies with regard to the FRMS, CRM Wet Drills, EGPWS training and the conduct of instrument rating renewals not in accordance with the legislation demonstrates that appropriate practices are not being conducted. Given the experience and competency of the staff, this finding suggests inadequate resources are available within the CAR 217 training and checking organisation and the company's system of internal audit…
  >
  > Given the fact that the company provide [sic] training and checking for 70 pilots it is important in the interest of operational safety for [the operator's] management to resolve the issues stated in this report and establish more effective and frequent internal audit of the conduct and recording of the training and checking of flight crew. Given the number of pilots currently employed and the company's proposed expansion into the Saab 340 aircraft, a review of the current workload of the Chief Pilot and Head of Training and Checking should also be considered

When the Sydney region manager advised CASA senior management of the safety alert, he noted he did not think the matter would escalate to a need to consider a 'serious and imminent risk', given that the operator was demonstrating a willingness to address the issue. However, he was considering what further action may be necessary.

At some stage after the audit, CASA held a meeting with the operator, with the attendees including the CASA Sydney regional manager, other CASA personnel, the chief pilot and one of the operator's directors. During the meeting, CASA expressed concern with the chief pilot's attitude to the importance of regulatory compliance and related cultural aspects. It also advised the operator it was considering action against the chief pilot.[315]

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315 The exact date of the meeting is unknown, and there was no note on CASA files about the meeting.

During the reopened investigation, CASA personnel advised the ATSB that it did not have sufficient evidence to initiate action against the then chief pilot's approval but it wanted to encourage a better attitude to regulatory compliance from the operator. Following the meeting they detected a more positive approach from the operator, and they were satisfied with the operator's response to the safety alert and other findings from the March 2008 audit. As noted in *Review of flight crew training and checking records*, at about this time, the operator's senior management had decided they would seek a new chief pilot.

CASA assessed the new chief pilot candidate in November 2008. The assessment process involved an interview and a check flight. The interview involved assessing the candidate's knowledge of regulations and the OM and his system management abilities. The completed assessment checklist indicated CASA believed the candidate had a demonstrated history as a 'good operator' in management and check pilot roles. CASA FOIs advised the ATSB they had previously encountered the chief pilot candidate during check pilot observations or approval processes and they had no concerns regarding his suitability for the role during CASA's assessment process in November 2008.

In addition to audits of the AOC, CASA routinely conducted audits of the organisation's maintenance certificate of approval (COA). The 2005 audit was conducted in conjunction with the June AOC audit, and identified a problem with the operator's internal auditing (discussed above). The RCA referred to the requirements of CAR 30 (Certificates of approval), which specifically required a COA organisation to have a quality control system, including an audit system.[316] Subsequently:

- A COA audit in August 2008 identified most internal audits of engineering aspects over the previous 2 years had not been conducted, which resulted in an RCA. In its response, the operator stated the previous compliance manager had been responsible for the internal auditing program and also had many other roles. It reported the operator's internal auditing function would soon be taken over by the parent airline and it outlined a proposed audit schedule for the next 12 months. In addition to engineering activities, the proposed schedule included audits of the FRMS, and several audits of flight operations, including the OM, aircraft documentation, training, approvals and facilities, as well as 'line safety audits'.
- A COA audit in August 2009 identified ongoing problems with internal auditing and that the previous proposed schedule of audits had not been completed, which resulted in an RCA. In response, the parent airline advised CASA it had conducted a review of the operator's engineering functions and was implementing measures to ensure appropriate systems were in place before finalising a new audit schedule.

As noted in *Operator requirements*, the operator submitted an SMS implementation plan to CASA in June 2009, which was approved by CASA in October 2009. The operator subsequently submitted version 1.1 of its SMS manual (September 2009) as required by CASA for phase 1 of the SMS implementation, and CASA approved the manual in January 2010. CASA's approval of these documents was via a desktop review by specially-trained inspectors using detailed checklists. No problems were identified with the operator's implementation plan or proposed manual (see also *Audit of CASA's implementation of safety management systems (2010)*).

Overall assessment of the operator

The ATSB reviewed the CASA files for the operator and the CASA Sydney Region files associated with the monthly office planning meetings for 2008 and 2009. There was no indication that, following the March 2008 audit, the operator was considered to be high risk relative to other AOC operators or in need of a special audit or increased surveillance activity. During 2008–2009, the weighted STI scores for the operator were never in the top 10 for the AOCs under the

316 The regulatory requirements for an AOC included no similar, explicit requirements for internal audits.

responsibility of the Bankstown office. The overall assessments on the STIs indicated the operator was similar to other operators, and that its (safety) performance was improving.

When interviewed during the reopened investigation, CASA Bankstown personnel confirmed that prior to the accident they did not consider the operator to be high risk. They had identified some problems in scheduled audits but they had not identified a need for a special audit or increased surveillance activity based on their oversight up to the time of the accident. There were no indications on CASA files of any consideration that a risk-based audit or additional surveillance was required. Accordingly, the next audit would probably have been scheduled in about March 2011.

CASA FOIs who conducted oversight activities of the operator after November 2008 reported they had a number of interactions with the new chief pilot. Based on these interactions, they had a high level of confidence in the work he was doing. They believed he was proactive in advising CASA about any problems that had been identified and the action being taken to address the problems, and he was also proactive in seeking CASA advice and responsive to any CASA advice. The CASA FOIs were aware of the work the chief pilot had undertaken to improve the turboprop fleet, and the other changes he had introduced, such as holding standards meetings with check pilots. They were also aware the new chief pilot was having some difficulties making changes in the military and Westwind fleets and was about to start work improving those operations when the accident occurred.

In addition, CASA personnel were aware that during 2009 the parent airline was taking a more active role in the operator's safety management, and that the SMG was regularly meeting to review safety matters.

CASA personnel stated they were aware that the operator's Westwind fleet was conducting international air ambulance operations, but were not aware of the extent of the operations. They were also not aware air ambulance operations had become the primary activity of the Westwind fleet, were being conducted from four bases with several aircraft, and were being conducted to a wide range of destinations, including many remote aerodromes.

CASA personnel also advised that, once a charter or aerial work operation was approved, there was no obligation for the operator to advise CASA about the frequency, scope of nature of the operations it conducted (as long as they were consistent with what had been approved). This included the number of flight crew, addition of new bases, the number of flights of each type of operation and the routes flown.

Special audit conducted after the accident

Following the accident, from 26 November to 15 December 2009, CASA commenced a special audit of the operator. The audit report stated:

> The audit included an extensive assessment of the Westwind operations as well as examination of the organisational aspects of [the operator] and the relationship between [the parent airline] and [the operator]. Additionally, the turbo-prop and military jet operations were audited to determine if the systemic deficiencies identified in the Westwind operations were prevalent in other parts of the organisation. Following identification of deficiencies in defect management, audit activities were also extended to assess the efficacy of maintenance control at [the operator].

The audit scope was based on factors potentially associated with the accident flight, and it was much broader than previous audits. It included some systems and elements covered in recent audits (such as training and checking and fatigue management) and some that had not been covered (such as flight planning/fuel planning and operational control).

The audit team consisted of 16 CASA personnel, including FOIs, human factors specialists, airworthiness inspectors, an air transport inspector and drug and alcohol inspector. The audit involved a review of manuals, flight records and other documentation, ramp checks of several aircraft, and interviews with most managers and many pilots (including most of the Westwind pilots and some pilots from other fleets).

The audit report identified many problems, resulting in 20 RCAs, 10 AOs and one ASR. Most of the findings related to flight planning, fuel planning or in-flight fuel management (three RCAs and four AOs), flight crew training and checking (eight RCAs and two AOs) and fatigue management (three RCAs and three AOs).[317]

The summary section of the report stated:

> The key deficiencies identified during the audit included:
>
> **Fuel Policy and Practice**
>
> • Inadequate fuel policy for Westwind operations;
>
> • Inadequate fuel policy for Lear military operations;
>
> • Pilots use their own planning tools and there is no control exercised by [the operator] to ensure the fuel figures entered are valid;
>
> • No policy exists to ensure that flight and fuel planning is cross-checked to detect errors;
>
> • No alternate requirements specified for remote area and remote island operations;
>
> • Operations Manual specifies 30 minute fuel checks – this is largely ignored by operating crew;
>
> • Criteria to obtain weather updates not specified in the Operations Manual and
>
> • Practice of obtaining weather varies among pilots and does not appear to be conducted at appropriate times to support decision making.
>
> **Obstacle Clearance**
>
> • Data to ensure obstacle clearance requirements are met is not provided for international operations.
>
> **Maintenance Control & Defect Reporting**
>
> • Defects are reported verbally, via email or on notes rather than on the Aircraft Maintenance Log;
>
> • Culture of apprehension among pilots in relation to writing up defects on Aircraft Maintenance Log; and
>
> • Maintenance Control procedures out of date and some aspects of maintenance control are performed independently of the maintenance controller.
>
> **Operational Control**
>
> • No operational decision-making tools provided to support crew in balancing aviation vs medical risks;
>
> • Once tasked, the pilots operate autonomously and make all decisions on behalf of the AOC. The AOC exercises little, if any, control over the operation once a task commences;
>
> • The company does not provide domestic charts or publications to pilots and does not ensure that the pilots maintain a complete and current set;
>
> • In many cases inadequate flight preparation time is provided. (Normally pilots are notified two hours prior to departure regardless of when the company becomes aware of the task);
>
> • Failure to maintain required flight records and no apparent checking by the company; and
>
> • Pilots use their own planning tools and there is no control exercised by [the operator] to ensure the data entered is valid.
>
> **Training**
>
> • Inadequate CAO 20.11 training (life raft refresher and emergency exit training deficient);
>
> • Inadequate documentation of training programs;
>
> • No formal training for international operations;
>
> • Inadequate training records for pilot endorsement and progression;

[317] One of the RCAs, relating to the absence of CRM training, was based on incorrect information and should not have been issued.

• Inadequate records of remedial training;

• Endorsement training is the minimum required (five hours) and relies on regular operations to consolidate training;

• No mentoring program for First Officer to Command; and

• Deficiencies in training records identified.

Fatigue Management

• Over-reliance on FAID as the primary fatigue decision making tool;

• Inadequate adherence to FRMS policy and procedures;

• Excessive periods of 24/7 standby;

• Lack of FRMS policy regarding fatigue management for multiple time zone changes; and

• Fatigue hazard identification, risk analysis, risk controls and mitigation strategies not up-to-date and documented. (Advice provided during the FRMS review indicates that [the operator] considers the ad hoc aero-medical operations to be its highest fatigue risk and yet there is no recent documented evidence to confirm these risks are being actively managed).

Drug and Alcohol Management

• Failure to ensure that drug and alcohol testing is conducted after an accident or serious incident.

The last sections of the audit report dealt with broader issues of safety management and safety culture. The report stated:

> Despite the existence of a comprehensive Operations Manual suite the Westwind Operations do not have appropriate procedures in place or adequate documentation relating to the company's required Standard Operating Procedures (SOP's). This lack of articulation in policy and procedures has led to a range of deficiencies that include deficient fuel policy; pilot's [sic] using unapproved flight and fuel planning figures, inconsistent and undocumented training practices; Proficiency checks conducted as a requirement under CAR 217, lack standardisation, appropriate documentation and in some cases have been conducted by unapproved persons; and lack of internal compliance or Quality audits…
>
> The Special Audit identified significant deficiencies within the Westwind operations in [the operator]. These deficiencies existed for many years because they had never been formally identified by [the operator's] management. Although a Safety Management System for [the operator] was defined in a manual, up until recently the process in practice, was not evident…
>
> A lack of formal company guidance in critical areas such as fuel policy, flight planning and defect reporting placed the onus on the individual pilot to apply his/her own personal standard of airmanship. Company standards have not been documented (although an FCOM does now exist for the Metroliner and Saab fleet) coupled with an absence of operational control once airborne (Westwind) leaving the pilot to make all decisions on behalf of the AOC. These decisions and judgements are not reviewed, post flight, through internal or quality audits.
>
> Prior to the accident there had not been a review of the Westwind operation nor had the company applied a mechanism, either through its SMS or CAR 217 organisation to review operational policy and procedures for effectiveness, compliance or safety standards.
>
> The audit revealed an absence of a coherent organisational culture within [the operator] which was evidenced by a lack of internal review and analysis. Safety Management is the deliberate application of management practices to mitigate, eliminate or reduce safety risks associated with the operational activity of the organisation. The audit found a deficiency in practices to monitor and improve safety health and to measure operational compliance.

The conclusion section of the report stated:

> The Special Audit identified significant deficiencies within the Westwind operations in [the operator]. These deficiencies existed and had not been identified or rectified which is indicative of broader organisational failures. The company's executive management relied upon the Westwind Standards Manager to apply company policy and procedures to ensure the standard of operations were conducted to the appropriate regulatory and safety levels. It was evident that this had not taken place to the regulatory or safety standard required.

> The review of the turboprop operation found that this part of the AOC was conducted compliant with the regulations, to a high safety standard and in accordance with company policy and procedures. It was evident that the company had committed significant resources to improving this part of the operation…
>
> The review of the Military Jet Operation (Lear and Westwind) found that this part of the AOC is conducted broadly compliant with the regulations, to a high a safety standard however not all aspects of the operation were clearly documented. This has resulted in deficiencies in policy and procedures most notably that the fuel policy did not meet regulatory requirements…
>
> While the organisational failures raised serious concerns for CASA, the actions initiated by [the operator's] Executive management following the accident of VH-NGA provided confidence to CASA that the Executive is committed to identifying and correcting those failures. The actions included the grounding of the Westwind fleet, re-training for all Westwind pilots and the initiation of a Management Action Plan (MAP) to initiate a range of corrective actions to ensure that safe operations of the Westwind fleet.

Further details of the actions taken by the operator to address the identified problems are provided in *Safety issues and actions*.

During the reopened investigation, the ATSB asked CASA personnel why the special audit identified many problems with the operator's flight operations that had not been identified in previous audits. They replied that the main reason was the extensive scope and depth of the special audit, which was conducted by 16 personnel and conducted over 3 weeks. In comparison, most scheduled audits were typically conducted by two to three inspectors over a couple of days. Therefore, because significantly more surveillance was done, and done at a deeper level, more problems were found.

Furthermore, CASA inspectors stated the special audit involved interviewing a large sample of line pilots, which had not been conducted in previous audits. These pilots provided much of the useful intelligence regarding discrepancies between procedures and practices, or areas where there was no consistent practice. Also, given the number of pilots interviewed, the pilots were probably less concerned about anonymity, which can occur in smaller operators or when only a small number of pilots are interviewed.

Internal evaluation of CASA oversight

Overview of the internal review

Following the audit, the CASA Executive Manager, Operations Division requested the Sydney Region manager conduct a review of CASA's oversight of the operator in the period leading up to the accident to identify any lessons learned.[318] The Sydney Region manager subsequently prepared a report in August 2010 based on his experience and a review of CASA's files on the operator and also some files on other operators.

The internal review identified several problems, including CASA's limited understanding of the operator's operations prior to the audit, and the limited amount of assessing 'process in practice' during surveillance.

Understanding of an operator's activities

The internal review report noted there was a problem with CASA's knowledge of the operator. More specifically:

> The [operator's] AOC permits world wide Charter and Aerial Work operations without limitations. CASA requires the company to have appropriate systems in place for the approved scope of the

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[318] This manager had been in the position since July 2009 and had no previous involvement in oversighting the operator prior to leading the 2009 special audit after the accident (other than conducting a ramp check in 2007).

> operations however CASA does not require the AOC holder to provide specific route information for Charter or Aerial Work functions.
>
> Sydney Region uses the Assigned Inspector method of managing the Oversight of the AOC. Over the past 5 years four different Inspectors were assigned to the operator at one time or another. The currently assigned Inspector[319] was familiar with the AOC systems, had a good relationship and regular contact with key personnel and had a general understanding of the routes flown. As the company was not required to provide specific route information the inspector and consequently the office had an incomplete understanding of the range of operations. This resulted in the oversighting office's inability to fully assess the extent of the operation and to conduct surveillance accordingly.
>
> For example the oversighting office was not aware that the company conducted operations over the route of the accident flight prior to the accident. It was also discovered after the accident that the Westwind fleet operated to locations such as Papua New Guinea highlands, Guam, Cocos Island, Christmas Island as well as many of the Pacific Islands popular with Australian holiday makers. Further it was understood that the Medivac operation was a small albeit an expanding part of the Westwind operation however subsequent to the accident it became evident that the majority of the Westwind operations were no longer conducting RPT freight.
>
> The relative familiarity with the company and key personnel resulted in a sense that CASA had detailed knowledge of the actual operations however this clearly was not the case. Ultimately CASA was not in a position to accurately assess oversight requirements without the understanding of the true nature of the operation.

Related to this issue, the internal report also noted problems with CASA's storage of information about an operator:

> CASA's knowledge of an operator commences at entry control and continues to expand over time through the surveillance and regulatory service processes.
>
> The recording and retention of that knowledge or data is problematic. For example, the data that CASA has available for [the operator] is stored in at least ***fourteen*** disparate and unconnected systems…
>
> Very few of these systems can be mined for data and none of the systems are integrated with each other to provide a comprehensive data set or profile of the operator. CASA is entirely reliant on individuals, usually the assigned Inspector, to analyse the information to form a picture of the operator. The result is a less than adequate view that invariably is stored in the mind of the Inspector.
>
> The overall knowledge of an operator varies considerably with the passage of time as Inspectors rotate and the company's operations change. The perpetual knowledge of the operator is dependent on the level of interaction between the individual Inspector and the operator and the diligence and skill the individual Inspector applies to building that comprehensive picture through stored documentation.
>
> CASA does not have a summary description of an operator (An Operator Profile). For the Manager or Team Leader to understand an operator they must obtain a verbal briefing from the inspector or review data from the fourteen available sources. Even with this data combined the perspective remains limited and often historical rather than current…

Understanding line operations in practice

Another key theme of the internal review report was associated with the importance of conducting interviews with line pilots and observing line operations. The report noted the systems auditing approach was resource intensive. Consequently:

> Where systems audits are implemented (as in the case of [the operator]) the genuine resource constraints continue to impact upon the outcome of the surveillance process. Typically this sees a significant portion of the audit time devoted to reviewing Ops Manuals, interviewing key personnel regarding the systems and reviewing flight & duty and training & checking records. These tasks are very important as part of the review of the system design and confirming from records that the systems are being applied however the effectiveness of this approach is not measured and therefore uncertain as the [the operator's] experience demonstrates…

[319] This inspector became the assigned FOI for the operator in mid-2008.

In a section titled 'Interaction with key personnel and line staff', the report stated:

> The element of systems auditing that receives the least attention is Process in Practice. Typically little audit time is spent with line personnel to evaluate the application of the systems and processes at the working level. The special audit of [the operator] highlighted that significantly more time needs to be spent with line personnel as it was the interviews with line pilots following the accident that identified that the systems and processes were not being used or were not effective to produce the desired safety outcome.
>
> Process in practice is product checking with a clear purpose. It is not and should never be a tick and flick exercise to complete a surveillance checklist. It is a qualitative assessment to determine that the systems implemented by the company are producing the desired safety outcome. This check determines compliance with the systems by line personnel. For line personnel to be compliant they must first know and understand the systems and apply them in practice. This was considered to be a key failing in [the operator] and was only evident through interviews with line pilots.
>
> It is likely that many of the deficiencies identified after the accident would have been detectable through interviews with line pilots and through the conduct of operational surveillance of line crews in addition to surveillance of management and check and training personnel.
>
> Interviews with line staff were the most influential factor in identifying the failings with in the [operator's] AOC. The use of a standard questionnaire produced consistent results from the audit process with line staff. This needs to be addressed in surveillance methodology…
>
> If a systems audit is conducted with inadequate product checking CASA is unable to genuinely confirm that the operator is managing their risks effectively. It is also essential that the product check is conducted with line personnel and not management staff or key personnel such as check pilots…

Other problems

In addition to understanding of the operator's activities and line operations in practice, the internal review report identified several other problems:

- limited resources having a negative effect on surveillance capability
- variations in the abilities of inspectors to deal with conflict and to investigate beyond 'scratching the surface'
- limitations in the selection, training and assessment processes for inspectors
- RCAs being acquitted on the basis of proposed plans of corrective action rather than on evidence that the corrective action had been implemented.

During the reopened investigation, the Executive Manager who requested the internal report advised the ATSB he thought the report provided a good summary of the problems he had also observed. He forwarded the report to the executive management of CASA, but did not receive a response. Nevertheless, CASA advised the report was used to help improve future CASA oversight processes. CASA also advised the ATSB there were no records of any personnel reviewing the report or commenting on the report. CASA personnel advised there were also no other similar reports conducted on CASA's surveillance activities.

CASA personnel from the Bankstown office reported they did not agree with some of the findings in the internal review, particularly in relation to inspectors' abilities and the acquittal of RCAs. However, they agreed there were problems with the storage of information and their understanding of an operator's activities. They also agreed there had been a significant problem with resources, and that due to limited resources they had not been able to conduct much en route surveillance and similar activities. One FOI noted that even if they had a better understanding of the operator's activities, it is unlikely they would have conducted more audits on the operator given their other priorities and limited resources.

One FOI also noted that interviewing pilots was very useful, however in some cases operators would not allow CASA to conduct interviews unless a management representative was present, which could limit the usefulness of the information obtained.

Other reviews of CASA oversight

ATSB report 200501977

In its investigation into the fatal accident involving a SA227-DC (Metro 23) at Lockhart River on 7 May 2005,[320] the ATSB examined CASA's regulatory oversight policies and practices. In that case, the oversight was conducted by the Brisbane airline office, which used some different processes than a CASA non-airline office such as Bankstown. In particular, they did not use STIs after 2003 and they also used a different model for describing systems and elements (and therefore scoping an audit).

The ATSB report identified safety issues associated with CASA's oversight processes. These included:

- CASA did not provide sufficient guidance to its inspectors to enable them to effectively and consistently evaluate several key aspects of operator management systems. These aspects included evaluating organisational structure and staff resources, evaluating the suitability of key personnel, evaluating organisational change, and evaluating risk management processes. (Safety Issue)
- CASA did not require operators to conduct structured and/or comprehensive risk assessments, or conduct such assessments itself, when evaluating applications for the initial issue or subsequent variation of an Air Operator's Certificate. (Safety Issue)
- CASA did not have a systematic process for determining the relative risk levels of airline operators. (Safety Issue)

In relation to the first finding, the ATSB report discussed the importance of obtaining information from operational personnel. The report stated:

> The Surveillance Procedures Manual contained general guidance on collecting evidence during audits. The guidelines stated that evidence should be objective, obtained with the knowledge of the operator, verified for correctness and completeness, and recorded accurately and concisely. The manual also stated that the audit team should 'verify what they say they do versus what they actually do'.
>
> There was no guidance in the manual regarding the importance of collecting information from line employees and personnel other than the key personnel. CASA advised that its inspectors were required to complete a 5-day audit course which included content on the importance of collecting information from other sources.
>
> There were also no mechanisms or guidance in the manual on how to encourage employees to volunteer information. More specifically, there were no mechanisms or guidance on how to obtain information confidentially, which could then be used to focus the search for further information rather than be used as evidence to justify findings…

The analysis section of the ATSB report stated:

> Basic audit methodology includes obtaining information from a variety of sources, including the personnel who are required to conduct the activities being audited. However, CASA's approval and surveillance processes appeared to primarily focus on obtaining information from management personnel. A more robust process would involve regularly obtaining information from other personnel, including those fulfilling an important role in facilitating and monitoring operational standards, such as deputy chief pilots, check and training pilots, and base managers. A more robust process would also include guidance for obtaining information from operational personnel in a structured manner, as well as mechanisms to encourage such personnel to provide information on management processes and operational standards.
>
> Conducting discussions with samples of operational personnel takes time, and it is possible that some information obtained through such discussions would be malicious or difficult to substantiate.

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[320] ATSB Aviation Occurrence Report 200501977, Collision with terrain, 11 km NW Lockhart River Aerodrome, 7 May 2005, VH-TFU, SA227 DC (Metro 23). Available at www.atsb.gov.au.

> However, such discussions have a real potential for identifying problems that would not be detected through discussions with senior management, reviews of documentation or product inspections.

The ATSB issued a recommendation regarding the first of the findings listed above. In response, CASA advised it had employed system safety specialists and air transport inspectors to help evaluate these types of organisational aspects. In addition, these personnel were developing improved guidance material.[321] CASA Bankstown personnel reported these specialists were primarily involved in the oversight of airline operators.

ICAO safety oversight audit (2008)

In February 2008, ICAO conducted a safety oversight audit of Australia, with the final report released in January 2009. The audit covered a broad range of topics.

The audit report included the following finding regarding the training of flight operations inspectors:

> While some ad hoc training is being provided to operations inspectorate staff, CASA has not developed and implemented a formal training programme and periodic training plan detailing the type of training to be provided. A requirement for each inspectorate staff member to satisfactorily complete on-the-job training prior to being assigned tasks and responsibilities has not been institutionalized.

In response, CASA stated it would develop a formal training program for inspectorate staff (including initial, on-the-job, recurrent and specialist training) by 31 December 2008, and would implement the formal training program by 31 December 2009.

The report also included the following finding regarding surveillance:

> CASA has delegated some tasks, such as flight proficiency checks, to qualified persons within an AOC holders' organization who conduct testing on behalf of CASA. However, CASA does not perform sufficient safety oversight of these delegated individuals, as the surveillance program is not being fully implemented.

In response, CASA noted CAR 217 organisations were subject to ongoing surveillance. It also advised it would 'develop a risk-based surveillance program relating to the frequency of surveillance of CAR 217 organisations to ensure effective oversight of associated delegated individuals'. The estimated implementation date was December 2009.

Audit of CASA's implementation of safety management systems (2010)

In response to a recommendation by the Senate Committee on Rural and Regional Affairs and Transport in September 2008, the Australian National Audit Office (ANAO) conducted an audit of CASA's implementation and administration of the regulation of aircraft operators' SMSs. The audit commenced in August 2009 and the final report was released in October 2010.[322]

As discussed in *Australian requirements and guidance*, CASA's approach to approving an operator's SMS was conducted using a phased approach, with operators required to submit their implementation plan and then sections of their SMS manual by specified dates. Regarding this process, the ANAO report concluded:

> A total of 35 operators submitted an SMS manual to CASA for assessment, comprising 18 high capacity operators and 17 low capacity operators. CASA employed and provided training to system specialists who were responsible for assessing the SMS manuals provided to CASA by operators. In addition, CASA developed a comprehensive checklist to inform the decision as to whether the SMS manual submitted by each operator should be approved. Nevertheless, there were some shortcomings in the documentation assessment process, including instances where there was not a clear and consistent evidentiary trail to support CASA's decision to approve the SMS manual that had

[321] For further information, see safety recommendation R20070002 at www.atsb.gov.au.

[322] Australian National Audit Office, Implementation and administration of the Civil Aviation Safety Authority's safety management system approach for aircraft operators, Audit Report No. 13 2010-1011, October 2010.

> been submitted by the operator. Accordingly, ANAO has made one recommendation aimed at enhancing the rigour of CASA's desktop review of an operator's SMS…[323]
>
> In order to have their SMS approved, operators had to satisfy CASA that their SMS manual documented and suitably described safety systems and processes that were appropriate to the operator, or that any missing/inadequate elements would be addressed in a timeframe that CASA considered acceptable. Accordingly, CASA approval of an operator's SMS was not on the basis that CASA was satisfied that the SMS manual was being used by the operator and that the documented systems and processes effectively managed safety risks. Rather, these aspects were to be addressed in the second stage of CASA's SMS approval process, referred to as 'Capability Assessment'.

In its response to the report, CASA stated:

> CASA welcomes any constructive review and external scrutiny of its processes and procedures. In addition to the recommendation, which CASA supports, the report has identified a number of areas where CASA can improve and it is the intention to apply appropriate measures to ensure that lessons learnt will be applied in future especially in relation to the introduction of new regulations.
>
> Notwithstanding this, it should be noted that CASA remains at the forefront of Civil Aviation Authorities worldwide and our implementation of safety management systems in the aviation industry is at the leading edge across ICAO member states. Although not indicated within the report, CASA undertook a review of lessons learnt from other regulators in their implementation of SMS and has diligently applied these in our approach. Ensuring the ongoing safety of aviation has been and will continue to be paramount to CASA in the introduction of any new systems or regulations.

Aviation Safety Regulation Review (2014)

In November 2013, the Deputy Prime Minister and Minister for Infrastructure and Regional Development commissioned a review of the effectiveness of Australian government agencies involved in aviation safety and related matters. The review panel's final report was released in May 2014.[324]

The report included a section that discussed CASA's audit and surveillance approach. Given the review was done in 2014, the relevance of the report's content about CASA processes prior to the 18 November 2009 is limited. However, one section that is potentially relevant concerned the classification of audit findings. The report stated:

> The CASA Surveillance Manual[325] outlines the differing levels of classification for audit findings, notably between immediate and urgent safety issues and all other findings. Auditors have the authority to raise a Safety Alert (serious system safety issue), but there is no alternative classification regarding the level of severity for other findings that result in the issuance of an NCN [non-compliance notice]. This approach is not in accordance with best practice of most audit programs and is causing the industry concern. For example, ISO 19011 specifically references 'grading' non-conformances. In the Panel's consultations in New Zealand, it was outlined that the New Zealand CAA grades their equivalent Finding Notices as 'Minor', 'Major' or 'Critical'.
>
> The Panel considers it is preferable to delineate between clear safety (regulatory) issues and minor issues. If there is a series of minor issues indicating a systemic management problem, a single NCN can be raised to cover the range of issues.
>
> The current system of giving equal weight to each NCN, unless they are raised as a serious safety issue, does not adequately represent the associated risk. It can result in the impression that an operator is conducting its business in an unsafe matter, when in fact all non-compliances may be

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[323] The recommendation stated: 'ANAO recommends that the Civil Aviation Safety Authority enhance the rigour of its desktop review of operators' safety management systems by introducing procedures that provide a clearer and more consistent evidentiary trail as to the basis on which approvals are granted, particularly in circumstances where the underlying records indicate that one or more elements required to be in place had not been found to be suitably present in the operator's safety management system documentation at the time of the assessment.'

[324] Australian Government 2014, *Aviation safety regulation review*, report prepared for the Australian Government, available from www.infrastructure.gov.au.

[325] In 2013, CASA replaced the SPM with the CASA Surveillance Manual (CSM). In addition, the term RCA was replaced by non-compliance notice (NCN), a term that was also previously used by CASA for an RCA prior to 2002.

> relatively minor and administrative. The Panel recommends a change to create a tiered ranking of non-compliances by severity, so that audit findings more accurately reflect the safety risk identified.

The report made a recommendation regarding this matter, as well as some recommendations regarding the full disclosure of audit findings at audit exit briefings and for CASA to assure the consistency of audits across regions.

CASA oversight of other air ambulance operators

During the reopened investigation, the ATSB requested CASA audit reports of other air ambulance operators conducted close to the time of the 18 November 2009 accident. CASA provided audit reports completed on four operators that conducted air ambulance operations in corporate jet aircraft. All of the operators had multiple aircraft and bases, but overall were significantly smaller than the operator of VH-NGA. Three operators conducted a mixture of charter and air ambulance operations, and one conducted only air ambulance operations. All of the operators conducted international, overwater operations.

Two of the audits were conducted by the Bankstown office (by different audit teams) and two by other non-airline offices in CASA. The audits appeared to be conducted in a similar way as the audits of the operator of VH-NGA, with small teams primarily reviewing manuals and documentation and interviewing key personnel. There was no indication in the reports that pilots were interviewed or that en route surveillance was conducted during or close to the time of the audit. There was notable variation in the structure of the reports, with the February 2011 report written as an ‘inspection report’, another report including only a one-page summary and the findings, and the other two reports written in a similar manner as the reports on the operator of VH-NGA, with detailed comments regarding the elements of CASA’s management systems model.

For one operator, the audit was the first conducted on the operator, 34 months after the AOC was issued. The audit report noted the operator had significantly expanded during this period. For two of the other operators, the audits were conducted 27 months and 34 months after the previous audit. For the fourth operator, it was unclear when the previous audit was conducted.

Summary details of the audit reports are provided in Table 36.

In terms of flight/fuel planning, none of the audit reports discussed the operator’s fuel policy.[326] The September 2009 audit specifically examined the operational support provided for flight/fuel planning. It noted the operator appeared to have good processes in place, but CASA issued an RCA as the procedures were not documented in the OM. One of the other audits included an RCA related to multiple instances of incorrect fuel quantities recorded on flight records.

With regard to fatigue management, one of the operators had an approved FRMS and the audit examined aspects of the FRMS as problems had been identified in a previous audit 2 years before, but no new problems were identified.[327] The other three audits involved reviewing samples of flight records and flight and duty times. All three reports included RCAs associated with breaches of the requirements of the standard industry exemption to CAO 48 or CAO 48.

Because none of these operators conducted RPT operations, there were no regulatory requirements for them to have an SMS. As indicated in the table, one of the audits specifically examined an operator’s safety management aspects and identified a number of problems, including no documented responsibilities for key personnel, no documented internal audit system and the safety manager not having received any formal training. Another audit report noted the

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326 CASA advised the ATSB that, following the 18 November 2009 accident, it reviewed the fuel planning procedures of several air ambulance operators (see *Safety issues and actions*). These reviews were not conducted as formal audits.

327 The ATSB obtained a copy of the FRMS manual for this operator. It contained a lot of similar content as the FRMS manual for the operator of VH-NGA. However, it did not have some of the additions that CASA had required the operator of VH-NGA to introduce. For example, the extension of duty process did not require any formal assessment other than the use of FAID. The manual also did not contain any rostering rules for minimum periods off duty.

operator stated its SMS manual was 'very scant'. This audit report also identified significant problems with record keeping and concluded there did not appear to be an internal auditing system to review records for completeness and accuracy. The other two reports did not discuss SMS or internal audit aspects in any detail.

Table 36: Overview of CASA audits of other air ambulance jet operators, including the number of requests for corrective action (RCAs), audit observations (AOs) and aircraft survey reports (ASRs)

Operator	Details	Systems / elements examined	RCAs	AOs	ASRs
A	Scheduled	Flight crew training and checking	9		
	(Sep 2009)	Fatigue management			
		Operational support	1		
		Aircraft airworthiness / maintenance	3		
		Aircraft load control			
		Total	13		
B	Scheduled	Flight crew training and checking	1		
	(Feb 2011)	Fatigue management	1		
		Aircraft airworthiness / maintenance	1		
		Flight operations: miscellaneous	1	1	
		Total	4	1	
C	Scheduled	Flight crew training and checking	8	1	
	(Mar 2011)	Fatigue management	1		
		Flight operations: miscellaneous	6	3	
		Aircraft airworthiness / maintenance	4	29	
		Safety management		9	
		Total	19	42	
D	Scheduled	Flight operations records	6	1	
	(Aug 2011)	Fatigue management	1		
		Flight operations: miscellaneous	2	1	
		Aircraft airworthiness / maintenance	3	1	
		Total	12	3	

Note: The classification of the systems and elements in this table has been modified from the original audit reports and documentation to provide consistency across the audits. Similarly, RCAs issued about specific aircraft in 2002 were reclassified as ASRs.

Safety analysis

Introduction

The air ambulance flight involving the Westwind 1124A registered VH-NGA on 18 November 2009 was being conducted from Apia, Samoa to Norfolk Island, Australia. The aircraft arrived at Norfolk Island without sufficient fuel to divert to another aerodrome or hold for an extended period of time. After the flight crew conducted four unsuccessful approaches in low cloud and reduced visibility conditions, they ditched the aircraft. The flight crew, medical personnel, patient and passenger evacuated the aircraft and were subsequently rescued.

As with many accidents involving an air transport aircraft, this accident involved a combination of multiple safety factors. In addition, the investigation identified many other factors that increased safety risk, although they may not have contributed to this accident. The following sections discuss the identified safety factors under the following headings:

- pre-flight fuel planning
- aerodrome weather forecasting
- provision of flight information
- in-flight fuel management
- planning and execution of instrument approaches
- ditching
- emergency procedures and survival factors
- crew resource management
- fatigue and fatigue management
- equipment installation and aircraft maintenance
- safety management and management oversight
- regulatory oversight.

Since the accident, a wide range of safety improvements have been undertaken or initiated by the operator (Pel-Air Aviation), the Civil Aviation Safety Authority (CASA) and other organisations that will reduce the risk associated with the types of safety factors discussed in this report (see *Safety issues and actions*). In addition, the accident has highlighted many safety lessons that are relevant to flight crew and operators, particularly those involved in conducting flights to remote islands or isolated aerodromes.

The following analysis utilised the ATSB investigation analysis model, which considers occurrence events, individual actions by operational personnel, local conditions, risk controls and organisational influences. Further details of this model are provided in appendix Q.

Pre-flight fuel planning

Overview

The flight crew were conducting a long-distance flight to a remote island at night. The aircraft was refuelled at Apia to full main tanks, or about 7,200 lb of fuel, prior to engine start. If the aircraft had been fully fuelled, with full main tanks and full tip tanks, it would have had about 8,700 lb prior to engine start.

There were no weather-related or other operational requirements at the time of departure, specified by the operator or the regulator, for the flight to carry alternate fuel (that is, sufficient fuel to conduct an approach at Norfolk Island and then divert to a suitable alternate aerodrome, including the required fuel reserves). Even if the flight had departed with full fuel on this occasion, this would not have provided for alternate fuel given the upper-level wind conditions that existed on the night of the accident. In other words, in the circumstances that existed at the time of the flight, Norfolk Island was an isolated aerodrome.

Nevertheless, departing with full fuel would have significantly reduced the risk associated with the flight. In general terms, extra fuel will:

- allow a flight to proceed closer to the destination aerodrome before the flight crew need to make a decision regarding a diversion, reducing the time and therefore the risk of weather or other conditions changing between the point of no return (PNR) and arriving at the aerodrome
- if the flight is continued to the destination aerodrome, allow the flight crew to have more time at or overhead the aerodrome to hold and consider the available options and/or wait for weather conditions to improve.

On this occasion, if the crew had departed Apia with full fuel, it is likely they would have arrived at the top of descent point with at least 2,400 lb, which is 1,040 lb more fuel than on the accident flight (see also *Considerations regarding access to RVSM flight levels*). This was sufficient fuel to divert to Noumea, New Caledonia or Auckland, New Zealand at that point. Given the weather reports at that time were consistently stating cloud was below the landing minima at Norfolk Island, it is very likely the crew would have diverted. Alternatively, arriving at the top of descent with about 2,400 lb would have allowed the crew to descend, conduct an instrument approach, hold at about 2,300 ft for about 60 minutes and then conduct another approach.

The operator's Westwind fleet often conducted long-distance flights to remote aerodromes. Westwind pilots reported they always took full fuel or as much fuel as possible for such flights, and a review of the operator's flight records supported these statements. In addition, for long-distance air ambulance flights, regardless of the destination, the operator's pilots almost always departed with full fuel.

Consequently, a key question is why the flight departed on this occasion with only full main tanks, or about 1,500 lb less than full fuel? There were no operational limitations, such as take-off weight, landing weight or obstacle heights during take-off that required less than full fuel be taken.

The ATSB considered a range of potential reasons, including:

- refuelling error
- flight planning limitations
- assessing the risk level of the flight
- financial considerations
- considerations regarding access to RVSM airspace
- access to flight planning assistance
- time pressure and distractions
- fatigue (discussed in Fatigue and fatigue management)
- operator's risk controls for fuel planning
- regulatory requirements and guidance for fuel planning
- pre-flight risk assessments.

Refuelling error

During the reopened investigation, the operator's Westwind pilots were asked if there were any specific situations for which they would take only full main tanks for a long-distance flight to Norfolk Island or a similar remote aerodrome. Most of the pilots stated the only scenario they could think of was the flight crew forgetting to pull down the tip tank manual fuel fill valves prior to refuelling, and then not detecting the error prior to the refueller departing (and the refueller being difficult to contact). Although the pilots could not recall this scenario ever occurring before, they thought it was plausible.

During the reopened investigation, both flight crew of the accident flight stated this scenario did not occur when the aircraft was refuelled at Apia. The captain, who supervised the refuelling, confirmed that departing with full main tanks (or 7,200 lb) was intentional. The first officer confirmed that she had noted the aircraft had not been refuelled to full fuel and she had raised the issue with the captain before the refueller had departed.

The refuelling was completed at about 0515 UTC, and the right engine was started at about 0524 to provide air conditioning for the patient, who had collapsed on the tarmac. This was a busy period for the flight crew with the potential for distraction from their normal tasks. Nevertheless, based on the available evidence, it is not possible to conclude a refuelling error occurred. Rather, departing with 7,200 lb of fuel appeared to be an intended action by the captain.

Flight planning limitations

The captain conducted the flight planning and fuel planning for the accident flight. There were several aspects of his planning on this occasion that increased risk:

- calculation of the total fuel required (for normal operations)
- consideration of the en route winds
- allowing for aircraft system failures
- obtaining relevant information when flight planning
- consideration of the point of no return (PNR).

Calculation of the total fuel required (for normal operations)

With regard to the calculation of the total fuel required, the captain reported he calculated that full main tanks (7,200 lb) would be sufficient fuel for the flight, including fuel reserves, and allow for a margin of 200–300 lb. This indicated he calculated the total fuel to be 6,900–7,000 lb.

Based on the available information, the ATSB could not determine the exact process the captain used to calculate the total fuel required for the accident flight. However, there were several aspects of the calculations that appeared to be problematic:

- Consistent with his usual practice for long-distance flights in a Westwind 1124A, he used a block planning speed of 420 kt instead of the operator's specified speed for Westwind operations of 380 kt. This resulted in an underestimation of the total fuel required of about 300 lb. The use of a block speed of 400 kt to allow for the better performance of the 1124A may have been reasonable. However, a block speed of 420 kt was unrealistic, even for a Westwind 1124A.
- Consistent with his usual practice, he did not include an amount for taxi fuel, which meant another underestimation of the fuel required of about 100–150 lb.
- He initially reported he used a fixed amount of 1,500 lb for the fuel reserves. This was a conservative approach and helped offset the limitations with the block speed and taxi fuel. However, using this approach and other aspects of his method, he should have calculated the total fuel required to be over 7,300 lb.
- He subsequently reported he used the operator's standard method of calculating the fuel reserves (including 10 per cent of the flight fuel for the variable reserve and 600 lb for the fixed reserve). Using this approach, his method resulted in a minimum total fuel required of about 7,000 lb. However, he stated his normal practice was to round figures up to be conservative. For example, if he rounded up the flight time to 4 hours, he should have calculated the total fuel required to be over 7,100 lb.

In other words, it appears the captain either made an error when applying his normal method, and/or he was using a method that underestimated the fuel required for the flight when compared to the operator's prescribed methods.

In comparison to other flights, it appeared the captain's calculations for the accident flight were erroneous rather than just the use of a consistent, inappropriate method.

More specifically:

- Even using a block speed of 420 kt, the captain should have calculated the flight time to be at least 4 hours. It was rare for the operator's flights, including those previously undertaken by the captain, to depart for a 4.00-hour flight of any type with only full main tanks. There were no specific circumstances that warranted an exception to be made on this occasion. Rather, the context of a flight to a remote island at night would suggest it should be rarer than normal to conduct such a flight with only full main tanks.
- During the accident flight, the captain calculated the total fuel required for the subsequent flight from Norfolk Island to Melbourne, involving a shorter distance but apparently with a similar headwind component, to be 7,500 lb, or about 500–600 lb more than his calculated total fuel required for the accident flight.

The nature of the apparent calculation error is unclear. One possibility is that the captain underestimated the flight time. He provided an estimated flight time of 3.50 hours when submitting his flight plan during a telephone call with the Brisbane briefing officer, and it is possible he did not subsequently conduct a more detailed calculation. However, he noted this approximate time was not necessarily what he would have used when fuel planning. As noted above, if he was using his normal block speed (420 kt), he should have calculated the flight time to be 4.00 hours. If he used a more appropriate block speed (380–400 kt), he should have calculated the flight time to be more than 4.00 hours.

Consideration of the en route winds

The captain did not obtain a current forecast of the upper-level winds between Apia and Norfolk Island for the period of the accident flight. Without a forecast for the relevant time period, he allowed for a 50-kt headwind component based on his estimation of the tailwind encountered on the outbound flight the previous night and an assumption that winds would be relatively stable in that region over a period of about 12 hours.

In cases where an upper-level wind forecast for the relevant time period was not able to be obtained, it would be prudent to be conservative and manage the uncertainty about the current winds by allowing for the realistic potential for the winds to increase. More specifically, there can be significant upper-level wind changes in the region around Norfolk Island associated with the sub-tropical jetstream. For example, the captain conducted flights from Norfolk Island to Apia and Apia to Norfolk Island on 29–30 September 2009, about 7 weeks before the accident flight. During those flights, the average wind component between Apia and Norfolk Island increased by an average of 20–25 kt over a period of 24 hours, with the wind component at waypoint DOLSI increasing by about 35–45 kt.

Consistent with the operator's requirements and normal practice, the captain's fuel planning for the flight included a variable reserve. This reserve is meant to cater for unanticipated factors that can influence fuel consumption, such as unforecast weather conditions. It is not meant to cater for situations where a current forecast for the relevant time period was available but not obtained.

Ultimately, on the 18 November 2009 flight there was a forecast average headwind component of about 45 kt at FL 340 and 55 kt at FL 385. There was also a significant crosswind component associated with the forecast winds, which exacerbated the headwind effect. Overall, if the captain had obtained the forecast winds and was expecting much of the flight to be conducted between FL 370 to 390, he should have allowed for a headwind component of at least 60 kt rather than 50 kt. This would have added about 150 lb to the total fuel required.

In summary, regardless of whether the captain obtained a relevant upper-level wind forecast or not on this occasion, he should have allowed for the likelihood of the winds increasing for the return flight. As a consequence, his estimate of the headwind component should have been more than 50 kt, and his calculation of the minimum total fuel required should have been higher.

Allowing for aircraft system failures

The captain was required by regulation and the operator's procedures to ensure there was sufficient fuel to allow for specific aircraft system emergencies, such as a depressurisation. On this occasion the captain did not calculate the critical point (CP), and therefore the additional fuel required for aircraft system failures, before the flight. Had the captain conducted the calculation, he should have estimated he needed at least 7,800 lb at engine start to safely conduct the flight.

The captain reported his normal approach was to include an amount of fuel to allow for a depressurised situation rather than calculate a critical point and the consequent additional fuel required. Such an approach is simpler to apply. However, given the wide variance in the amount required, such an approach would need to include a substantial amount to ensure it would be effective. It is possible the captain assumed that, with a perceived margin of 200–300 lb in addition to the fuel reserves, he had sufficient fuel to allow for aircraft system failures for the accident flight. However, given the limited alternate aerodromes available en route, the length of the flight and a starting fuel load of only full main tanks, this was not a safe assumption and a more detailed calculation was necessary.

Some of the operator's Westwind pilots also reported they did not routinely do CP calculations before flight. Rather, the normal approach for these pilots was to depart with full fuel or as much fuel as possible, which almost always provided a substantial margin to cover a range of potential contingencies. Although undesirable, not calculating a CP before flight is more understandable when there is a substantial fuel margin available for normal operations. However, it is more difficult to understand when the flight is planned with significantly less than full fuel and little if any margin available for normal operations.

Obtaining relevant information when flight planning

As a result of no internet access at Apia, the captain only obtained details from an aerodrome forecast (TAF) for Norfolk Island when planning the return flight from Apia to Norfolk Island. However, he also needed to obtain or review a range of other items of information in order to safely conduct the flight. These included:

- the current NOTAMs for Norfolk Island
- the current TAFs and NOTAMs for potential alternate aerodromes
- a grid point wind and temperature (GPWT) forecast chart and/or upper air (wind and temperature) chart
- a current significant weather (SIGWX) forecast chart for the region.

The absence of this information increased the level of uncertainty for the flight crew when making decisions regarding potential in-flight diversions (see *In-flight fuel management*). In addition, current forecasts and NOTAMs for potential alternate aerodromes were important for pre-flight fuel planning. Although the captain was not specifically required to nominate an alternate aerodrome on the flight plan, or include alternate fuel in his fuel planning calculations, he needed to consider an alternate aerodrome(s) for the purpose of calculating a CP and a PNR. In order to calculate these points, it was important to obtain the latest forecast and NOTAMs for the alternate aerodrome(s) being considered to assess their suitability.

In this case, the captain's CP and PNR considerations should have included Nadi, Fiji and Noumea. The forecast for Nadi indicated a requirement for 60 minutes holding fuel for normal operations. The forecast for Noumea also indicated a TEMPO applied for flights arriving up until 0830, but this TEMPO did not create a formal requirement to include holding fuel for normal operations.

In summary, the captain should have obtained the forecasts and NOTAMs for the relevant alternate aerodromes. Had he done so, the forecasts for these aerodromes would have provided additional reason to consider the context of the flight and the minimum total fuel required. Overall, in the absence of current forecasts and NOTAMs, as well as relevant en route information, a more conservative approach to fuel planning was warranted.

Considering the point of no return (PNR)

In addition to not calculating a CP, the captain also did not calculate a PNR before the flight. Calculating the PNR before flight will provide an indication of the potential risk associated with the flight, in terms of the duration of the flight where the crew will not be able to divert to another aerodrome.

Calculating the PNR before flight also provides the crew with more context for their in-flight decision-making. In addition, calculating a PNR can be complex, and it is easier to do it on the ground when flight planning rather than in the cockpit. If the calculation is done before flight, it is then relatively simple to amend the position of the point in-flight to account for the actual conditions compared to doing the initial calculation of the PNR in-flight.

The captain and some other pilots reported they did not routinely calculate PNRs before flight. As with the CP calculations, such an approach is more understandable if the flight departs with as much fuel as possible, rather than for a flight departing to a remote island with only full main tanks and minimal discretionary fuel.

Other flight planning aspects

The lack of internet access made it more difficult for the captain to obtain weather information on this occasion. However, it was also noted there appeared to be limitations in the information obtained when planning some other flights. More specifically:

- When flight planning in Sydney on 17 November 2009 for the outbound flights from Sydney to Norfolk Island and Norfolk Island to Apia, the captain obtained the winds for the direct route between Sydney, Norfolk Island and Apia. However, he did not obtain a GPWT forecast chart or upper-air wind and temperature chart. For long-distance flights in remote areas, it is beneficial to have as much meteorological information as possible. This is particularly important when considering potential diversions to alternate aerodromes that are not on the flight planned route.
- When flight planning in Sydney on 17 November 2009 for the outbound flights, the captain obtained an Australian SIGWX forecast chart. However, the validity period did not include the planned time of the Norfolk Island to Apia flight, and the chart did not cover half of the flight planned track for that flight.
- The captain submitted a safety report following the 29–30 September 2009 trip to Apia that provided reasons why the return flights from Apia to Sydney via Norfolk Island were delayed. The report indicated the delay was partially due to there being a difference between the forecast and actual winds, although a review of the forecast and actual winds for the time of the flight found no difference. This suggests the crew may not have obtained a current upper-level wind forecast prior to the 30 September 2009 flight from Apia to Norfolk Island. However, the ATSB was not able to confirm what forecast information the crew obtained prior to that flight.

During the reopened investigation, the ATSB was unable to obtain information to evaluate the information requested by the captain or other Westwind pilots for similar flights.

Summary

Overall, the captain’s pre-flight planning for the accident flight was limited and did not include many of the elements needed to reduce the risk of a long-distance flight to a remote island or isolated aerodrome. Limitations included:

- miscalculating the total fuel required for the flight under normal operations
- not obtaining relevant forecasts of upper-level winds and, in the absence of such forecasts, underestimating the potential headwind component
- not calculating the additional fuel required to allow for aircraft system failures
- not obtaining a current aerodrome forecast and NOTAMs for potential alternate aerodromes

- not calculating a point of no return (PNR).

If these limitations and omissions had been addressed, the captain should have calculated the minimum total fuel required to be more than 7,200 lb.

It could be argued that if the captain had calculated the minimum total fuel required to be just over 7,200 lb, he may have only refuelled the aircraft to the minimum amount required. For example, if he calculated that he needed only 7,800 lb fuel, he would have only taken an additional 600 lb. Although an additional 600 lb of fuel would have decreased risk, it may not have influenced the outcome of the accident flight.

However, the captain’s stated normal practice was to refuel to full fuel if he calculated the total fuel required to be more than 7,200 lb. On the small number of occasions where he had refuelled to an amount between 7,200 and 8,700 lb, the total fuel on board still appeared to be significantly more than the minimum total fuel required for the flight. In addition, the occasions where he had elected to refuel to an amount between 7,200 and 8,700 lb involved flights to major airports with an ILS approach rather than a remote aerodrome.

In summary, had the captain conducted an appropriate level of flight planning, he should have calculated the minimum total fuel required to be more than 7,200 lb. In the context of the flight and his previous experience, he would then have probably decided to depart with full fuel (8,700 lb). As already discussed, this would have enabled the flight crew to divert to Noumea (or Auckland) from the top of descent point, or hold for at least 60 minutes at Norfolk Island after conducting an instrument approach.

Assessing the risk level of the flight

The captain indicated he was comfortable with the fuel load he selected for the accident flight because the forecast weather conditions at Norfolk Island were significantly above the alternate minima. Accordingly, had the forecast conditions been closer to the alternate minima, he would have elected to depart with more fuel.

The captain had flown to Norfolk Island on four previous occasions, and on each occasion the reported weather conditions upon arrival were better than the forecast conditions. Given what occurred on the previous night’s flight to Norfolk Island, he also believed the automatic weather station (AWS) overestimated the amount of cloud (see *Expectancies*). He also reported the operator did not provide him with any specific training or guidance regarding operations to Norfolk Island, and he had not been provided with information about the potential problems associated with the weather conditions at the island. Overall, this evidence suggests the captain had a limited appreciation of the inherent risk associated with flights to Norfolk Island or other remote islands.

However, flight records from the captain’s previous flights to remote aerodromes and semi-remote aerodromes indicated he always departed with full fuel, or in the case of shorter flights at least sufficient fuel to divert to an alternate aerodrome. This was consistent with the approach used by the operator’s other Westwind pilots, and suggests the operator’s pilots (including the captain) generally took a conservative approach when fuel planning flights to such aerodromes. Similarly, the captain’s previous air ambulance flights to other types of aerodromes were also consistent with the generally conservative approach of other captains.

Overall, the limited extent of the captain’s flight planning for the accident flight was more consistent with an approach where he thought he would be departing with full fuel and therefore had a substantial amount of discretionary fuel available to allow for various contingencies. However, as noted above, the captain stated the decision to depart with 7,200 lb was intentional.

The captain reported the operator did not brief him or provide him with statistics about what fuel loads were normally taken for different types of flights, and therefore he did not have a sense of what was normal or consistent practice across the Westwind fleet. Nevertheless, he conducted numerous flights with other captains before achieving command himself, as well as several flights with newly-qualified captains after he became a captain. It seems reasonable that discussions about fuel planning practices would have occurred during such flights. In addition, the captain reported his common practice was to review an aircraft's previous flight records during a flight. Ultimately, the extent to which the captain had a different approach to other captains regarding what fuel loads were appropriate or normal for a long-distance flight could not be determined.

Taking everything into account, it is difficult to reconcile the captain's fuel planning for the accident flight with his fuel planning on previous flights to Norfolk Island and similar aerodromes. Given he had not obtained any flight planning information other than details of the TAF at Norfolk Island, it would be reasonable to expect the captain should have taken a more conservative approach than normal to fuel planning rather than a less conservative approach. Although this set of information is difficult to reconcile, his behaviour on this occasion would be more understandable if he had significantly underestimated the duration of the flight and/or the minimum fuel required.

In summary, it appeared the captain underestimated the risk of conducting the flight to Norfolk Island. However, the extent to which this underestimation was associated with fuel planning errors on this occasion, or broader factors, was difficult to determine.

Financial considerations

One of the reasons the captain provided for his decision to depart Apia with only full main tanks was the price of fuel. He said he was aware that fuel at 'remotish' places was expensive, and therefore he believed it was in the operator's interest to minimise unnecessary costs.

The price of fuel had an influence on the captain's fuel planning in at least some circumstances. For example, on the cockpit voice recorder (CVR) recording when discussing his flight plan for the next flight from Norfolk Island to Melbourne, the captain stated fuel was expensive at Norfolk Island, and that was a reason to only take 7,500 lb rather than full fuel for that flight. With regard to the Norfolk Island to Melbourne flight:

- Fuel at Norfolk Island was significantly more expensive than most of the other aerodromes the operator used.
- A fuel amount of 7,500 lb was more than sufficient for the flight from Norfolk Island to Melbourne (via overhead Sydney). This fuel load allowed for a headwind component of at least 100 kt, which was substantially more than was forecast or that the flight crew had experienced on the outbound flight from Sydney to Norfolk Island. A flight to Melbourne is also a different scenario to a flight to a remote island such as Norfolk Island. Melbourne airport has multiple approach options, including ILS approaches, and there are closer alternate aerodromes en route and near the destination.

In contrast, the extent to which the price of fuel was a consideration when planning the flight from Apia to Norfolk Island is less obvious. More specifically:

- Westwind pilots consistently reported the price of fuel was not a consideration when they were planning long-distance trips to remote aerodromes. They all reported they never received any feedback or concern from management about the amount of fuel they uploaded.
- Records showed the price of fuel at Apia was less than the price of fuel at Norfolk Island. Therefore there was limited if any benefit in restricting the uptake of fuel when departing from Apia.

In summary, the available evidence suggests there was no reason for the captain to consider the price of fuel as a reason for limiting the amount of fuel taken on the flight from Apia to Norfolk Island. If it was a consideration for him, there was no evidence to suggest it was one shared by other flight crew or encouraged by management.

Considerations regarding access to RVSM flight levels

The captain reported another reason he elected to depart with 7,200 lb of fuel instead of full fuel was associated with the aircraft not being approved for reduced vertical separation minima (RVSM) operations. As the aircraft was not RVSM-approved, the captain believed Auckland air traffic services (ATS) would regard his flight as a low priority for operating in RVSM airspace (FL 290–410) if there was a traffic conflict. By taking less fuel and having a lower aircraft weight, the aircraft could climb more quickly and therefore they had more chance of accessing the desirable, higher flight levels within the RVSM airspace.

It would certainly have been preferable if aircraft used by the operator for international operations in RVSM airspace were RVSM-approved. In lieu of such approvals, the operator should have provided specific fuel planning guidance to its Westwind flight crews for operating outside RVSM airspace. Nevertheless, the operator's air ambulance flight crews were still able to plan and conduct flights in the airspace, provided they complied with the relevant procedural requirements.

The captain had expressed concern about accessing RVSM airspace in an email to the operator's maintenance manager in December 2008. However, there is doubt as to whether this concern influenced his decision-making when fuel planning for the 18 November 2009 flight. The captain did not mention RVSM aspects in initial interviews after the accident when discussing why he elected to depart Apia with 7,200 lb of fuel.

The available evidence also indicates:

- Due to generally low traffic levels on the route between Apia and Norfolk Island, it would be unlikely the flight crew would have expected to be denied access to desirable flight levels in RVSM airspace for an extended period.
- If ATS requested the flight crew to operate below RVSM airspace, the crew could have stated they were a medical priority flight, and they would have received priority handling. Therefore, even if there was other (RVSM-approved) traffic present, it is unlikely this would have resulted in the aircraft operating at an undesirable flight level for an extended period.
- If the aircraft was held at an undesirable flight level for a period of time, the flight crew could have used long-range cruise settings to minimise the additional fuel burn off to a relatively small amount.
- Other Westwind pilots reported taking less fuel in order to improve climb performance was not a strategy they would have used for this type of flight. Rather, they would have taken full fuel to maximise the amount of fuel they would have had available later in the flight.

If the captain was concerned about restricted access to desirable flight levels in RVSM-airspace when fuel planning, then carrying less fuel to improve climb performance was a problematic solution. It may have increased the likelihood of the flight crew being given a clearance to operate at higher flight levels within RVSM airspace by a small percentage. However, if they were still not given clearance to enter RVSM airspace, they would have then been in a much less desirable situation, with insufficient fuel to complete the flight to Norfolk Island. In contrast, taking full fuel would have provided more assurance of managing any potential problem associated with the assigned flight level, even in the unlikely event that the crew were not cleared to operate in RVSM airspace for an extended period.

It is noted that, during the accident flight, when climbing to FL 350, the flight crew were asked to descend to FL 270 due to a traffic conflict. The crew were subsequently cleared to FL 390 instead. It could be argued that, if the flight crew had departed with full fuel, they would not have been able to climb to FL 390 at that time, and therefore been forced to descend, significantly increasing the fuel burn and reducing the potential advantage of departing with full fuel. However, as already noted, the available evidence indicates that if the flight crew had advised ATS they were a medical flight, they would have received priority and therefore not have been required to descend. Regardless of whether they stated they were a medical flight, even if they did descend it is unlikely this would have been for an extended period. In addition, if the flight crew used long-range cruise settings during the period they were at FL 270, they would have minimised any additional fuel burn.

In summary, there is some doubt regarding the extent to which the captain's concern about accessing RVSM airspace influenced his fuel planning for the accident flight. If it did influence his decision to conduct the flight with only full main tanks, this decision did not appear to be based on a sound understanding of aircraft performance, or the requirements for operating in RVSM airspace within the Auckland Oceanic flight information region.

Access to flight planning assistance

As already noted, the lack of internet access at the hotel in Apia disrupted the captain's normal flight planning process. He stated that, after identifying the internet problem, he attempted to contact the Westwind standards manager to obtain flight planning assistance. His phone call was not answered and he did not leave a message. Other than obtaining details of the Norfolk Island TAF, he did not obtain any other information from the Brisbane briefing officer.

The Westwind standards manager routinely provided flight planning assistance to the operator's Westwind pilots, and he was generally available when required. However, the operator's processes for providing flight planning assistance were not formalised. In addition, there were also no specific procedures in place for what would occur if the standards manager was unavailable due to flying duties or other commitments, or could not be contacted.

In a major airline environment, flight crew receive a significant amount of flight planning assistance, including the provision of relevant weather information, preparation of a fuel plan and calculation of decision points (such as CPs and PNRs). However, a full flight planning service was more difficult to achieve for smaller operators and/or an ad hoc operation. Nevertheless, the operator's Westwind flight crew could have been provided with better access to flight planning software tools that facilitated the planning of complex flights at short notice (see also *Operator's risk controls for fuel planning*).

On this occasion, the captain had a number of other options available to obtain information and/or flight planning assistance. For example, he had been in regular contact with the Westwind operations manager during the day, and could have called her to get flight planning assistance from the standards manager or another experienced pilot. The standards manager was at the operator's office attending a meeting, and could have easily provided assistance if he had been contacted via the operations manager. The captain also could have contacted another pilot directly, or sought assistance at the airport in Apia from the ground handling agent, another operator or the local ATS provider.

In summary, the captain had viable options available to him for obtaining the necessary flight planning information. Nevertheless, if the operator had a more formalised process in place for obtaining flight planning assistance in these types of situations, it could have reduced the risk of flight planning limitations and omissions.

Time pressure and distractions

The captain reported there was often an element of time pressure with air ambulance trips until the patient had been transported to the hospital. On this occasion, the difficulties associated with the lack of internet access and submitting a flight plan for the accident flight involved some workload and stress, and took some time to resolve. Obtaining additional flight planning information before the flight would have required an additional delay.

However, the flight crew and medical personnel reported there was no specific time pressure in this case to commence the return flight from Apia. There was also no evidence to indicate that anyone would have considered an additional delay to conduct essential flight planning activities to be unreasonable given the situation.

Several of the Westwind pilots noted the difficulties associated with flight planning in situations where there was limited information available about the destination aerodrome(s), the destination aerodrome(s) had limited facilities, and/or the flight was required to depart within a relatively-short time frame. However, in the case of a flight from Apia to Norfolk Island, the captain had been to both locations before, the destination aerodrome had published instrument approaches, and there were no specific aspects of the flight that had unique, complex flight planning requirements.

To calculate a CP and a PNR before flight would have required some time, as well as access to relevant information such as charts and en route weather conditions. However, not conducting these tasks appeared to be consistent with the captain's (and some other pilots') normal practice, rather than stemming from the specific circumstances that occurred for this flight. As indicated above, such an approach is more understandable when the fuel planning is conservative and includes a substantial amount of discretionary fuel.

As already indicated, the captain's flight planning process was disrupted by the lack of internet access, resulting in flight planning tasks being conducted in a different order to his normal process. Such disruptions or distractions can increase the risk of error. In addition, the captain also had a series of personal phone calls during his rest period in Apia, although the extent to which these may have been a source of distraction when flight planning is unknown. The potential role of the related issue of fatigue is discussed later in the analysis.

Overall, there was no evidence to indicate that any unusual or significant time pressure on this occasion was being imposed by the operator, the air ambulance provider or the aircraft's other occupants. There was also no evidence to indicate there were organisationally-induced pressures to take short cuts with flight planning for this type of flight. However, due to the difficulties encountered during flight planning on this occasion, the captain may have perceived a degree of time pressure, and this may have combined with other factors to increase the potential for flight planning errors or his decisions regarding the thoroughness of his flight planning.

Operator's risk controls for fuel planning

Based on many previous flights conducted by many different pilots, the operator would have expected with a high level of confidence that the captain would have elected to depart with full fuel for the accident flight. However, human performance is variable, and this variability will increase when there are no clearly defined policies or procedures for safety-critical operations.

The operator's fuel policy did not have a clear statement regarding fuel planning for remote islands or isolated aerodromes. Given the number of flights it did to such aerodromes, this was a significant omission. A clear policy to always have sufficient fuel to either divert to an alternate aerodrome or arrive with sufficient fuel to hold for an extended period would have provided more assurance the risk of such operations was minimised.

In addition to not having specific requirements for remote islands or isolated aerodromes in its operations manual (OM), the operator's fuel planning requirements and guidance for the Westwind fleet had a number of other limitations. These included:

- no specific figures for taxi fuel, fixed fuel reserve or approach fuel
- no guidance regarding fuel planning for operations in RVSM airspace
- no specified fuel burn off figures for operations at FL 270 or for depressurised operations
- no formal training for fuel planning flights to remote islands or isolated aerodromes
- no formal training for flight planning international operations
- no guidance information about potential hazards at commonly-used aerodromes.

In addition, the operator's flight crew proficiency checks had minimal focus on fuel planning aspects. The checks were generally conducted on short flights where fuel planning considerations were of limited relevance, and check pilots rarely flew with captains on normal line flights to monitor operations. Consequently, the operator had limited capacity to check the ongoing proficiency and practices of its captains when conducting fuel planning for long-distance flights and/or flights to remote aerodromes.

Similarly, there was no formal procedure requiring the captain's calculation of the total fuel required to be checked by another pilot. The Westwind standards manager frequently provided flight planning assistance when requested to do so, but this process was not formalised. First officers also checked a captain's fuel planning on some occasions, but such checking did not appear to be routine or widespread across the fleet. In general, the benefits of requiring all fuel planning calculations to be cross-checked would have been somewhat limited in the absence of a clearly defined policy on key aspects, such as the fuel required for flights to remote islands or isolated aerodromes. Nevertheless, in the context of the accident flight, a formal cross-checking of the captain's fuel planning should have identified deficiencies (with the information obtained and the resulting calculation).

Finally, there were limitations in the tools and resources provided to pilots when flight planning, particularly when planning complex flights at short notice. As already noted, although the Westwind standards manager was generally available to provide flight planning assistance, the process for obtaining such assistance was not formalised. In addition, although flight crews were provided with a flight planning software tool at their bases, this tool was not available when away from a base. There were also limitations with the effectiveness of the tool and/or the training provided to flight crew to effectively use the tool. Due to these problems, some pilots had elected to purchase their own flight planning software tools, but the operator did not have a process in place to control the data used by these tools or the way the tools were being used.

In summary, the operator did not effectively control the flight planning and fuel planning practices of its Westwind pilots. The overall result was that pilots were using a variety of methods to do these tasks, and their calculations were often not being checked. Although pilots were generally taking more than sufficient fuel for operations to remote islands and isolated aerodromes, there was the realistic potential that at some time a pilot would make fuel planning errors and these would not be detected prior to the flight.

The extent to which the operator's limited fuel planning policies, procedures and guidance could have influenced the outcome of the accident flight is somewhat uncertain, as the reasons for the captain electing to depart with significantly less fuel than normal on this occasion are somewhat unclear. Nevertheless, a more appropriate system of policies, procedures and guidance should have reduced the potential for such problems in most cases, regardless of the reasons for the problem.

Regulatory requirements and guidance for fuel planning

The International Civil Aviation Organization (ICAO) had specified a standard for commercial air transport operations to isolated aerodromes, which effectively required that such flights have sufficient fuel to fly to the (isolated) destination aerodrome and then hold for 2 hours (including the 30 minutes fixed reserve). Australia had no such regulatory requirement. With the exception of European countries, other leading aviation countries also did not follow the ICAO standard, except in some cases for airline operations. However, in comparison to Australia, other countries generally had more conservative weather-related requirements (in terms of cloud ceiling) regarding when flights could be conducted without an alternate aerodrome.

CASA advised the differences between Australian regulatory requirements and ICAO standards were historical, based on Australia's unique context, with less aviation infrastructure and more benign weather conditions than many other countries. However, the lack of infrastructure in some regions could be argued as a reason for introducing specific requirements for isolated aerodromes rather than not having such requirements. In addition, although Australia does generally have more benign weather conditions than many other countries, problematic weather events still occur, particularly at some locations.

Nevertheless, following a series of incidents at Norfolk Island in 1998–1999, CASA introduced specific requirements in Civil Aviation Order (CAO) 82.0 for fuel planning some types of flights to Australian remote islands (namely, Norfolk Island, Christmas Island and Lord Howe Island). These requirements were more onerous than the ICAO standards for isolated aerodromes, as they always required sufficient fuel for an alternate aerodrome. However, these requirements were restricted to passenger-carrying charter operations, with the assumption that the requirements for regular public transport (RPT) operators would be addressed on an individual basis.

A focus on fare-paying passenger operations was consistent with government policy at the time. However, it meant some types of operations where passengers were being carried, such as air ambulance flights, were not subject to the same regulatory requirements.

Similar to the policies regarding fuel planning requirements and isolated aerodromes, Australia's classification of air ambulance flights as aerial work rather than air transport was historical. However, this classification was not consistent with other leading aviation countries. The number of passengers on an air ambulance flight is small, and the number of air ambulance flights each year to remote islands such as Norfolk Island is also relatively low. Nevertheless, air ambulance flights are still passenger transport flights. As such, they should have been subject to the same types of requirements applied to other passenger transport flights with the same types of aircraft and with the same numbers of passengers.

CASA made efforts in the 1990s and 2000s to revise its policies on the classification of operations, including passenger-carrying operations. However, as with many other aspects of regulatory reform, the change process was difficult to progress with industry support and ultimately CASA's considerations did not result in any formal proposal to change the classification of air ambulance flights.

Even if CASA had classified air ambulance flights as passenger transport, it does not automatically follow that the operator would have changed its policies and procedures. For example, the operator had not incorporated the CAO 82.0 requirements for passenger-carrying charter flights to remote islands into its OM. However, this was probably associated with the fact that the operator conducted relatively few passenger-carrying charter flights to remote islands.

In contrast, the operator was conducting a significant number of air ambulance flights to remote islands, particularly to Norfolk Island. Therefore, it seems reasonable to conclude that, had the CAO 82.0 requirements applied to air ambulance operations, these requirements would probably have been formally integrated into the operator's fuel planning requirements (and/or the captains' fuel planning practices). As it was, the operator's pilots generally complied with the CAO 82.0 requirements for remote islands for all flights, not just passenger-carrying charter flights, and incorporating the CAO 82.0 requirements would have had minimal impact on the operator.

It is noted that the Westwind standards manager had a significant influence on the conduct of the Westwind fleet's operations. He reported his interpretation of CAO 82.0 was that it did not necessitate the carriage of alternate fuel on passenger-carrying charter flights to remote islands. This is consistent with the fact that the operator's only passenger-carrying charter flight that did not comply with the CAO 82.0 requirements was conducted by the standards manager.

Although paragraph 2.3 of CAO 82.0 could have been written more clearly, the ATSB believes the intent and meaning of the order were straightforward; if an operator did not have specific procedures for calculating fuel on a flight to a remote island, then it was required to comply with paragraph 2.4, which required the carriage of alternate fuel. Given the significant number of the operator's air ambulance flights to remote islands, it is likely that had CAO 82.0 applied to these flights, any uncertainty regarding its intent or meaning would have been clarified through internal discussions or liaison with CASA.

Furthermore, if CASA had promulgated explicit requirements for isolated aerodromes consistent with ICAO's standards, then it seems reasonable to expect these would have been incorporated into the operator's processes. Other than the CAO 82.0 requirements for passenger-carrying charter operations, the operator appeared to have incorporated other regulatory requirements regarding fuel planning into its OM and existing processes, and in some cases the operator's requirements exceeded the regulatory requirements.

Pre-flight risk assessments

Although not limited to fuel planning, a related aspect is the process for deciding whether to conduct an air ambulance task or flight. In the US, there have been many fatal accidents involving emergency medical services (EMS) flights, particularly involving helicopters. As a result, in 2006, the US National Transportation Safety Board (NTSB) released a special investigation report about EMS operations.[328]

One of the safety issues identified by the NTSB was the absence of flight risk evaluations, or pre-flight risk assessments, prior to initiating a task. It noted such risk assessments should follow a systematic or structured process, and be conducted without the flight crew being influenced by the sense of urgency that can accompany EMS tasks. It also noted that if the risk reached a predefined level, then consultation with appropriate management personnel other than the flight crew should be required. The NTSB issued a recommendation to the US Federal Aviation Administration (FAA) to require EMS operators to develop and implement flight risk evaluation programs.

In 2014, the FAA introduced a regulatory requirement for helicopter EMS operators in the US to develop a pre-flight risk analysis worksheet, and for the flight crew to complete the worksheet prior to the first flight of any task.[329] The worksheet was required to include factors such as

- flight considerations (such as obstacles and terrain along the planned route, landing zone considerations, and fuel requirements)
- human factors (such as fatigue, life events and other stressors)
- weather
- a procedure for determining if another operator has already rejected the proposed task.

The ATSB has investigated some fatal helicopter EMS accidents in Australia where a structured, pre-flight risk assessment could have reduced the task risk.[330] The ATSB is also aware that some Australian EMS helicopter operators have been conducting pre-flight risk assessment in some form for several years. It is also aware that some air ambulance organisations have processes in place to consider a patient's medical criticality with flight operational safety factors before deciding whether to conduct a task. However, air ambulance operators generally had no such procedures outlined in their OMs. In addition, there was no regulatory requirement in Australia for EMS operators or air ambulance operators to conduct pre-flight risk assessments.

At the time of the 2009 accident, the operator and the air ambulance provider considered a range of factors prior to initiating an air ambulance task. However, there was no formal, structured process in place to consider both flight operations risks and patient criticality in order to minimise unnecessary risk when deciding whether to proceed with a task. Its processes largely relied on the flight crew considering flight operational factors such as weather and aerodrome lighting when flight planning, and the operator considering fatigue level as part of its fatigue risk management system (FRMS). Unless there was an overt problem with such factors, the general approach appeared to be to proceed with the task. Therefore, while the operator's processes would have often identified hazards and reduced risks, there was the potential for risk to be reduced further.

Similarly, once a task had been initiated, there was no formal, structured process in place to review the situation prior to conducting the return flights with the patient. Both the operator and the air ambulance provider were in contact with their personnel, and therefore could assess any

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328 National Transportation Safety Board, 2006, *Special investigation report on emergency medical services operations*, NTSB/SIR-06/01. Available from www.ntsb.gov.

329 US FAR 135.617.

330 For example, B200003130 (Bell Helicopter Co 206L-3, VH-FFI, 1 km NW Marlborough, Queensland, 24 July 2000) and B2003042

issues that were raised. However, this process relied on the personnel conducting the task to raise the issues. Pilots reported there was a general expectation that the task would proceed until the patient had been transported to a hospital.

Helicopter EMS operations generally involve more flight safety hazards than fixed-wing air ambulance operations that primarily focus on hospital-to-hospital transfers. However, there are still hazards involved. For example, in the case of the return flight on 18 November 2009 from Apia to Norfolk Island, the flight was being conducted to a remote island, was being conducted at night, and the flight crew had a disrupted sleep pattern in the previous 24 hours.

For the 17–18 November 2009 trip, after receiving some initial treatment, the patient did not need immediate transportation. Nevertheless, there were a range of logistical and commercial aspects to consider, such as the appropriateness of providing ongoing care for a patient in a hotel room and the availability of the aircraft, flight crew and medical personnel for other tasks. As such, even if the operator had a structured pre-flight risk assessment process in place, it is not clear on this occasion whether it would have resulted in a decision to delay the flight until the next day.

Although the flight may not have been rescheduled, depending on how the risk assessment process was designed and implemented, a formal pre-flight risk assessment could have provided an opportunity for the operator to ensure the relevant risk factors were considered and appropriate risk controls were in place prior to conducting the flight. More specifically, it could have provided greater assurance that appropriate flight planning had been (or would be) conducted and an appropriate fuel load was being used, as well as reviewing the flight crew's level of alertness for the flight.[331]

In summary, the ATSB supports the use of formal, pre-flight risk assessments during ad hoc activities such as EMS and air ambulance flights. However, it is not clear the use of such an assessment would have influenced the outcome on this occasion. In particular, the effectiveness of any structured pre-flight risk assessment would have been limited unless the risks inherent in operations to remote islands and isolated aerodromes were formally recognised and included within the risk assessment process. As already discussed, the operator did not have any formal policies and procedures in place regarding flights to such destinations.

Aerodrome weather forecasting

Reliability of forecasting

The meteorological conditions were below the landing minima at the time the aircraft arrived at Norfolk Island (1003 UTC). This level of deterioration had not been included in the aerodrome forecast (TAF) that was available when the captain planned the flight (issued at 0437).

The Bureau of Meteorology (BoM) process for preparing meteorological TAFs relied on forecasters applying their specialised meteorological knowledge and expertise when reviewing computerised models, aerodrome climatological information and real-time observational data to predict the probable weather conditions at an aerodrome at some point in the future. Despite this process, unexpected events can occasionally result in a forecast not accurately predicting conditions. On this occasion, the event was the higher than expected humidity associated with the passage of the trailing weather front. When the winds backed following the frontal passage, the humidity did not reduce as anticipated.

The quality of any computerised meteorological model relies heavily on the accuracy of the data used to generate the model. The location of remote islands often means that there is less observational data available surrounding the aerodrome when compared to mainland locations, and thus a greater likelihood any variation from the model output as a weather system approaches a remote island will be unnoticed. The unique topographical features of islands such as Norfolk Island and Christmas Island also increase forecasting difficulty.

Although the conditions associated with the frontal passage on the night of the accident were worse than originally forecast, they were initially above the alternate minima. In addition, while the 0739 SPECI indicated the presence of cloud below the alternate minima, the cloud at that stage remained above the landing minima and the visibility was greater than 10 km. Although the 0800 observation was also issued as a SPECI, the conditions did not deteriorate between 0739 and 0800.

In response to the 0739 SPECI, the BoM meteorologist at the New South Wales Regional Forecasting Centre promptly amended the TAF to indicate the presence of cloud below the alternate minima. This inclusion created a requirement for pilots planning flights to Norfolk Island to make provision for fuel to fly to an alternate aerodrome.

Although the SPECI at 0830 indicated broken cloud below the aerodrome's landing minima, there was a significant improvement in conditions soon after, which was consistent with the meteorologist's expectation of a reduction in humidity following the passage of the weak front. Given the TAF for Norfolk Island already included cloud below the aerodrome's alternate minima, and in view of the improving trend, the meteorologist's assessment was the TAF did not require further revision. The subsequent further deterioration in conditions was unexpected and difficult to predict.

In summary, the TAF for Norfolk Island issued at 0437 UTC did not indicate a potential problem with the weather at the time the aircraft was expected to arrive. Although the amended TAF issued at 0803 did not correctly reflect the actual conditions at Norfolk Island at the time the aircraft arrived, it included a planning requirement for an alternate aerodrome, and METAR and SPECI reports were being regularly issued that indicated the deteriorating conditions. The difficulties associated with communicating this information to the flight crew are discussed in the next section.

Unforecast low cloud had previously been identified as an issue for aircraft arriving at Norfolk Island in 1999. BoM subsequently initiated several activities to improve its forecasting ability, including the installation of a weather radar, ceilometer and visibility meter, access to minute-by-minute data, and the introduction of processes to ensure forecasters were provided with more timely information on discrepancies between observations and forecasts.

These changes improved BoM's capabilities for forecasting at Norfolk Island. Data from BoM's TAF verification system indicated forecasting reliability improved from 2003 to 2009. Data from ATSB's predictive weather analysis algorithm indicated that in 2009 there were 296 hours of conditions below the landing minima for a Category C aircraft (such as a Westwind), which equated to 3.4 per cent of the total time. However, unforecast weather below the landing minima (that is, where the TAF was forecasting conditions above the alternate minima) was rare, occurring for a total of 10.5 hours or 0.12 per cent of the time. Overall, the amount of unforecast weather below the landing minima was comparable to the average for remote islands and capital city airports (average of 0.13 per cent per year).

This relatively low level of unforecast weather appeared to be due at least in part to BoM using a more conservative approach to forecasting at remote islands compared to capital city airports, consistent with the difficulties in forecasting at such locations. Such an approach is also compatible with the inherent risk of operations to remote locations.

Due to Norfolk Island's isolation and its unique environment, weather forecasting will never be 100 per cent accurate. However, given the overall level of forecast accuracy at remote islands in 2009, it is difficult to conclude that a safety issue existed with the forecasting process. Nevertheless, any further activities considered by BoM to enhance the accuracy of forecasting adverse weather, without creating problematic false alarms, is encouraged.

Advisory information about weather at remote islands

At the time of the accident, there was no formal guidance information provided to pilots in the En Route Supplement Australia (ERSA) or other publicly-available advisory publications about the frequency of adverse weather at Norfolk Island, and the fact these conditions can change rapidly and be difficult to forecast. However, although the ERSA is intended to be used for communicating aerodrome-specific hazards, this generally does not include seasonal meteorological conditions or forecasting difficulties. In addition, unforecast weather can occur at any aerodrome.

Rather than relying on advisory information in the ERSA, the safety system (through regulatory requirements) relies on operators advising their pilots about local meteorological hazards at aerodromes and the appropriate procedures and practices to use to manage these hazards. In this case, the operator was aware of the nature of the weather at Norfolk Island and this nature was widely known amongst its flight crew. However, as already noted, the operator did not provide its flight crew with formal guidance material about Norfolk Island or other similar remote destinations.

The captain of the accident flight reported he had not received any guidance from the operator regarding the potential for adverse weather conditions at Norfolk Island. Therefore it would seem possible that had some advisory information been available in the ERSA, this could have influenced the captain’s consideration of the weather conditions during flight planning or his decision-making during the flight. However, his consideration of conditions appeared to be strongly influenced by events during the flight crew’s flight to Norfolk Island the previous night (see *Expectancies*). Accordingly, it is difficult to make a conclusion about whether formal advice in the ERSA would probably have affected the conduct of the accident flight.

In conclusion, unforecast weather can occur at any aerodrome. Including advisory information in the ERSA about general weather conditions or the reliability of forecasting could help to remind flight crews to consider this issue when planning or conducting flights. However, operators and flight crews should already have appropriate procedures and practices in place to minimise the risk of operations to remote islands and other similar locations, regardless of whether there is advisory information.

Provision of flight information

The provision of a flight information service (FIS) to flight crews is a safety-critical function. Information about significant adverse weather needs to be provided promptly and accurately to help ensure a crew can make effective and safe decisions regarding the conduct of their flight.

During the accident flight, following requests from the captain for the latest weather report, the Nadi international flight information service officer (IFISO) provided the captain with the 0630 METAR and the 0800 SPECI, and the Auckland air/ground (A/G) operator provided the 0902 SPECI. However, there were several problems with the provision of FIS during communications with the flight crew of VH-NGA. More specifically:

- The Nadi IFISO did not proactively provide the 0739 SPECI, which included overcast cloud below the alternate minima.
- During the provision of the 0630 METAR at 0801, the Nadi IFISO stated the cloud as few at 6,000 ft instead of few at 600 ft.
- The Nadi IFISO did not proactively provide the 0803 amended TAF, which forecast conditions below the alternate minima.
- The Nadi IFISO did not proactively provide the 0830 SPECI, which included broken cloud below the landing minima.
- After responsibility for the aircraft was transferred to Auckland ATS at 0835, the Auckland A/G operator did not confirm the crew had received the 0803 TAF and/or the 0830 SPECI.

The captain asked the Nadi IFISO for the latest METAR at 0756. At 0801, the IFISO provided the 0630 METAR and said that was the latest one he had. It is not clear why the operator did not have ready access to the 0700 METAR, 0730 METAR or the 0739 SPECI. There was no apparent problem with the transmission of these weather reports to other jurisdictions. The IFISO that received the request at 0756 was not the same one that passed the information at 0801, and it is possible that there was a problem finding the most suitable information during the officers' handover.

The error of reading 600 ft as 6,000 ft was a simple slip (or error when performing at a skill-based or automatic level of behaviour). Such errors are relatively rare and difficult to eliminate, and the reasons for the error in this case are unknown. However, the potential effects of the error should have been mitigated as the IFISO correctly provided the 0800 SPECI immediately afterwards (see also *Assessment of the 0630 and 0800 weather reports*).

The 0803 amended TAF was broadly similar to the 0800 SPECI. The reason why the IFISO did not provide it to the flight crew is unclear, but it is possible he believed the crew had already just received similar information (in the 0800 SPECI). The workload of the IFISO during this period, and therefore the potential to provide additional information, is unknown.

The 0830 SPECI was a safety-critical item of information as it indicated the cloud conditions had deteriorated below the landing minima, although the visibility was still at least 10,000 m. Both flight crew were awake at that time and, had they received this information, they almost certainly would have discussed diversion options. At that stage, the aircraft had more than sufficient fuel to divert, and it seems reasonable to conclude the crew would probably have elected to divert. The Nadi IFISO may not have passed this information on because he had insufficient time to do so prior to control of the aircraft being transferred to Auckland Oceanic at 0835.

In order to minimise the potential for problems with the provision of FIS close to the transfer of control, Airways New Zealand had a procedure for the Auckland A/G operator to ensure flight crew had received advice of any significant weather issued in the previous hour. This also did not occur on this occasion. The Auckland A/G operator reported she was aware the crew had received the 0800 SPECI, thought they had also received the 0803 amended TAF, and was planning to update the crew with the 0900 SPECI.

Although ATS personnel are required to advise a flight crew of the existence of pertinent or relevant SPECIs and amended TAFs, this is on the basis of workload permitting. It is understandable that this requirement would appear to be burdensome when the conditions included in each SPECI are similar or perhaps improving. Therefore it is likely at times ATS personnel will conduct some filtering or prioritisation of the SPECIs, particularly if they are dealing with other tasks at the time. Nevertheless, as already noted, the 0830 SPECI should have been reviewed, assessed as safety-critical and promptly passed on to the crew by ATS on this occasion.

The errors in the provision of FIS increased risk. Although the available evidence indicates such errors do occasionally occur, there was insufficient evidence to indicate there were any systemic problems associated with the provision of weather information by either Nadi or Auckland ATS.

As discussed later (in *Assessment of the 0630 and 0800 weather reports*), there is some uncertainty regarding whether the captain correctly heard the 0800 SPECI, or recognised that it was in fact a SPECI. The ATSB considered whether additional procedures could be introduced into ATS-flight crew communication requirements to ensure flight crews correctly receive such communications. For example, if ATS provide a weather report that is a SPECI, the flight crew could be required to acknowledge the weather report they received was actually a SPECI. This process probably happens to some extent already on in informal basis. However, introducing a formal requirement would require changes to a well-established process on an international basis, as well as perhaps introducing additional workload on busy frequencies. This would require a clearer demonstration of the risk associated with the current requirements than is evident at this stage.

In summary, multiple errors in the ATS provision of weather information by the Nadi IFISO and the Auckland A/G operator occurred on this occasion, and it is likely such errors will occasionally occur in the provision of flight information in the future. It is also likely there will be situations where ATS personnel are prioritising activities and do not have the time to provide flight information. High-reliability or safety-critical systems need to have multiple layers of risk controls in order to manage situations where changes in weather conditions have not been provided to a flight crew. In particular, flight crews cannot rely on being provided weather information, and they are responsible for ensuring that they actively request relevant weather information at the appropriate times to ensure they can make effective decisions regarding their flight.

In-flight fuel management

Overview

As noted above, even if the flight had departed with full fuel, the aircraft would not have had sufficient fuel to conduct a missed approach at Norfolk Island and then divert. Therefore, it was essential the flight crew had a robust method of determining the PNR and monitored the weather conditions at Norfolk Island prior to reaching the PNR. Having not departed with as much fuel as possible, the PNR was further away from Norfolk Island than it would otherwise have been, and therefore the importance of monitoring the weather conditions and the PNR in relation to fuel on board was even more critical.

As already noted, the weather conditions at Norfolk Island deteriorated during the flight, and the flight crew were not provided with some of the relevant information about this deterioration. However, they were still provided some information that indicated a deterioration was occurring.

This section discusses the flight crew's assessment of the weather information and the PNR, and the factors which could have influenced these assessments. It also discusses the operator's risk controls for in-flight fuel management and weather-related decision-making, and the associated regulatory requirements and guidance.

Crew assessment of the weather information and the point of no return

Assessment of the 0630 and 0800 weather reports

The 0630 METAR was broadly consistent with the details from the TAF the captain obtained before the flight. The METAR, as provided by the Nadi IFISO at 0801, included few cloud at 6,000 ft and broken cloud at 2,400 ft and a temperature-dewpoint difference of 2°C.

The captain's perception of the situation may have changed had he been correctly provided few cloud at 600 ft rather than few cloud at 6,000 ft. The indication of a small amount of cloud at 600 ft could have increased his awareness of a potential deterioration by that time. However, the better conditions as incorrectly reported at 0630 should have resulted in subsequent weather reports being perceived as indicating a more significant rate of deterioration. In addition, the sequence of the provided cloud base information (with the higher cloud given before the lower) should have suggested the 6,000 ft figure was erroneous.

Nevertheless, the 0630 weather report was almost 90 minutes old when it was provided, and it was followed immediately by the current and therefore more relevant 0800 weather report. The Nadi IFISO correctly read out this report, and it included several key elements of information. These included emphasis that it was a SPECI, cloud was overcast at 1,100 ft, and there was a temperature-dewpoint difference of 2°C.

It is unclear exactly how the captain perceived the 0800 weather report. He initially recalled being aware there was some degree of deterioration and some cloud at about 1,000 ft. However, he subsequently reported he could not recall being aware the report was a SPECI, or that there was overcast cloud at 1,100 ft.

There was potential for the captain to not correctly perceive some of the information. For example, HF radio transmissions are commonly associated with a level of static and interference, which can mask and potentially distort the received radio transmissions. In addition, the captain may have developed an expectancy that the weather conditions at Norfolk Island were not problematic, based on the 0437 TAF and/or the 0630 weather report. Expectancies can influence the perception of information, particularly when the information is ambiguous or difficult to perceive (Wickens and Hollands 2000).

Although there was a potential for elements of the 0800 SPECI to be misperceived:

- The available information suggests the level of static and interference on the HF frequency at the time of the transmissions would not have been abnormal.
- If there are difficulties in understanding HF transmissions, the receiving party normally asks for the information to be repeated. However, the transmissions between the IFISO and the captain between 0801 and 0803 indicated each party was correctly receiving the information. The only item the captain asked to be repeated was the time of the initial METAR, as that item of information was unexpected. However, he had heard the time correctly. It seems unlikely multiple elements of information would have been masked or distorted to the extent they were not comprehended correctly, yet the information was not requested to be repeated.
- If the captain misperceived the 0800 weather report and thought the cloud conditions at that stage were better than the reported conditions, it would be reasonable to expect that the 0902 weather report would have indicated a significant deterioration in the conditions and been a surprise and a significant concern to the flight crew. However, based on interviews and the CVR recording, the crew did not appear to be surprised or significantly concerned when they received the 0902 weather report (see *Assessment of the 0902 weather report*).
- It is possible the captain heard some or all of the key details of the 0800 SPECI correctly but considered them unreliable, as the SPECI was an automatic (AUTO) report and he had developed an expectancy that such AUTO reports overestimated the amount of cloud (see also *Expectancies*).

The available evidence indicates the first officer was having a cockpit nap at the time of the 0801 to 0803 transmissions, and therefore did not hear the weather reports. Such cockpit rests were an important part of the operator's fatigue risk management system. However, on this occasion a cockpit nap could have resulted in a missed opportunity to detect the captain's possible misperception of the IFISO's transmissions.

In summary, although exactly how the captain perceived the 0800 weather report cannot be determined, it is evident he did become aware there was some deterioration in the conditions at Norfolk Island at this time. He was also aware the TAF he obtained before the flight indicated there would be a future deterioration, albeit some hours after their expected arrival time.

Consequently, given the aircraft was still about 2 hours from Norfolk Island at 0803, and there was still significant time before the aircraft reached its PNR, it was important for the flight crew to obtain additional weather information prior to committing to a landing at Norfolk Island. This should have included at least one more weather report. In addition, given the context, it would have been prudent to check whether an amended TAF for Norfolk Island had been issued.

Estimation of the point of no return (PNR)

The method the captain reported using for estimating the PNR to an off-track alternate aerodrome was to identify the last waypoint the aircraft could reach and still divert to the alternate aerodrome with the required fuel reserves. After passing this waypoint, his method involved periodic checks of whether the aircraft could still divert from its current position.

Although the captain's method was relatively simple to apply, it was problematic as it could generally provide only a broad indication of where the PNR was before it was reached. In other words, it did not actually calculate a specific point or time that could be used as a basis for gathering weather information and making a decision. In addition, if the periodic checks after the last waypoint before the PNR were not being done frequently, there was a potential to inadvertently pass the PNR without having gathered the required information to make a diversion decision.

Based on the available evidence, it is difficult to identify when the captain would have done checks on the ability to divert and what he would have estimated during any of these checks. He could not recall where the PNR was, which is consistent with using a method that does not actually calculate a specific point or time. There was also no indication on the CVR recording of any discussions between the crew relating to the PNR, although it was reported this could occur even when a captain had calculated a PNR.

The ATSB's recreation of the application of the captain's method for checking the ability to divert at selected times involved a number of assumptions and potential limitations. Nevertheless, the available information indicates:

- If the captain conducted a check prior to reaching DOLSI (the last waypoint before Norfolk Island) at 0839, he should have determined the PNR was beyond DOLSI with a significant margin available. It is very unlikely that he could have estimated the PNR to be before DOLSI.
- If he conducted a periodic check during 0839–0848, he should have determined that the aircraft was still able to divert to either Nadi (with a sizeable margin) or Noumea (with a minimal margin). Although he appeared to be conducting flight planning for the next flight during this period, he potentially had the capacity to conduct a check.
- During 0848–0900, the crew's attention was focussed on entering waypoints for the next flight from Norfolk Island to Melbourne into a GPS unit, and from 0900 to 0901 the crew were discussing the fuel required for the next flight. Therefore, during 0848–0901 there was little if any capacity for him to conduct a check.
- If he conducted a periodic check during 0901–0903, he should have determined the aircraft could probably still have diverted to Nadi. Therefore, they were at or approaching the PNR.
- During 0904–0911, the crew's attention was focussed on other tasks and there appeared to be little if any capacity for the captain to check their ability to divert. In particular, there appeared to be no opportunity for the captain to conduct a check between the time he requested the latest weather report at 0904 and the time he made the decision to conduct an approach to runway 29 at 0907.

Other methods of calculating a PNR that produce a specific point and time are significantly more effective as a basis for in-flight decision-making. These methods generally take longer to apply, particularly when conducting the initial calculation. However, if the initial calculation is conducted before flight, it is relatively easy to modify the calculation in-flight to suit the actual conditions. If the captain had calculated a specific PNR pre-flight, then the limitations of his method could have been reduced. Rather than using waypoints to make his initial, broad assessment of where the PNR was, he could have used the initial PNR. In most cases this would reduce the period of time where he was relying on estimations of his current ability to divert.

Alternatively, the flight crew could have developed and applied a how-goes-it chart in flight to monitor the PNR. However, although the operator had introduced this technique some years before, many current flight crew (including the crew of VH-NGA) had not been trained to use it (see also *Operator's risk controls for in-flight fuel management*).

Decision about when to request additional weather information

It is essential for a flight crew to request weather information before reaching their PNR. However, the crew also needs to allow sufficient time to obtain the information, assess the situation and make a decision regarding diversion.

When obtaining weather information via HF radio, the process requires time due to the difficulties in using the frequency, the time required for ATS to retrieve the information and the need for ATS to prioritise other activities ahead of the provision of FIS. In this case there were significant gaps in transmissions on the HF frequency during the relevant period, and no apparent problems with HF communications. However, obtaining a weather report could still have taken several minutes.

In addition to obtaining information about the destination aerodrome, the flight crew also needed to allow time to obtain additional information if required. For example, if the reported conditions at the destination aerodrome were adverse, the crew needed to check or obtain the latest information about the alternate aerodrome(s). In this case the crew had no current information about alternate aerodromes, and therefore they would have needed to allow more time than normal.

In other words, even if the captain estimated the PNR to be at about 0900, he should have been requesting information at least several minutes before 0900. In this case, requesting the weather information at some time prior to 0856 would have resulted in the crew being provided with the 0830 SPECI. As noted above, this indicated conditions were below the landing minima, which would probably have resulted in the crew diverting to an alternate aerodrome.

Ultimately, the captain requested the latest weather report at 0904. This was prompted by the first officer's suggestion to get wind information, which the crew needed to select the most suitable runway for an approach. It is unclear whether the captain also requested the weather information at 0904 for the purpose of evaluating whether to continue or divert. As indicated above, he should have requested an additional weather report after receiving the 0800 weather and before committing to continue to Norfolk Island. It is possible he intended to request a weather report prior to 0900 and got distracted by other tasks, or he intended to wait until just after 0900 before getting the latest weather information before deciding whether to proceed to Norfolk Island.

Assessment of the 0902 weather report

The Auckland A/G operator correctly read out the 0902 SPECI and the flight crew correctly perceived the information. Although the reported conditions were still above the landing minima, they had deteriorated since the 0800 report, with reductions in the lowest level of cloud (now scattered at 500 ft), visibility (now 7,000 m) and the temperature-dewpoint difference (now 1°C).

Regardless of how the captain perceived the 0630 and 0800 weather reports, the 0902 SPECI indicated a significant, worsening trend in the weather conditions. Although the crew correctly perceived the weather report, and had some level of concern, there was no apparent indication that they were surprised or significantly concerned at that stage.

The captain later reported that, after receiving the 0902 weather report, he decided to continue the flight to Norfolk Island. The CVR recording indicates the captain promptly made the decision to conduct an approach to runway 29, and the first officer agreed.

As noted above, the captain cannot recall where he thought the PNR may have been. Ultimately, there are three primary scenarios in relation to the 0902 weather report:

- The captain believed they had not yet passed the PNR and he was content to proceed to Norfolk Island on the basis of the weather report.
- The captain had no specific awareness of the PNR at that time but was content to proceed to Norfolk Island on the basis of the weather report.
- The captain believed they had passed the PNR and there was no need to review the situation.

The available evidence is inconclusive about which of these actually occurred. Nevertheless, even if the third scenario occurred, it is likely the aircraft had only just passed the PNR. A review of the situation was warranted, including checking calculations, considering a diversion with long-range cruise settings, and/or considering the potential for an emergency diversion.

Assessment of the risk level of continuing to Norfolk Island

Decision-making in real-world settings involves using experience to assess a situation and select an appropriate course of action, often under conditions of time pressure and workload. Research shows people usually do not identify all the options and systematically consider the advantages and disadvantages of each option. Instead, they generally use techniques and heuristics to simplify the process. Although decision-making based on expertise often results in the desired outcome, it can be influenced by a range of contextual and cognitive factors and result in biases and errors.

For example, research has shown that many aviation accidents in both air transport and general aviation involve a ‘plan continuation bias’ or ‘plan continuation error’. That is, a flight crew decides to continue with the original plan of action despite the presence of cues or information that suggests changing the course of action would be the safer option (Orasanu and others 2001, Dismukes and others 2007, Orasanu 2010). Plan continuation bias is often associated with situations involving dynamically changing risk and pilots underestimating the risk level (Orasanu and others 2001; Wiegmann and others 2002).

In the case of the accident flight, a plan continuation bias may have been evident in the captain’s decision to continue to Norfolk Island after receiving the 0902 weather report, without considering or discussing other options. A plan continuation bias was more clearly apparent in his decision to continue with an instrument approach to runway 29 after receiving more adverse weather information at 0928, even though a more suitable approach to runway 11 was available (see *Conduct of the instrument approaches*). It also appeared to be evident when the captain elected to conduct the second approach to runway 29 rather than consider other available options at that stage.

As already noted, the captain reported he was aware the conditions were gradually deteriorating at Norfolk Island, but he did not believe the deterioration would be significant enough to preclude a successful landing. Overall, it seems that he underestimated the potential risk of continuing the flight to Norfolk Island.

Summary

Ultimately, the extent to which the captain was monitoring the PNR, and what assessments he made regarding the PNR, could not be determined. However, the available evidence indicates that if he had been regularly checking his ability to divert, he probably should have realised the PNR was at about 0900.

Given that the last weather information was obtained at 0800 and the captain was aware of some deterioration, he did not request sufficient weather information at an appropriate time prior to reaching the PNR to support effective decision-making. In addition, his method for estimating the PNR to an off-track alternate aerodrome during a flight would generally not produce a specific, accurate time that could be used as an effective basis for deciding when to gather relevant weather information.

Overall, the captain underestimated the risk associated with continuing the flight to Norfolk Island. This underestimation was associated with the limited weather information he had been provided during the flight and the limited information he had requested. A range of other local conditions may also have influenced the captain’s assessment of the risk level with continuing the flight and his related decision-making. These cognitive and contextual factors are discussed in the next section. The potential influence of fatigue is discussed in *Crew fatigue*.

Local conditions

Expectancies

Underestimating the risk level can be associated with expectations based on previous experience. In this case the captain had previously flown to Norfolk Island four times, and on each occasion the actual weather conditions were better than the forecast conditions. He had also not previously encountered a situation that involved a rapid deterioration in weather conditions.

The captain also reported the events of the previous night’s approach into Norfolk Island had a significant influence on his decision-making during the accident flight. As a result of that flight, he had developed an expectancy that the AWS at Norfolk Island routinely overestimated the severity of the weather conditions. He appeared to have limited confidence in the weather reports, particularly if they were inconsistent with his expectations or other information.

Although the AWS may have overestimated the cloud on the previous night's flight, this was not routinely the case, and therefore his expectancy was incorrect. Although the captain reported his expectancy was partially based on conversations with the Unicom operator, the exact nature of those conversations and the potential for misunderstanding what was said could not be determined.

Ambiguity

Although the weather reports provided to the flight crew indicated a deteriorating trend at Norfolk Island, the conditions reported in the 0902 SPECI were still above the landing minima. Therefore, there was still a degree of uncertainty as to what the conditions would be like in an hour when the crew would be conducting the approach.

As noted by Orasanu and others (2001):

> Cues that signal a problem are not always clear cut. Conditions can deteriorate gradually, and the decision-maker's situation assessment may not keep pace. Ambiguous cues permit multiple interpretations. If this ambiguity is not recognized, a pilot or crew may be confident in their interpretation of a situation, when in fact they are wrong. People are often not likely to question their interpretation of a situation unless there are powerful cues to suggest their current interpretation is wrong.
>
> [People]… may find it difficult to justify a change in plan in the face of ambiguous cues. For decisions that have expensive consequences, such as rejecting a takeoff or diverting, the decision maker may need to feel very confident that the change is warranted. If the situation is ambiguous, a change of plan may be more difficult to justify than if the situation is clear-cut, which may contribute to plan continuation events.

In other words, if the 0902 weather provided more definitive evidence of the problem, such as significant cloud below the landing minima, it should have prompted more discussion and consideration of options by the crew. However, the reported conditions allowed a range of potential interpretations, which enabled other factors to have more influence.

A further aspect of ambiguity was the dewpoint information in the 0902 weather report. The Auckland A/G operator provided the dewpoint from the 0800 weather report. Although the 0900 dewpoint was likely to have been the same as the 0800 dewpoint, this was not certain.

Absence of information

Related to ambiguity is the absence of information. Due to the captain's limited flight planning, the flight crew had no information about the en route forecast winds needed to appropriately plan a diversion. They also had no current information on the availability of facilities at en route alternate aerodromes or the local weather conditions at these aerodromes.

In the absence of this information, there was increased uncertainty and therefore complexity associated with any decision to continue or divert. For example, the captain was asked during the investigation what he would do if, at some point after he received the 0902 weather report, he calculated he could still divert and land at an alternate aerodrome with less than the fixed fuel reserve. He stated he would have been reluctant to divert on such a long leg with an unknown off-route wind component as winds can be unpredictable.

Associated with the absence of information is the potential difficulty involved in obtaining information via HF radio. The captain reported he was reluctant to request weather information for alternate aerodromes given the possible problems associated with communicating on HF radio and the inconvenience that using the frequency for an extended period of time would create for ATS and other parties. This suggested the captain believed he needed a strong justification, in terms of the severity of the conditions at Norfolk Island, before directly requesting additional information. Alternatively, the flight crew could have obtained information about alternate aerodromes via VOLMET, if they had identified the need to do so.

Confirmation bias

People seek information that confirms or supports their hypotheses or beliefs, and either discount or do not seek information that contradicts those hypotheses or beliefs. When the available information is ambiguous, it will generally be interpreted as supporting the hypothesis. This confirmation bias is an inherent aspect of human decision-making and has been demonstrated to occur in a wide range of contexts (Wickens and Hollands 2000).

Confirmation bias appeared evident in the captain's decision-making during the accident flight. For example, the captain advised the first officer during the flight that he used the difference in temperature and dewpoint as a means of checking the accuracy of the lowest level of cloud reported by an AWS. However, even though the 0902 SPECI included a 1°C difference and scattered cloud at 500 ft, this situation did not appear to lead to any significant concern or surprise, or discussion about their current situation.[332]

Time constraints

By the time the flight crew finished receiving the 0902 SPECI at 0907, they were probably around or just past the PNR. As noted above, to make a considered decision about whether to continue or divert requires time to collect relevant information, including checking the availability and current conditions at alternate aerodromes.

Given the crew had no recent information about the alternate aerodromes, this process would have taken several minutes. By the time they obtained this information, the crew would probably be forced to decide between continuing toward Norfolk Island or diverting to an alternate aerodrome with less than the required fuel reserves. The longer it took to obtain the information, the less fuel they would have to divert.

In effect, a diversion to Nadi or Noumea after reaching the PNR and then obtaining additional information would probably have required declaring an emergency. It is more likely this course of action would have only been considered if the reported conditions at Norfolk Island were worse than the conditions in the 0902 weather report, such as conditions being below the landing minima.

Other goals and consequences

In addition to safety and operational factors, there are also a range of personal, social and organisational factors that can have an influence on a decision to continue or divert (Paletz and others 2009). For example, diverting can be associated with inconvenience to those on board and financial costs. Although in this case the patient was stable, a delay would still have been undesirable. However, there was no evidence of any specific personal motivations to complete the task as quickly as possible, or any financial penalties associated with not completing the flight on schedule, other than the cost of some additional fuel.

One consequence associated with diverting to Nadi was that the aircraft would probably not have been able to fly direct from Nadi to Melbourne. Therefore, the crew would have had to refuel at another location on the way, adding further delay to the trip.

A potential consequence of diverting to Noumea was attention from the French regulatory authority, given the operator was still banned from conducting planned flights to Noumea. Although this should not have precluded an unplanned flight to Noumea because of operational

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[332] It should be noted the temperature-dewpoint difference (dewpoint depression) can be useful information but it needs to be used with caution. It does not apply to all types of cloud formation. The captain used a figure of 500 ft per degree for the purpose of his calculation, whereas the figure cited by BoM was closer to 400 ft. In addition, METARs and SPECIs report temperatures and dewpoints to the nearest 1°C. Therefore, when dealing with differences of 1°C or 2°C, the amount of error due to rounding can be significant.

reasons, such as unforecast weather conditions at Norfolk Island, it may have meant the crew believed they needed a strong justification for a diversion to Noumea. There should have been no such concerns associated with Nadi.

Another issue of potential concern for the captain was that the operator would have wanted to understand the reasons for a diversion. There was no evidence to indicate there would have been negative consequences for the crew if they conducted a diversion on the basis of unforecast weather conditions at Norfolk Island. However, it is likely that concerns may have been raised about why the captain had elected to depart without full fuel and with incomplete flight planning.

One aspect of comparing options is the framing effect. When decision-makers are faced with options that are perceived as a choice between two different benefits, they tend to be risk averse (that is, preferring a higher likelihood of receiving a small benefit compared to a lower likelihood of receiving a larger benefit). On the other hand, when decision-makers are faced with options that are perceived as a choice between two different losses, they tend to be risk seeking (that is, preferring a lower likelihood of a larger loss compared to a higher likelihood of a smaller loss) (Kahneman 2011). A comparison between potential losses has been proposed as an explanation of plan continuation bias (O'Hare and Smitheram 1995). For example, continuing a flight to Norfolk Island could be perceived as having a relatively low likelihood of encountering adverse weather, but diverting to Nadi or Noumea could be perceived as being associated with very likely (though less significant) negative consequences.

Fuel quantity gauge indications during the cruise

The available evidence indicates the fuel quantity gauges were underreading by about 260 lb throughout much of the gauges' range. Fuel quantity indicating systems will often not be totally accurate, and the gauges are often such that a precise indicated amount is difficult to determine. Nevertheless, a 260-lb discrepancy at low fuel volumes is significant. For example, if there was 2,000 lb of fuel on board, the underreading is 13 per cent.

A significant underreading of the fuel quantity indication can create difficulties for a flight crew when determining how much fuel is on board. However, in this case, the captain was aware that the gauges were underreading by about 300 lb, prior to, at the start of, and during the accident flight. Therefore, it seems unlikely that the gauge inaccuracy would have had a significant influence on his decisions regarding the ability to divert. However, the inaccuracy did introduce another item of ambiguity and added to the complexity of the situation. It also became significantly more problematic when the fuel quantity indications approached zero (see *Fuel quantity gauge indications during the approaches*). Further discussion of the fuel system maintenance is provided in *Maintenance of the fuel quantity indicating system*.

Fuel flow gauge indications

In addition to the fuel quantity gauges underreading, the fuel flow gauges were also probably underreading. The extent of underreading was hard to estimate, but appeared to be at least 10 per cent. During the accident flight, the flight crew both reported the indicated total fuel flow was about 1,100 lb/hour after they were established in cruise at FL 390, whereas the ATSB estimated the actual fuel flow was about 1,310 lb/hour.

A significant underreading of the fuel flow indications can increase difficulties associated with predicting the fuel remaining at a future point in time. Depending on the methods being used, it could also have adverse implications for flight crews when calculating their range or their ability to divert. In the case of the accident flight, the captain reported using the current indicated fuel flow in his calculations. Therefore, there was the potential for him to develop a more conservative conclusion on the PNR had the fuel flow indicators displayed a more accurate value. The extent to which this would have influenced the outcome of the 18 November 2009 flight is difficult to determine given the uncertainties regarding the actual decision-making process.

Summary

The flight crew were undoubtedly faced with a difficult set of circumstances for making a decision to continue the flight to Norfolk Island or divert. The destination weather conditions were deteriorating, and the limited information the crew received about this deterioration did not provide a definitive indication as to the likely conditions they would experience when they reached Norfolk Island.

A range of factors may have influenced the crew's assessments and decisions regarding the risk of continuing to Norfolk Island. In particular, the captain's expectancy that the AWS at Norfolk Island generally overestimated the amount of low cloud probably had an influence on his decision-making. However, the relative influence of other specific factors was not able to be determined.

Operator's risk controls for in-flight fuel management

Most of the operator's flights to remote aerodromes had sufficient fuel to conduct an approach and then divert to an alternate aerodrome. However, it still undertook a number of flights where there was insufficient fuel available to conduct a missed approach and then divert. Therefore it was essential flight crews knew how to calculate a PNR and use this as a basis for gathering adequate information before making a decision to continue or divert.

The guidance in the operator's OM for calculating a PNR was limited and it contained some ambiguous content. Most importantly however, there was no formal guidance about how to calculate a PNR to an off-track alternate aerodrome. Although the operator had adopted a suitable and relatively simple method for calculating PNRs during flight using a how-goes-it chart, this method was not widely taught to or used by the current Westwind pilots.

All pilots are required to learn how to calculate PNRs to off-track alternate aerodromes when completing their theory examinations for an Air Transport Pilot Licence. The operator also provided its Westwind captains with training in calculating PNRs during line training. However, the available evidence indicates that in many cases the depth of this training was limited.

There are many methods that can be used for calculating an off-track PNR, each with its advantages and disadvantages. However, all the methods involve a series of procedural steps, some complexity and some time. Procedural tasks with multiple steps are prone to skill decay if they are not well learnt and then regularly practised (Arthur and others 1998, Casner and others 2014, Wisher and others 1999). The operator's flight crew proficiency checks had minimal focus on in-flight fuel management aspects, and were conducted on short flights where such aspects were of limited relevance. The ability of crews to calculate PNRs was not routinely assessed or discussed during proficiency checks, even though the operator's OM required it to be checked or discussed during a line check.

The operator's OM specifically required a PNR be calculated prior to flight for overwater flights (more than 200 NM from land). Other than the pilots who used a flight planning software tool that automatically calculated a PNR, it appeared many of the Westwind pilots only calculated or considered PNRs during flight. Calculating a PNR to an off-track alternate aerodrome in-flight using an appropriate method is complex and difficult (unless perhaps a method like the how-goes-it chart had been learnt and regularly practiced). To some extent therefore, it is understandable that some captains, such as the captain of the accident flight, had started using a more simplistic approach.

In addition to limited guidance material for calculating a PNR for an off-track alternate aerodrome, and limited training and proficiency checking for this task:

- There were no formal procedures requiring a PNR calculation to be checked by another pilot prior to the flight, or for a PNR calculation to be cross-checked and discussed during the flight. Given the complexity involved in some PNR calculations, this meant there was a realistic potential for undetected errors.

- The operator provided no specific guidance regarding what types of weather information to collect prior to passing a PNR and when to obtain this information. Although not every possible scenario can be covered by procedures and guidance material, some general instruction would have been beneficial on the relative importance of checking updated forecasts in certain situations, or at particular locations, in addition to obtaining weather reports.

The operator's aircraft were fitted with all of the required communications equipment for conducting long-distance flights to remote aerodromes. However, most of the aircraft (including VH-NGA) were not equipped with satellite phones usable within the aircraft. Satellite phones could be used to obtain weather information at Australian remote island aerodromes in-flight, at a greater range than could be done through VHF communications, or in situations where HF communications were difficult. Nevertheless, the absence of a satellite phone should not have precluded the flight crew from obtaining additional weather information during the accident flight via HF radio.

The 2006 NTSB special investigation report into EMS accidents (see

Pre-flight risk assessments) recommended that EMS operators have a formalised dispatch and flight-following procedures 'that included up-to-date weather information and assistance in flight risk assessment'. In 2014, the FAA introduced a requirement for EMS helicopter operators with more than 10 EMS helicopters to have an operations centre that provided two-way communications with pilots during flights. Although such operations centres are highly desirable, the extent to which they could be a justifiable, pragmatic option for fixed-wing air ambulance operators with a small number of aircraft is limited. However, the increasing availability of satellite-based internet systems for aircraft offer another option to provide flight crew with access to real-time data and improved communications during flight.

In summary, the operator did not effectively control the in-flight fuel management activities of its Westwind pilots. Flight crew were using a variety of methods for calculating or estimating the PNR, with some of these methods being inherently weak and the calculations not checked.

Regulatory requirements and guidance for in-flight fuel management

There were no explicit regulatory requirements for in-flight fuel checks and calculations of the PNR, and there was minimal regulatory guidance material that discussed aspects of in-flight fuel management and en route weather updates. The absence of this guidance increased the risk of inconsistent in-flight fuel management and the likely variability of flight crew decisions to divert.

As noted above, there were limitations with the operator's procedures and guidance relating to the calculation of PNRs for off-track alternate aerodromes and related tasks. The ATSB also found similar limitations in the operations manuals of several other air ambulance operators. The broader extent of these limitations in operator requirements and guidance material suggests additional industry guidance was warranted.

It would be difficult to provide detailed regulatory guidance material that would be applicable to all types of operations and situations. However, some level of guidance to operators and flight crew to reinforce the importance of in-flight fuel monitoring and provide some basic principles would have been beneficial. Nevertheless, given the operator already had some procedures and guidance material in place, albeit problematic, it is difficult to evaluate whether the introduction of regulatory guidance material by itself would have significantly improved the operator's risk controls for in-flight fuel management.

Planning and execution of instrument approaches

Overview

Before ditching the aircraft, the flight crew conducted four instrument approaches, and in each instance they were unable to obtain visual reference with the runway. They then proceeded to ditch the aircraft. However, a ditching at night with no ambient illumination and unknown sea conditions involves a very high level of risk. There were alternative means to respond to the developing emergency situation that could have been considered, discussed and applied prior to conducting a ditching.

This section reviews the planning and conduct of the four approaches, and the crew's consideration of available options. It then discusses the factors that potentially influenced these considerations.

Conduct of the instrument approaches

First approach

As noted above, after receiving the 0902 weather report, the captain promptly decided the flight crew would conduct an approach to runway 29 and the first officer agreed. The crew briefed relevant aspects of the published approach chart, and also discussed the amount of fuel they had remaining. They subsequently discussed some of the potential implications of the weather conditions for their VOR instrument approach to runway 29. However, they did not discuss alternative options to a runway 29 approach. More specifically, the captain did not ask for options, and the first officer did not volunteer any alternatives.

For the first approach, a VOR instrument approach to runway 11 provided a greater likelihood of the crew becoming visual than a VOR instrument approach to runway 29, as the runway 11 minimum descent altitude (MDA) was 100 ft lower. Although the 0630 and 0800 weather reports had indicated a wind advantage for runway 29, the 0902 weather report (and subsequent reports) indicated there was no wind advantage for either runway.[333] The runway 29 approach involved a slightly shorter flight time given the crew's inbound flight path. It was also the approach they had used the night before,[334] although on that occasion they joined the approach from a different direction.

After the flight crew received the first weather information from the Norfolk Island Unicom operator at 0928, they realised the reported conditions had deteriorated below the landing minima. By this time they did not have enough fuel to conduct an emergency diversion to Noumea. It was evident the crew were surprised and significantly concerned at this stage. In response, the captain sought additional information from the Unicom operator. He also advised the first officer that, if required, he would take over flying the aircraft during the approach in order to maximise their chances of becoming visual.

Therefore, by this time the flight crew had clearly identified the potential threat associated with the deteriorating weather. However, they did not revise their plan to conduct a VOR approach to runway 29. They had already briefed that approach, and briefing a different approach would have increased workload. Nevertheless, given the situation, it would have been worthwhile to review all the available approaches to evaluate whether other options may have provided more potential of becoming visual.

In addition, it would have been useful for the flight crew to discuss in more detail what they would do if they could not land off the first approach. Furthermore, although the crew had noted the final approach track was not aligned with the extended runway centreline and there was no circling allowed to the north of the runways, it would have been useful to conduct a more detailed review and discussion of the terrain hazards and limitations surrounding the runways.

Discussing and planning options takes time. However, the crew had time available prior to commencing their descent from FL 390 at 0940. If required, they could have elected to briefly hold at FL 390 near the top of descent point to further review the situation.

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[333] The 0437 aerodrome forecast the captain obtained before the flight indicated a slight wind advantage for runway 11.

[334] Based on reported wind conditions, it is likely that the captain would have landed on runway 29 on his two recent flights to Norfolk Island in September 2009.

During the conduct of the first approach, the first officer flew the aircraft close to the required speed and slightly above the published profile. The captain took over control and, after advising the first officer, descended slightly (80 ft) below the MDA to improve the chances of becoming visual, without success. Given the context, descending slightly below the published MDA was understandable. However, before doing so, it would have been appropriate for the crew to have discussed and agreed a revised MDA.

The flight crew were in a very difficult situation. At the end of the start of the missed approach procedure, the fuel quantity gauges were probably indicating they only had about 800 lb of fuel remaining, although the actual amount was probably closer to about 1,040 lb. The crew had also now realised the AWS reports regarding the low cloud were accurate.

Second approach

After the first approach was unsuccessful, the flight crew initially appeared to be uncertain about what to do next. The first officer suggested conducting an approach to runway 11, and the captain indicated he was considering this option. The captain then decided to conduct another approach to runway 29, although he did not effectively communicate this intention to the first officer.

The captain's decision to conduct another approach to runway 29 may have been influenced by his seeing some lights to the west of the airport during the first approach. In addition the crew had already briefed that approach. Nevertheless, as noted above, a VOR approach to runway 11 would have afforded more opportunity for successfully acquiring visual reference.

It is unclear whether the flight crew thought they were in an emergency situation at this stage. If the crew assessed they were in an emergency situation, there was a broader range of options available than conducting the published approach to runway 11 (see next section). In addition, rather than simply conducting another approach to runway 29, the crew could have held over the water at an appropriate altitude for a brief period after the first approach to discuss the available options and develop a course of action to maximise the likelihood of landing safely off the second approach.

During the second approach, the captain descended down to the MDA about 1 NM earlier than the first approach, but he did not descend any further below the MDA. In effect, the second approach had the same outcome as the weather conditions had not changed.

At the start of the second missed approach procedure, the flight crew were definitely in an emergency situation. The fuel quantity gauges were indicating there was probably about 600 lb of fuel remaining (the fixed fuel reserve), although the actual amount was closer to 820 lb. In addition, the FUEL LEVEL LOW warning light had illuminated, and the weather conditions had not improved.

The crew did not discuss the warning light or the amount of fuel remaining, and they did not review the abnormal procedure associated with the warning light. Had they done so, they could have confirmed the light would illuminate when there was at least 830 lb of fuel remaining. This should have reinforced the crew's understanding that the fuel quantity gauges were still underreading by about 300 lb. Additionally, by reviewing the abnormal procedure, the crew should have realised they needed to open the fuel interconnect valve to minimise the risk associated with one fuselage fuel tank having less fuel than the other.

Overall, if the flight crew had discussed their fuel situation following the annunciation of the warning light, they could also have discussed and developed a shared understanding of how many more approaches they were able to conduct. Such discussions could also have provided more context about how they should have conducted the next approach.

Third approach

The captain elected to conduct the third approach to runway 11 and the first officer immediately agreed. The flight crew also agreed the captain would descend to the MDA early, and use a revised MDA of 700 ft (50 ft below the published MDA).

It is difficult to determine exactly what the cloud and visibility conditions would have been at any specific time during the approaches. However, the available AWS information indicated the cloud base was fluctuating between 200–300 ft above the ground, or an altitude of 570–670 ft. Accordingly, descending to 700 ft provided limited chance of a successful landing.

Given the flight crew were in an emergency situation, there were other options available. These included:

- Descending to a height further below the published MDA for an approach to runway 11. For example, if the flight crew had descended to 600–650 ft altitude (or 100–150 ft below the published MDA) during the final approach, they would have significantly increased the likelihood of acquiring visual reference with the runway lighting and landing off the approach.
- Conducting an approach to runway 04. Runway 04 was not suitable for normal operations for a Westwind due to its length. In addition, the published MDA for this approach was 190 ft higher than the minima for runway 11, the runway lighting was of lower intensity, there was a light tailwind and the high terrain to the north of the runways was closer to the missed approach path than for the other approaches. Nevertheless, the VOR/DME was located on the runway centreline and about 150 m before the runway threshold. If the flight crew had descended to a selected height significantly below the published minima, they had a reasonable prospect of acquiring visual reference and landing.
- For either an approach to runway 11 or runway 04, descending to the published landing minima (or a revised altitude) over the water at a further distance from the runway, and establishing the aircraft in the appropriate configuration and airspeed prior to reaching the final approach segment.

It must be emphasised that descending significantly below the published MDA would only be a suitable course of action in an emergency. Such a course of action obviously involves increased risk, but if done in a carefully controlled manner, it would probably involve less risk than ditching at night into the sea with an unknown sea state. A carefully controlled manner in this context means the flight crew fully planning and briefing the approach, including any planned deviations from the published approach, and effectively using the available equipment on the aircraft, including the radio altimeter, EGPWS and altitude alerter.

The ATSB discussed some of these options with the captain after the accident. The captain noted that, after the second approach, the crew did not have time to start planning and considering different types of approach. He also noted that he did not have the local knowledge of the airport to be comfortable conducting an approach to runway 04, given the terrain to the north of the airport. Overall, he believed that descending to below the minima on a runway 29 or 11 approach was a much better option than conducting an approach to runway 04.

Both the flight crew also advised that, based on their previous training, they believed descending more than 50–100 ft below the MDA to be a high-risk situation. However, they also both thought - a ditching at night had a very high likelihood of resulting in fatalities. Due to the dynamic nature of the sequence of events, the crew did not have the opportunity to discuss and effectively compare a ditching with other emergency options prior to commencing the third approach.

During the third approach, the captain turned onto the approach path at 5 NM from the intercept point in order to save time. Although this decreased the time required to conduct the approach, it increased the difficulty in stabilising the approach. He descended to the MDA well before the intercept point, but the resulting airspeed was 15–25 kt above the nominated final approach speed, which reduced the time available to acquire visual reference with the runway. He descended to 650 ft very briefly, before climbing back to 700–750 ft in the period prior to passing through the extended centreline of the runway.

Fourth approach

After the third approach, the captain advised the first officer - they needed to ditch the aircraft. The flight crew briefly assessed the fuel situation, with the first officer noting the captain had previously advised they had 300 lb more than indicated on the fuel quantity gauges. However, the gauges were approaching 0 lb, and the crew had no other source of reliable information about the fuel quantity at that time.

The first officer proposed other options to a ditching, including conducting an approach to runway 11 and descending over the water and coming down a lot lower to the runway. However, the captain perceived there was very little fuel remaining and therefore very limited time available to consider such options.

The captain ultimately agreed to conduct a fourth approach. However, in order to save time it was conducted to runway 29 instead of runway 11. During the fourth approach, the flight crew did not select landing flap, and the airspeed was 20–35 kt above the nominated final approach airspeed. The aircraft's track was also 30° left of the published final approach track, and this variation to the published procedure was not briefed by the captain. The crew did not discuss a revised MDA, and the captain descended to about 760 ft, 90 ft below the published MDA, before discontinuing the approach and deciding to proceed with the ditching. Overall, the fourth approach was conducted in a manner that provided little likelihood of successfully acquiring visual reference and landing in the prevailing conditions.

Unfortunately, an unintended consequence of conducting the fourth approach is that it decreased the available time the crew had to prepare for a ditching. In other words, it could be argued that it was appropriate to spend more time planning for the ditching rather than conducting the fourth approach. However, the first officer was certainly justified in questioning the decision to ditch and to assertively propose options to a ditching, given the risk involved in such a manoeuvre. Nevertheless, it appears by that stage they had run out of time to effectively consider alternative emergency options.

Summary

There were some positive aspects about the way the flight crew conducted the approaches. They fully briefed and discussed the published procedure for the first approach. They also effectively completed checklist items during the first two approaches, and the pilot not flying regularly called exceedances and provided support to the pilot flying. In addition, for the third approach the crew specifically briefed a different (lower) MDA to the published MDA.

The ATSB acknowledges it is much easier with hindsight to propose and consider alternative options for a situation, and such options may not be apparent to a flight crew actively involved in the situation. However, discussing options in hindsight can provide important learning opportunities for other pilots.

A key lesson from this aspect of the accident flight was that the flight crew invested little time discussing options for managing the threat of degraded weather conditions prior to the first approach, even after they knew the reported conditions were below the landing minima. They also spent minimal time discussing their current fuel situation and available options prior to the second and third approaches. Although the crew briefly reviewed their fuel situation and discussed options to a ditching before the fourth approach, it appeared they had this discussion too late to effectively consider alternative emergency options before ditching the aircraft.

The crew were obviously operating under very difficult circumstances, and a range of contextual, cognitive and organisational factors had the potential to influence their performance. These are discussed in the next section. The potential influence of fatigue is discussed in *Crew fatigue*.

Local conditions

Expectancies

The captain later reported that, prior to the first approach, he was still confident that they would be able to conduct a successful landing. This indicates that, as with the in-flight fuel management, a key factor influencing his decision-making during this period was an underestimation of the level of potential risk, based on his expectancies associated with the weather conditions.

As indicated above, the decision to conduct the second approach to runway 29 may have been influenced by the captain sighting some lights to the west of the airport prior to the runway. The captain reported sighting these lights gave him some comfort that the weather would pass. Accordingly, consistent with the influence of confirmation bias, the captain may have continued to underestimate the potential risk until after the second approach was conducted.

Workload and time pressure

High workload and time pressure, and the associated stress, often results in people conducting tasks with simple strategies and considering fewer options when making decisions. There is a tendency for people to rely on responses or strategies with which they are familiar, and to persevere with a response or strategy even when it has proven to be unsuccessful (Staal 2004, Wickens and Hollands 2000). In addition, people are likely to miss important cues and experience difficulty integrating disparate pieces of information and making sense of them (Burian and others 2005). Overall, under high levels of workload, time pressure and stress an individual's ability to deal with an unfamiliar problem will be significantly compromised.

In this case, the flight crew's level of stress started increasing after they initially contacted the Unicom operator at 0928. Although their workload prior to the top of descent was not significant, it increased during the first approach, as is normal during an instrument approach. This workload further increased after the first approach, as the crew were conducting a go-around, deciding their next option and then executing the next approach.

More importantly, the workload and perceived time pressure significantly increased after the second approach. The captain's method of conducting the third approach, by intercepting the inbound track 5 NM out and then descending to the minima early, resulted in a very high workload. The first officer's attention was focussed entirely on reviewing and briefing the runway 11 approach and monitoring the captain's performance. Overall, the crew had very limited capacity to consider their situation and develop an effective plan. Unfortunately, it was at the beginning of this high workload period that the FUEL LEVEL LOW warning light illuminated, increasing the likelihood it was not effectively reviewed or discussed.

After the third approach, the crew were experiencing a high level of time pressure and stress. The fourth approach was flown in a non-standard manner, which further increased the crew's workload, time pressure and stress.

In some cases, high workload results in some tasks being shed completely, either efficiently by eliminating performance on lower priority tasks or inefficiently by abandoning tasks that should be performed (Wickens and Hollands 2000). Task shedding was evident in the crew's performance during the third and fourth approaches, as some checklist items were not verbalised, standard calls were omitted and some important actions were not completed. For example, during the fourth approach the first officer did not advise the Unicom operator of which runway they were approaching and the crew did not select the landing flap.

In summary, the flight crew's workload, time pressure and stress increased after the first approach, and further increased after each subsequent approach. This combination of related factors significantly influenced the crew's ability to assess and discuss their situation, make effective decisions and conduct the approaches. The detrimental effects of such factors further reinforces the need for a flight crew to plan for contingencies when there is available time to do so.

Fuel quantity gauge indications during the approaches

As already discussed, the fuel quantity gauges were probably underreading by about 260 lb. The captain believed they were probably underreading by about 300 lb, and he allowed for this underestimation when considering the amount of fuel remaining earlier in the flight. The captain also thought that the gauges were underreading throughout most of their range.

However, when the fuel gauges approached 0 lb after the third approach, he was clearly less confident the fuel quantity gauges were still underreading. This is understandable, given that at that stage he had no other reliable source of information regarding the amount of fuel remaining. Had the crew reviewed the fuel situation soon after the FUEL LEVEL LOW light illuminated, they may have been better placed to establish the fuel remaining at that point. Having not done that review, they realistically did not have the spare capacity to estimate the fuel remaining later in the flight.

It is also understandable that the captain did not want the aircraft to run out of fuel and then have to manage the loss of one or both engines while conducting an approach. Accordingly, as the fuel quantity gauge indications approached 0 lb, the captain perceived significant pressure to ditch the aircraft as soon as possible.

Due to their inherent nature, fuel quantity gauges will never be perfectly accurate. However, the amount of underreading in this case was significant, particularly as the gauge indications approached 0 lb. It is difficult to determine exactly what would have occurred if the fuel gauges had been more accurate, or had been indicating more than they were at the time key decisions were made. The outcome would depend on when the flight crew reviewed their fuel situation, and what the gauges were indicating at the time of those reviews. If the flight crew believed they had more fuel, the fourth approach may have been flown more accurately and the crew may have even considered a fifth approach. However, given the previous approaches and the overall context, it is unclear whether the flight crew would have been successful in obtaining visual reference during these approaches, or whether they would have had more time to prepare for the ditching.

Approach design

The VOR was located near the threshold of runway 04. Consequently, the inbound track for the approaches to runway 11 and runway 29 were not aligned with the extended runway centreline. For each approach, the inbound approach passed through the extended runway centreline at about where the published descent profile reached the minima.

This characteristic of some non-precision approaches can make it more difficult for a flight crew in poor visibility conditions to detect the runway lighting. In addition it means that if the crew become visual late in the approach there is increased difficulty with manoeuvring the aircraft onto the extended runway centreline for a landing. However, this characteristic is not uncommon with non-precision approaches, and on this occasion the crew were aware of the situation. Although not applicable to the operator’s Westwind operations, the increasing availability of runway-aligned GNSS-based approaches will minimise the future risk associated with this aspect of some ground-based non-precision approaches.

Risk controls for managing abnormal and emergency situations during approaches

A flight crew’s response to an abnormal or a developing emergency situation will generally be better if they have had the opportunity to practice responding to that situation with a clearly defined set of steps, with the more practice the better. However, crews cannot be exposed to every possible situation in training. In particular, it is difficult to provide opportunities to practice responding to some types of emergencies when the training and checking is done in the actual aircraft rather than a simulator.

The operator’s flight crew training and checking focussed heavily on managing engine, instrument and system failures. However, as far as could be determined, there was minimal coverage of managing situations involving arriving with limited fuel at a destination aerodrome affected by degraded visibility, nor would such training normally be expected for charter or air ambulance operators. There was also limited options available to conduct such training without the use of simulators. Another type of training that has the potential to be beneficial in this type of situation is crew resource management (CRM) training (see *Crew resource management*).

One option for minimising workload during instrument flying is the use of an autopilot. In this case, it could have been particularly effective if the flight crew had elected to hold at a set altitude after one of the approaches to review and discuss the situation. However, the operator's normal practice for Westwind operations was not to use the autopilot below FL 200, and this normal practice probably reduced the likelihood the crew would have considered using it in this situation. In any event, as the situation developed, the crew did not consider the option of holding for a brief period, and therefore the potential benefits of the autopilot were less obvious.

Another risk control that could have been considered for operations at Norfolk Island was the use of SCAT-1 approaches, as these approaches had a significantly lower MDA than the VOR approaches. However, the cost of equipping aircraft with the relevant equipment, and training flight crew, in order to conduct a relatively small number of flights each year at one aerodrome would have been difficult to justify. Rather, as discussed in previous sections, it would have been more appropriate for the operator to review the suitability of its fuel planning and in-flight fuel management risk controls to ensure they were adequate to conduct operations to aerodromes such as Norfolk Island.

Ditching

Overview

Many air transport aircraft, including the Westwind 1124/1124A, are designed and certified for a ditching. This means that, if the aircraft is able to be ditched in accordance within specified parameters, the aircraft will be relatively undamaged and it will float in the water for sufficient time to allow all occupants to evacuate into the life rafts.

However, many factors can influence the extent to which a ditching can be conducted in accordance with the specified parameters. Accordingly, this section discusses:

- conduct of the ditching approach
- impact forces, aircraft damage and flooding
- aircraft design and certification
- risk controls for the ditching manoeuvre.

Conduct of the ditching approach

After the third approach, and the captain's statement that they needed to ditch, the first officer commenced preparing the other occupants for a ditching. However, the flight crew did not discuss how to conduct the ditching manoeuvre itself. After the fourth approach, the captain assessed that the aircraft had very little fuel remaining, and he elected to proceed with the ditching immediately. As a result, the crew had very little time available to prepare for the ditching manoeuvre, and they did not have time to refer to the emergency procedures checklist for ditching.

Some aspects of the ditching manoeuvre were conducted effectively. For example, the captain elected to set the aircraft up in the appropriate approach configuration as early as possible and he requested that full (landing) flap be selected. The first officer subsequently identified the need to select the landing gear UP late in the approach. In addition, noting that the EGPWS was not providing altitude advisory callouts, the first officer called out heights from the radio altimeter to assist with the captain's vertical awareness. The captain was focussing on the attitude indicator and the radio altimeter, and the available evidence indicates he increased the aircraft's pitch up angle in order to flare the aircraft at an appropriate height (about 30 ft).

However, two key aspects of the ditching manoeuvre were not conducted or not able to be conducted in accordance with the checklist. Firstly, the checklist indicated the final approach needed to be flown at the reference landing speed (V_{REF}), with the increased pitch angle (or flare) initiated after the aircraft descended below 50 ft. The last V_{REF} calculated by the crew was 120 kt; if they had recalculated it for the ditching it would have been 116 kt. However, the captain could not recall the appropriate airspeed to use during a ditching, and he decided to reduce the airspeed to about 100 kt before initiating the flare.

Reducing the airspeed as low as possible prior to impacting the water is important for reducing some types of impact forces. However, the airspeed reduction needs to be done in a way that ensures the vertical descent rate is controlled. In this case, the airspeed was significantly below V_{REF}, and steadily decreasing, when the captain attempted to flare the aircraft. Due to the aircraft's low energy state, the increase in pitch attitude appeared to only result in a minimal and/or brief reduction in the descent rate. Based on the available data, the descent rate at impact was likely about 500–600 ft/minute and very likely to be in the range of 400–700 ft/minute.

The purpose of abnormal and emergency checklists is to ensure all relevant actions are completed and to minimise performance variability under workload and stress. The emergency procedure checklist for ditching is not intended to be conducted from memory (that is, the initial key actions were not recall items or memory items that flight crew were expected to conduct without reference to the relevant checklist). Although a person's long-term memory for well-learned tasks is generally quite resistant to the effects of workload, time pressure and stress (Staal 2004), such conditions will result in difficulties in retrieving information if that information is not frequently used or well learned (Dismukes and others 2007). Given the very high level of workload, time pressure and stress during the approach to the ditching, and the low frequency that crews would review this procedure, it was very likely that some checklist items would not be recalled correctly.

The second important checklist item that was not able to be completed was to ditch the aircraft parallel to the main swell. The ditching was conducted in dark night conditions, and both flight crew reported they could not see the water prior to the impact. In addition to increasing the difficulty of judging the flare manoeuvre, these conditions meant the flight crew could not determine the nature or extent of the swell. The aircraft's landing lights should have provided some illumination of the water ahead, but if the aircraft had a relatively-high pitch angle there would have been minimal time to see the water during the descent. The crew's visual attention was also directed at key flight instruments during the final moments prior to impact.

In addition to no external visual cues, the flight did not have ready access to other sources of information to provide information on the forecast or actual swell. Requesting a ditching report[335] via ATS would have required significantly more time than the crew had available.

As already noted, the flight crew were experiencing a very high level of workload, time pressure and stress during the ditching approach. One source of workload and stress were the continuous EGPWS alerts for the last 38 seconds prior to impact and, for the last 15 seconds, the landing gear warning horn. As noted above, the continuous EGPWS warnings also replaced the automatic altitude callouts, which further increased the crew's monitoring workload. The flight crew had the ability to inhibit the EGPWS and gear warning horn alerts, but did not appear to have the spare mental capacity or time to initiate these tasks.

In summary, the flight crew conducted the ditching in very difficult circumstances, with dark night conditions, very high levels of workload, time pressure and stress, and no prior opportunity to practice the manoeuvre in the aircraft. Ultimately, many aspects of the ditching the flight crew could control were conducted well. However, some key aspects, such as maintaining a suitable airspeed prior to flaring the aircraft, and therefore managing the vertical descent rate, were not in accordance with the checklist or widely recommended practice.

[335] A ditching report is an assessment of current conditions at a location where an aircraft in difficulty will attempt a forced landing. The information is designed to assist the crew to make decisions about how to prepare for the landing with minimum risk to safety. Requests for ditching reports normally come from the relevant Rescue Coordination Centre and are communicated to the aircraft by ATS.

Impact forces, aircraft damage and flooding

Given the available evidence, it appears that the aircraft initially impacted the water with a nose-high pitch attitude, an airspeed of about 90 kt and a descent rate likely to be about 500–600 ft/minute. The recorded vertical acceleration during the first impact was 3.24 g, however due to the limited sampling rate of this parameter the peak acceleration was probably higher. Based on the description by the flight nurse, who was seated closest to the impact, there was a significant vertical force, and the nurse and the doctor both experienced injuries consistent with a significant vertical force.

The aircraft skipped twice before entering the water on the third impact. After the first impact, the captain would have had limited ability to control the aircraft. Based on the occupants' descriptions, the aircraft's nose entered the water on the third impact, resulting in a significant longitudinal deceleration.

The exact nature of the water surface the aircraft encountered during the three impacts could not be determined. The aircraft's heading during the impact sequence was about 230–233°M, and the surface weather forecast indicated there was a moderate swell from the south to south-west, which was about 190°M. Therefore the aircraft's impacts were probably about 40–45° from directly into the direction of the main swell, and it is likely the aircraft encountered waves or an uneven water surface during the impact sequence.[336] Overall, impact with the swell or waves may have contributed to the aircraft skipping, and probably increased the magnitude of the vertical and horizontal decelerations during the impact sequence.

Given the limited information available, it is very difficult to estimate the exact nature and extent of the forces acting on the aircraft during the impact sequence. However, in addition to significant vertical and longitudinal decelerations, it is likely the aircraft experienced significant longitudinal bending and twisting stresses. It is also likely the aircraft experienced significant hydrodynamic forces when the aircraft entered the water after the second skip.

The impact sequence resulted in rapid flooding of the cabin and a very limited time available for the occupants to evacuate. There appeared to be two major sources of water ingress:

- The fuselage separated just aft of the rear pressure bulkhead. The visible damage was consistent with significant longitudinal bending, which could have occurred during the vertical decelerations and/or the longitudinal deceleration when the aircraft's nose entered the water. Given the nature of the fuselage damage, it is likely the aft pressure bulkhead was compromised, and water was able to access the cabin via this breach.
- The main entry door opened inwards during the last impact. The exact failure mechanism is unclear. It is possible the impact and hydrodynamic forces, and associated bending and distortion of the fuselage structure, compromised the integrity of the door's single latch. As a result, the door opened inwards, consistent with its normal opening behaviour, with the pressure of the inflowing water maintaining the door in that position until the aircraft sank. Alternatively, it is possible the bottom part of the door structure was distorted during the impact sequence, while the top part of the door remained relatively undamaged. The direction of the swell relative to the aircraft heading suggests the front left of the fuselage may have sustained the highest forces, which could have been influential in either possibility. However, given that aircraft doors are generally robust structures, it seems more likely the door structure itself remained intact and the hinges or latch were compromised.

Although the fuselage separated, it is important to note the survivable space within the cabin was maintained, and the occupants' injuries appeared to be associated with the impact forces rather than any failures of the structure and fittings within the cabin. In addition, there was no damage

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336 The aircraft's heading was close to perpendicular to the wind, and therefore parallel to any waves generated by the local wind. However, the waves due to the reported 9 kt wind would probably have been significantly smaller than those due to the forecast swell.

that affected the operation of the emergency exits or the occupants' access to those exits, and the emergency lighting illuminated.

In summary, the aircraft and its occupants were exposed to a combination of forces during the impact sequence resulting from the higher than desired descent rate, the aircraft's nose entering the water and the likely impact with the swell and/or waves. Ideally, an aircraft will be able to withstand the forces encountered during a ditching such that the aircraft will remain afloat for sufficient time for the occupants to evacuate in a controlled and safe manner. However, in this case the ditching was conducted in difficult circumstances. Although the full magnitude and nature of the forces during the ditching are unknown, it is likely they significantly exceeded those typically considered by aircraft manufacturers during the aircraft design process.

Aircraft design and certification

During the process of certifying an aircraft for ditching, an aircraft manufacturer is required to demonstrate the aircraft will be able to withstand the expected forces involved in a ditching, such that the occupants are not injured and they will be able to successfully evacuate. The certification process assumes the aircraft will impact with the water within a narrow range of touchdown parameters, including a relatively low airspeed, relatively low descent rate, and on calm water or perpendicular to the direction of the swell.

Several accidents have shown flight crew cannot achieve the specified touchdown parameters in some situations. More specifically, if the aircraft has no engine power, particularly if the loss of engine power occurs soon after take-off, then it is very difficult for the flight crew to effectively manage the aircraft's descent rate.

The ditching of VH-NGA also illustrates that, when ditching in a dark night conditions, it is very difficult for a flight crew to achieve the required touchdown parameters. In addition to the increased difficulty of judging the flare, the inability to determine the direction of the main swell significantly increases the risk involved.

The extent to which this problem can be addressed is limited. Requiring aircraft to be designed to withstand more significant forces in a ditching would involve substantial expense, and potentially increased weight. Ditchings in air transport aircraft are very rare events, and ditching in dark night conditions in water with a sizeable swell are even rarer. Therefore, the cost-benefit considerations of substantially changing the design requirements may be unfavourable.

Nevertheless, ditching certification requirements have remained virtually unchanged since 1953. Recognising the limitations of these requirements for some situations, the international aviation community is currently in the process of reviewing the suitability of the ditching certification requirements (see *Safety issues and actions*). The ATSB strongly endorses any efforts to review these requirements.

Risk controls for the ditching manoeuvre

As already noted, the flight crew of VH-NGA did not refer to the aircraft manufacturer's emergency procedures checklist for ditching, and therefore the design of the checklist had no influence on the accident sequence. Nevertheless, the ATSB reviewed aspects of the 1124/1124A ditching checklist to ascertain whether it could be made clearer to minimise risk.

Although the checklists provided by some other aircraft manufacturers clearly specified the required airspeed and vertical descent rate, the Westwind 1124/1124A checklist was less explicit regarding the target outcome. Instead its required actions included setting the angle of attack (AoA) bug and the airspeed bug to V_{REF}, with the implicit requirement that the flight crew fly the aircraft according to those targets. It could be argued that a more explicit reference to the need to fly the approach at V_{REF} may have been more appropriate. However, it is also recognised that emergency procedures checklists need to be as brief as possible, and as relevant to the specific situation as possible. In this case, the manufacturer's checklist appeared to be suitable.

Another item on the checklist referred to disabling the landing gear warning horn. However, there was no similar action for inhibiting the EGPWS, even though the EGPWS equipment manufacturer recommended such a procedure. To assure appropriate performance in an emergency, flight crews need to be able to obtain all the key actions in a single, consolidated checklist rather than having to recall actions from multiple sources. In this case, it was a responsibility of the operator rather than the aircraft manufacturer to ensure the emergency procedures checklist in the aircraft was updated (see also *Introduction of new aircraft systems*).

As already noted, ditchings in air transport aircraft are very rare, and they are generally not practiced by flight crew, even in an airline environment. Although the operator’s flight crew would have discussed ditchings during their training and their proficiency checks, the ditching checklist is not a recall item. In other words, a flight crew was not expected to remember all the required actions without referring to the checklist. However, in some ditchings, such as soon after take-off, a flight crew will not be able to refer to the checklist.

The best means to address this situation are unclear. Some operators of aircraft that extensively conduct overwater operations have developed procedures to practice ditching manoeuvres in aircraft at a significant altitude above the water (Flight Safety Foundation 2003). The extent to which this is practicable for other operators is unclear. Alternatively, operators should ensure the conduct of ditchings are routinely covered during proficiency checks, and that training and proficiency checks emphasise the importance of key actions, such as maintaining the airspeed at V_{REF} prior to flaring the aircraft at the relevant height.

Emergency procedures and survival factors

Overview

Although the aircraft cabin rapidly filled with water, the six occupants were able to evacuate the aircraft and were subsequently rescued. However, they were only able to evacuate with three life jackets, even though there were six life jackets and two life rafts on board. A further concern is that, even though the ditching occurred only 6.4 km from the airport, search and rescue personnel had minimal information on the location of the ditching and it took 85 minutes to reach the evacuees.

Although the events following the impact sequence did not appear to increase the severity of the occupants’ physical injuries, there was a significant potential for loss of life if there had been further delays in reaching the occupants. In addition, the events following the ditching increased the evacuees’ level of distress.

There were several aspects that potentially affected the occupants’ safety in the event of a ditching. These are discussed under the following topics:

- cabin preparation prior to the flight
- cabin preparation for the ditching
- effectiveness of the life jackets
- identification of the accident site location.

Cabin preparation prior to the flight

Prior to departing Apia, the flight crew did not conduct a pre-flight safety briefing. The medical personnel had flown with the operator before, and were familiar with the briefings. However, the patient and the passenger had not flown with the operator before, and a safety briefing was essential.

Exactly why the flight crew did not conduct a safety briefing is unclear. The need to start an engine for the cabin air conditioning for the patient may have disrupted the crew’s normal sequence of events and the safety briefing was then inadvertently omitted. The doctor, who had not received formal emergency procedures training, took the initiative to provide the passenger with a limited briefing.

As far as could be determined, the safety briefings conducted by Westwind flight crew for overwater flights generally did not demonstrate how to don and use the life jackets on board the aircraft, and there was no demonstration equipment on board. There were safety briefing cards on board, but these did not provide sufficient detail regarding the model of life jackets on the aircraft and how to inflate the life jackets. The familiarisation training the operator provided to most of the medical personnel also did not demonstrate how to don and use the life jackets.

Although the occupants had flown on commercial aircraft before and been provided with demonstrations on how to use life jackets, these briefings were not necessarily relevant to the Westwind aircraft and the equipment on board the aircraft. Recent research by the US FAA has shown many passengers have difficulty opening and donning life jackets (Corbett and others 2014). In the ditching accident involving VH-NGA, the flight nurse initially had difficulty with donning her life jacket, and the nurse and the passenger had difficulty inflating their life jackets in the water. A demonstration of the life jacket's use prior to flight could have minimised these problems. Had the medical personnel been provided with practical training on using the life jackets, as is required for flight crew and cabin crew, this would have been even more effective.

Cabin preparation for the ditching

After the third approach, the first officer advised the occupants in the cabin they were going to ditch, and she instructed the doctor to conduct some key tasks to prepare the cabin. She did not have the capacity to provide the occupants with further briefings prior to the ditching approach due to her workload and the limited time available. However, she provided a brace call as the aircraft descended from 440 ft, which helped the seated occupants prepare for the impact.

A more fundamental problem was the lack of clarity regarding the responsibilities and duties of the flight crew and medical personnel in respect of evacuating a patient in an emergency. It is clear the medical personnel needed to be involved in evacuating a patient as they knew the patient's condition and how to use the stretcher and related equipment. They also needed to be able to respond promptly in an emergency to manage their own safety so they could then assist a patient. Therefore they needed practical training and experience in using the emergency equipment on board the aircraft. However, the operator did not provide medical personnel with formal emergency procedures or training for the task, and the aircraft familiarisation training the medical personnel received did not ensure they had adequate knowledge and skills.

In addition, there was no designated and well-understood location for a stretchered-patient's life jacket. In this case the medical personnel perceived the ditching was imminent and therefore they did not believe they had sufficient time to find and don a life jacket on the patient before the ditching. If they had been able to quickly locate the life jacket they could have fitted it to the patient, or at least taken it (or an alternate flotation device) with them to assist their ability to manage the post-evacuation phase.

Ultimately, in very difficult circumstances, the medical personnel did an excellent job evacuating the patient, and then assisting the patient and the injured first officer in the water. The medical personnel reported their previous helicopter underwater escape training (HUET) assisted them in their response to the situation. However, their task would have been made easier, with more assurance of success, if they had been provided with more relevant and practical procedures and training that was specific to their role in an emergency on the operator's air ambulance aircraft.

Obviously, if the evacuees had been able to use the life rafts, their survival time would have been greatly enhanced. Operators' procedures and training for a ditching are generally based on the assumption an aircraft will float for a period of time before the occupants evacuate. Therefore, it is expected there will be time available after an aircraft comes to rest to retrieve the life rafts, open the emergency exits above the water, secure the life rafts to the aircraft and then board the life rafts. However, this generic sequence is not always possible, as was illustrated in this case.

Prior to the ditching, the first officer asked the doctor to retrieve the life rafts from their storage, and the doctor placed them in the aisle so they would be ready to retrieve. Unfortunately, they were not able to be secured. The operator did not have formal or specific procedures about where to place life rafts and how to secure the rafts in an appropriate, readily-accessible location prior to a ditching. In addition, he doctor and other medical personnel had not been provided with any training for this task, and the available evidence indicates flight crew were also not provided with adequate training on this task. Although it may be difficult to achieve on a small transport aircraft, the life rafts should have had a secure storage location near the emergency exits, and the flight crew and medical personnel should have been trained on how to secure the life rafts prior to a ditching. If the life rafts were meant to remain in their initially stowed locations, this needed to be clearly communicated to the flight crew and medical personnel.

Effectiveness of the life jackets

Unfortunately the flight nurse's task of holding the patient in the water was made more difficult as only one of the two cells of her life jacket was inflated. The available evidence indicates the life jacket was technically able to be inflated, and if it was inflated it would have remained inflated for the period she was in the water. However, the nurse was dealing with very difficult circumstances, with a serious arm injury, and holding up the patient in water conditions that included a moderate swell. Life jackets are designed to be used by one person, and it is difficult to see how the design of the life jacket could practically be improved to overcome the difficulties the nurse encountered on this occasion.

It was reported one of the lights on the life jackets failed prior to the occupants being rescued. The lights are designed to operate for 8 hours, but in this case one failed within 85 minutes. It is likely the light failed because the water-activated battery had been exposed to moisture in the past. Exactly when or how the battery was exposed to moisture could not be determined. The extent to which the other two lights may not have been operating at the required level of intensity also could not be reliably determined. Ultimately, personnel on the search vessel sighted the lights from some distance, suggesting they were still operating at some level of effectiveness.

Although problems with some water-activated batteries have been identified over the years during routine inspections, the available evidence indicates there was not a significant reliability issue associated with the types of batteries used on the life jackets recovered from the aircraft.

A review of previous ditching accidents noted there have been few reported problems with the use and performance of life jackets following accidents (R.G.W. Cherry & Associates Limited 2015). However, the review noted there were more frequent and significant problems reported with retrieving and donning life jackets. The circumstances of this accident are similar, with the most fundamental problem being that only three of the six occupants were able to evacuate with a life jacket.

Identification of the accident site location

The effectiveness of a search and rescue is dependent on the extent to which the search and rescue personnel have accurate information on the location of the accident site. In this case, the search and rescue personnel had very little information, either from the flight crew or via an emergency locator transmitter (ELT).

After the third approach, the captain advised the Norfolk Island Unicom operator they intended to ditch the aircraft. Shortly after, the first officer advised the Unicom operator they would 'come around again' for another approach, but she did not indicate which runway the crew would be using. After the approach, at 1025:05, she advised they were proceeding with the ditching but she did not indicate where they were ditching and she did not declare a MAYDAY.

Although the Unicom operator realised the flight crew were in an emergency situation, the sequence of information and the nature of the transmissions provided to the Unicom operator at 1025:05 were not sufficient for him to realise the crew were actually proceeding with the ditching.

The crew's urgency and intentions may have become more apparent if the first officer stated where they were going to ditch and/or had used the term MAYDAY.

During this period, the first officer was experiencing very high level of workload, time pressure and stress. As discussed above, in such situations it is common for tasks to be prioritised and truncated, and unfortunately on this occasion this meant she did not broadcast some essential information.

In the event of an accident, ideally the aircraft's 406 MHz fixed emergency located transmitter (ELT) would activate and remain operational for sufficient time for the position of the ELT to be established. In this case, the ELT activated as designed but only transmitted a single alert signal. However, for this type of non-GNSS equipped beacon, the Cospas-Sarsat satellite system normally needed multiple alert signals over a period to fix a position, and the average time to fix a position was in the order of 90 minutes.

In summary, conventional ELTs were of limited effectiveness in the event of a ditching unless both the ELT and its aerial could remain above water for an extended period of time. Even if the flight crew had activated the fixed ELT prior to impacting the water, this situation would not have changed.[337]

One means of minimising this limitation was to equip the ELT so it transmitted a GNSS-derived position. However, such fitment was not a regulatory requirement, and the ability to equip the ELT model on VH-NGA had only recently become available. These limitations with ELTs and the processing of their signals for water-impact accidents is likely to be overcome with future developments in signal processing (see *Safety issues and actions*). Nevertheless, GNSS-equipped 406 MHz ELTs provide the fastest and most accurate position alerts, and should be fitted whenever it is practical to do so.

In addition to the fixed ELT, there were four portable and waterproof portable distress beacons on board the aircraft that would have assisted the search. Two of these beacons would have been available if the life rafts were deployed from the aircraft. However, because these beacons were not GNSS-equipped, it could have still taken about 90 minutes for a distress location to be calculated. However, one of the other beacons was GNSS-equipped and capable of transmitting the distress location. As with the life rafts, the occupants had not prepared to retrieve this beacon before the ditching, and were not able to retrieve it after the ditching. As is evident from this accident, preparations for a ditching should involve considerations of portable distress beacons as well as other emergency equipment, such as life jackets and life rafts.

Ultimately, it was fortuitous the first search vessel was able to proceed to the accident site as quickly as it did. The captain was able to shine a waterproof torch above the water, which was seen by a firefighter who, on his own initiative, happened to be in the right position to see the light. Had this chance event not occurred, it is likely that the search would have initially focussed on the area to the south east of the airport, based on the Unicom operator's understanding the last approach had been conducted to runway 11 rather than runway 29.

Crew resource management

Utilising a crew of two pilots should significantly reduce the risk associated with flight operations, provided that they have appropriate procedures and are effectively trained in multi-crew operations.

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[337] Although it would have had little influence on this occasion, manually activating an ELT before a forced landing or impact could be very beneficial in other situations. AMSA advise that if a pilot is attempting a forced landing, is having serious control difficulties, or becomes disorientated by flying into instrument or dangerous weather conditions, proactively activating an ELT could greatly increase the likelihood of the search and rescue coordination centre knowing the exact position of the aircraft.

As previously noted, there were some positive aspects in the way the flight crew conducted their tasks as a team, such as the non-flying pilot's support to the pilot flying during the approaches. However, there were several aspects of the flight where the benefit of having two crew was not fully realised. Examples included:

- The captain conducted the flight/fuel planning for the flight without any involvement from the first officer, and the first officer was not involved in reviewing fuel planning calculations or the suitability of the weather and other briefing information that was obtained.
- There was no evidence of a discussion between the crew regarding the PNR and diversion options, and the first officer was not involved in checking any PNR calculations.
- Prior to the first approach, the crew did not discuss approach options, or effectively discuss contingencies if they could not successfully land off the first approach.
- After the first approach, the crew did not effectively review their fuel situation and consider alternate emergency options prior to ditching the aircraft.
- When conducting the ditching, the crew did not refer to the ditching checklist or discuss how they would conduct the task, and they did not complete some of the key actions.

As already discussed, the minimal involvement of the first officer in flight planning and PNR considerations appeared to be relatively common practice across the operator's Westwind fleet, and it was at least partly associated with the absence of formal procedures for the first officer to be actively involved in these tasks. In addition, the crew were dealing with a very difficult set of circumstances towards the end of the flight, which increased the likelihood of error. Nevertheless, the difficulties the crew encountered may have been reduced or better managed if there had been more effective coordination and communication.

The flight crew reported they had a good working relationship, and neither indicated there were any barriers to them communicating effectively with each other. However, in this case a good working relationship was not sufficient to ensure effective teamwork on some important tasks.

The effective use of crew resource management (CRM) and/or threat and error management (TEM) will minimise risk in abnormal and emergency situations through identifying and discussing threats and hazards, ensuring both crew have the same understanding of the situation, involving both crew in key decisions and minimising workload. To ensure CRM will be effective, flight crew need appropriate training and guidance.

The aim of any flight crew training is to ensure pilots learn and transfer what they have learned into the cockpit environment. Although its effectiveness is difficult to evaluate, research has shown that CRM training can result in improved crew performance (Salas and others 2006a, Salas and others 2008, O'Connor and others 2008). The transfer of effective CRM skills is best achieved when trainees have been presented with information about the task, are given examples of both effective and ineffective performances, are given practice, and are provided with meaningful and timely feedback both during and after the task (Salas and others 2006b).

ICAO (1998) has also stated CRM training should include at least three stages:

> a) an awareness phase where CRM issues are defined and discussed;
>
> b) a practice and feedback phase where trainees gain experience with CRM techniques; and
>
> c) a continual reinforcement phase where CRM principles are addressed on a long term basis.

In addition, ICAO noted that relying on classroom instruction alone will probably not significantly alter pilot attitudes and behaviours in the long term.

The operator's CRM training was very basic in nature. It did not involve any classroom-based training, or the use of any detailed case studies. Although computer-based training (CBT) has practical advantages when dealing with relatively small numbers of pilots in many bases, it is not well suited to the subject matter of CRM or for practicing CRM (or TEM) skills.

Undoubtedly, aspects of CRM and TEM would have been taught to some extent during pilots' line training and evaluated to some extent during proficiency checks. However, this appeared to be done in an informal rather than structured manner. Therefore, it is difficult to evaluate the potential effectiveness of these activities.

Overall, it is difficult to know how any flight crew will respond under high levels of workload, time pressure and stress. It is also unclear whether more sophisticated CRM or TEM training would have led to different crew performance on this occasion. However, in general, a more sophisticated approach to providing CRM/TEM training, practice and performance feedback than that provided by the operator will lead to better safety outcomes.

Fatigue and fatigue management

Crew fatigue

ICAO (2011) defined fatigue as:

> A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties.

Fatigue can have a range of adverse influences on human performance (Battelle Memorial Institute 1998). These include:

- slowed reaction time
- decreased work efficiency
- reduced motivational drive
- increased variability in work performance
- more lapses or errors of omission.

Research has also shown fatigue can influence many aspects of decision-making, including increased inflexibility, over-reliance on previous strategies, unwillingness to try new strategies and inability to deal with unexpected events (Harrison and Horne 2000). In addition, fatigue has been reported to increase the level of acceptable risk an individual will tolerate (Battelle Memorial Institute 1998). However, the relationship between fatigue and crew performance in real-world settings is complex, and some research has also shown airline pilots make more conservative decisions when they are experiencing fatigue (Thomas and others 2006).

Sleep is vital for recovery from fatigue, with both the quantity and quality of sleep being important. It is generally agreed most people need at least 7–8 hours of sleep each day to achieve maximum levels of alertness and performance. Many of the reported symptoms of fatigue are only consistently demonstrated with significant levels of sleep deprivation. Nevertheless, a review of relevant research (Dawson and McCulloch 2005) concluded that obtaining less than 5 hours sleep in the previous 24 hours is inconsistent with a safe system of work.

Other research has indicated less than 6 hours sleep in the previous 24 hours can increase risk. Thomas and Ferguson (2010) found the occurrence of crew errors was higher, and performance at managing threats was poorer, during flights when a flight crew included a captain with less than 6 hours sleep or a first officer with less than 5 hours sleep. Road safety research has also shown that less than 6 hours sleep is associated with significantly more risk of an accident than 7–8 hours sleep (Williamson and others 2011).

Key aspects to consider when evaluating whether the captain was experiencing fatigue when planning or conducting the accident flight include:

- In terms of sleep during the previous 24 hours, he had about 3.5–4 hours sleep at Apia. Given this sleep occurred during the day, and was interrupted, it is likely to have been of lesser quality than normal.

- His sleep during previous days was reportedly normal, although his sleep the night before the outbound flight may have been slightly truncated by up to 1.5 hours due to personal factors. He reported he normally had a nap during an afternoon when on standby, although it is unclear whether he had a nap on the afternoon prior to the outbound flight. He also had a cockpit nap during the outbound flights the night before.
- The times of day of key interest were when the fuel planning was done from 0430 to 0530 UTC (or 1530 to 1630 local time for the captain) and when weather information was received and key decisions made from 0800 to 0930 UTC (or 1900 to 2030 local time). These times are generally not associated with significant performance decrements. The early afternoon period (about 1400–1600 local time) is known to be associated with a small performance decrement, at least for some people in some situations (Monk 2005). However, the effect of this 'post-lunch dip' is significantly less than the effects of the circadian low during the early morning period, and a delay in the previous sleep period can also reduce the effect (Bes and others 2009).
- Task-related factors and workload did not appear to be excessive during the flight prior to the descent, although maintaining a listening watch on HF radio had the potential to contribute somewhat to fatigue.
- The captain reported he did not feel fatigued. However, most people generally underestimate their level of fatigue (Battelle Memorial Institute 1998).

Overall, primarily due to restricted sleep in the previous 24 hours, it is likely the captain was experiencing a level of fatigue likely to have a demonstrated effect on performance. However, there was insufficient evidence to conclude he was experiencing a significant level of fatigue.

The first officer reported the amount and quality of sleep she had during the day in Apia was better than the captain's, and that the amount of sleep was also close to what she normally had each night. There were three yawns recorded on the CVR, but yawning is not solely linked to fatigue or sleepiness. Yawning is also associated with boredom, and is more frequent in the period soon after wakening as well as in the period before a person normally goes to sleep (Provine 2005, Zilli and others 2008). Overall, it is likely the first officer had a lower level of fatigue than the captain.

Determining whether the existence of a mild to moderate level of fatigue could have contributed to specific errors or actions is a difficult process.[338] Certainly plan continuation errors can be consistent with the effects of fatigue. However, there were contextual factors, particularly the captain's expectancies regarding the weather conditions, that can also explain such errors. In other words, although fatigue could have contributed to or increased the likelihood of some of the captain's errors before and during the flight, such errors can also occur without fatigue. Therefore, it is difficult to conclude that fatigue contributed to the captain's actions on this occasion.

As already noted, the flight crew experienced significant workload, time pressure and stress during the latter stage of the flight, which influenced their ability to assess and discuss their situation, make effective decisions and conduct the approaches. It is also possible that fatigue adversely influenced the crew's performance during the latter stage of the flight. However, the assessment of the influence of fatigue during this period is complicated by the crew's elevated arousal level.

The accident occurred during the first flight of three flights scheduled for the flight crew following their rest period in Apia. Had the duty period proceeded as planned, ATSB analysis showed it was likely both of the flight crew would have been experiencing a significant level of fatigue towards the end of the duty period. Accordingly, the suitability of the rest period and the operator's fatigue management processes were examined.

[338] For example, the CASA (2014) guidance document on BMMF, developed by Dédale Asia Pacific, stated '...it is extremely difficult to prove that a safety occurrence was contributed to by fatigue. While the potential for fatigue and its effects to be present can be noted, a causal relationship is extremely difficult to establish… Isolating fatigue from the numerous other factors that may have contributed to an event, then proving its contribution may not be possible.'

Opportunity for rest

An operator's processes for rostering flight crew needs to ensure they have sufficient opportunity to rest at suitable accommodation between duty periods. The operator's procedures required a minimum break between duty periods of 10 hours, unless mutually agreed between the operator and the crew. A minimum period of 10 hours time off duty was also consistent with the regulatory requirements at the time that applied to Australian air transport operators which were not using an FRMS. A period of 10 hours generally allows for at least 8 hours sleep opportunity.

In this case, the flight crew's time off duty was initially expected to be less than 8 hours. It was extended to about 8 hours only after the crew experienced a delay getting access to rooms at the hotel in Apia. Ultimately, the crew did not have 8 hours sleep opportunity, which was not consistent with good fatigue management practice.

The effectiveness of a time off duty period depends on when it occurs, with periods during normal sleeping hours being the most beneficial. The benefits of increasing the length of a time-off-duty period during the day will not necessarily result in a significant amount of additional sleep for many people. This was indicated in the results of the fatigue modelling on this occasion. However, to maximise the opportunity for rest and cater for individual differences in sleeping patterns, the time-off-duty period should allow for 8 hours sleep opportunity.

Although most people will not be able to sleep as effectively during the day as during their normal sleep periods at night, flight crew have a responsibility to use their rest periods as effectively as possible. In this case, the captain's restricted sleep was partially due to personal phone calls.

In summary, the flight crew should have been provided with a longer time off duty in Apia to enable them to have more sleep opportunity. The extent to which more sleep opportunity would have resulted in more sleep on this occasion is unclear.

The available evidence indicates a time-off-duty period of less than 10 hours was relatively rare for the operator's flight crews under normal circumstances since the operator upgraded its fatigue management processes in 2007. On this occasion it was unclear whether the shorter time-off-duty period was initiated by the air ambulance provider, the Westwind operations manager or the flight crew, or it was associated with some misunderstanding between different parties regarding the meaning of time on the ground, time off duty and the rest period at suitable accommodation.

Regardless of the reasons for restricted sleep, a sound FRMS needs to have processes in place to identify when inadequate sleep has occurred and manage the associated risk. This did not occur on this occasion, and is likely not to have occurred on some other occasions as well.

Other aspects of the operator's fatigue risk management system

A key area of concern regarding the operator's FRMS was that the operator's processes for rostering flight crew, and assessing their level of fatigue when rostering, heavily relied on a bio-mathematical model of fatigue (BMMF). Furthermore, the BMMF it used, FAID (Fatigue Audit InterDyne), was unsuited to the operator's ad hoc air ambulance operations. In particular, FAID underestimated the level of fatigue if there had been minimal duty time in the previous 7 days and then there was one or two long duty periods, particularly if these duty periods happened overnight.

Since 2009, there has been significantly more guidance material produced regarding general principles for using BMMFs as part of an FRMS (for example, CASA 2010, CASA 2014). However, the problem of over-reliance on FAID had been identified by both CASA and the operator since 2004. Although improvements were made to the operator's processes to upgrade their fatigue management system (FMS) to an FRMS, this underlying problem was not effectively addressed. FAID was still being used as the primary means of determining whether a Westwind flight crew member could be assigned a new task.

To use a BMMF, an operator needs to understand the assumptions and limitations associated with the model it is using. In this case, the operator's personnel involved in rostering and safety management at the time of the accident had a very limited understanding of FAID's assumptions and limitations. None of the operator's personnel had received advanced training in using FAID, and the operator had not discussed its unique rostering requirements with the BMMF provider or a fatigue management specialist since it started operations with an FMS in 2002. Since that time, the nature of the Westwind fleet's operations had significantly changed.

In addition to the over-reliance on FAID, the operator's FRMS had other limitations. For example, some of the Westwind flight crew were allocated 24-hour standby for long periods, sometimes weeks at a time. Although some of these pilots reported this had limited impact on their sleep and stress levels, others reported it did have an impact.

There has been limited research that has examined the effect of standby or on-call work on people's sleep, stress and health in situations where they did not get called into work. However, the available research shows standby does impact sleep quantity and quality, stress and health (Hall and others 2017, Nicol and Botterill 2004).

A review of the initial introduction of fatigue management systems by Australian operators (McCulloch and others 2003) noted there was a wide variety of opinions within industry regarding standby, although many operators argued it should not be considered as duty time or contribute to a FAID score. The review noted a variety of factors could influence the effect of standby, such as whether it was done from home or at work, time required to respond and likelihood of being called out on a task. It concluded:

> While standby at home conditions, and to some degree standby at work conditions, are less fatiguing than actual work, they are undoubtedly more fatiguing than actual time off. That is, under standby conditions, an individual is unlikely to accrue the same level and quality of rest as when they are on a break period from work...
>
> As reported in the results, the lower quality of rest associated with standby conditions was evident in some of the interviewees responses. However, many individuals perceived that standby rostering has no effect on fatigue. This was particularly so for those who had worked standby rosters for a significant period of time. That is, interviewees perceived that while at first standby rostering reduced the quality of rest time, it became easier as they developed time management strategies.

The review also recommended CASA should clearly define standby rostering and what it meant for specific operations. As far as could be determined, CASA did not formally respond to the recommendations in the review, and it did not develop a formal position regarding standby within an FRMS.

Maintaining 24-hour operational readiness at four bases with a relatively-small number of pilots obviously has logistical difficulties. However, to manage the potential difficulties associated with extended periods of 24-hour standby, the operator could have developed alternative arrangements that allowed pilots at its remote bases (Perth and Cairns) to have more regular periods of time free of duty.

In addition to the over-reliance on FAID and the management of standby, the operator needed to more actively obtain information about pilots' alertness levels prior to allocating a task, particularly in situations where pilots had been on long periods of standby, flight times coincided with normal sleep times, and/or pilots were conducting trips that involved disrupted sleep patterns. Relying on pilots to proactively report problems with sleep or alertness is only likely to be effective if the operator has a mature and well-functioning reporting culture.

Another limitation of the operator's FRMS was it heavily relied on fatigue occurrences being reported before rostering processes and related factors were examined. Although this process had identified problems and resulted in positive changes, it was reactive and limited. Fatigue occurrences were generally only being reported if requested by the operator when a pilot's FAID score exceeded the threshold, and therefore many relevant situations were not being examined. In addition, there had been no proactive examination of rostering patterns or surveys of flight crew since the FMS was first designed and implemented in 2001–2002.

Ultimately, the operator's Westwind pilots did not conduct a significant amount of duty time overall, and the duty periods associated with many of their trips were not problematic. Nevertheless, the length and timing of the duty periods associated with some of their trips were likely to result in significant levels of fatigue, and this fatigue was not being effectively identified, assessed and managed. Overall, the operator did not have sufficient risk controls in place in addition to FAID to manage the duration and timing of duty, rest and standby periods.

Guidance material associated with the use of BMMF

All BMMFs are based on many assumptions and all have a number of limitations. As indicated above, the users of such models need to have the appropriate skills and knowledge to be able to use a model effectively.

Nevertheless, BMMF providers also need to clearly communicate potential problems users may encounter and outline how to address these problems. As discussed above, the FAID model was not well-suited to the operator's air ambulance operations, which often involved few duty periods in the previous 7 days before assigning a crew a new task. As far as could be determined, this limitation was not clearly described in any publicly available guidance material associated with the model.

The ATSB understands it is unrealistic for a BMMF provider to provide guidance material on all potential problems users may encounter, and that users should ensure they have the appropriate knowledge and skills before applying a model, or seek specialist advice. However, in this case the model limitation could potentially apply to a wide range of transport organisations, and guidance information about the problem and how to manage it would be beneficial.

Fatigue management of the medical personnel

The air ambulance provider reported the general assumption for air ambulance flights was that the medical personnel would get similar rest periods as the flight crew during trips when there was a rest period required during the trip. In addition, they had more opportunity to rest during flights.

However, in this case, the medical personnel obtained virtually no rest during the time on the ground in Apia, due to the unusual circumstance associated with visiting the patient at her home and then transporting the patient to the hotel. Although the medical personnel obtained some sleep on the outbound flights, and may have obtained some sleep on the return flights, it is likely both of them would have been experiencing a moderate level of fatigue toward the end of the accident flight.

Medical personnel fatigue is obviously a potential concern for the delivery of medical care. However, during air ambulance flights, it is also a potential aviation safety issue if the personnel have a role to play during aviation activities. As discussed above, they did have an important role to play in aviation emergencies, although this was not clearly defined.

Equipment installation and aircraft maintenance

Introduction of new aircraft systems

VH-NGA was the operator's only Westwind aircraft fitted with an EGPWS and/or a traffic alert and collision avoidance system (TCAS). These systems were fitted in August 2009, but flight crew who operated the aircraft after this time were not provided with any formal training in the use of the equipment. In addition to not providing EGPWS training, the emergency procedures were not updated to incorporate relevant changes.

The effective use of the EGPWS was important for managing the circumstances associated with the approaches, particularly in terms of using the terrain alerting and display function, and also understanding the different alerts. In addition, it was important for conducting the ditching, in terms of using the inhibiting function to minimise unnecessary, distracting alerts and ensuring the system provided altitude callouts.

Although the crew had not received formal training from the operator, the operator had provided procedures in its OM, the manufacturer's manual was included in the Airplane Flight Manual on the aircraft and the captain also appeared to understand how to use the system. Nevertheless, it was essential for the operator to provide relevant training on new, complex, safety-critical aircraft systems for relevant flight crew.

The exact reasons why the need for training was not identified were unclear. However, as of August 2009, the operator did not have any formal change management procedures specified in its OM or its safety management system (SMS) manual. According to its SMS implementation plan, approved by CASA, it was intending to introduce change management requirements in February 2011.

Maintenance of the fuel quantity indicating system

The aircraft manufacturer's maintenance procedures clearly stated a dry calibration was the preferred method for calibrating the fuel quantity indicating system. A dry calibration involved emptying the aircraft's fuel tanks, and calibrating the 0 lb indication on the fuel quantity gauges with the actual capacitance value of the tanks when no fuel was present. In contrast a wet calibration or an indicator test involved using a simulated rather than an actual value when calibrating the 0 lb reading. Accordingly, a dry calibration would generally provide more accurate fuel gauge readings, particularly as the amount of fuel on board decreased towards 0 lb.

The last known dry calibration of the fuel quantity indicating system occurred in August 2009, after the fuselage fuel tanks were replaced. Following a pilot's report of erratic fuel quantity gauge readings on 11 September 2009, the operator's maintenance personnel checked the aircraft's fuel quantity indicating system. They identified there was a problem with a capacitance probe, replaced the probe and conducted a 'wet' calibration of the gauges.

The operator advised the ATSB that conducting only a wet calibration following the 11 September pilot report was reasonable, given maintenance had identified the indication problem was associated with a hard fault of a capacitance probe. Nevertheless, conducting a dry calibration would have provided more assurance the fuel gauges were effectively calibrated after one of the probes was replaced. The ATSB's review of flight records found that following the maintenance activity, the aircraft's fuel gauge were underreading by about 330 lb, and the amount of underreading did not decrease as the amount of fuel on board decreased.

Another pilot subsequently reported the fuel gauges were underreading on 9 October 2009, and maintenance personnel checked the system and recorded they conducted an indicator test (which is similar to a wet calibration). Although not stated in the maintenance records, it is possible a dry calibration was also conducted. However, the ATSB's review of the aircraft's flight records indicated the fuel gauges were not effectively calibrated. As already noted, the fuel quantity gauges were still underreading by about 260 lb. In addition, the amount of underreading did not decrease as the amount of fuel on board decreased, which was inconsistent with what would be expected if an effective dry calibration had been conducted.

In summary, based on the available evidence, a 'dry' calibration of the fuel quantity indicating system was probably not conducted following the 9 October pilot report. Had a dry calibration been conducted, it is likely the fuel quantity gauges would have been more accurate on subsequent flights, particularly as the amount of fuel on board decreased.

The reason why a dry calibration was not conducted during the October 2009 maintenance was not able to be determined. The aircraft manufacturer's procedures clearly stated a dry calibration was the preferred procedure and a wet calibration should only be considered a temporary measure. Certainly a dry calibration, which involves draining the fuel tanks, is a more time consuming procedure. Although there were several days between when the fuel quantity system maintenance was conducted and when the aircraft was returned to service, the extent of the maintenance personnel's other activities during this period is unknown.

The maintenance of the fuel quantity indicating system depended on pilot reports of observed problems. The operator's OM required that flight crews report events where the difference between the actual and expected fuel quantity gauge readings exceeded 3 per cent. This probably applied to several of the flights after 9 October 2009. It is possible any discrepancies noted by pilots were attributed to factors such as variations in the specific gravity of the fuel or calculation rounding errors. The fact that flight crews almost always refuelled to a known capacity, and almost always carried a substantial amount of discretionary fuel, may also have reduced any perceived risk associated with problematic fuel gauge indications.

Overall, the operator's other Westwind aircraft did not appear to have similar problems with fuel quantity gauges, indicating there was not a systemic issue associated with the design of the fuel quantity indicating system, the maintenance task or maintenance practices.

Maintenance of the fuel flow indicating system

As previously noted, the fuel flow indicating system was probably also underreading, although the exact amount of underreading could not be determined.

The maintenance of the fuel flow indicating system also depended on pilot reports of observed problems. However, the last calibration was conducted in April 2007, and the ATSB identified no indication of reported problems in maintenance records reviewed during the 14 month prior to the accident. It would be reasonable to expect that at some stage during this period a flight crew had compared the indicated fuel flows with the manufacturer's predicted fuel flows in the 1124A Operational Planning Manual, or compared their predicted fuel burn over a given time period with their actual fuel burn (based on a difference in fuel gauge readings). Why such comparisons did not detect a problem are unclear. It is possible flight crews were often not at the same altitude with a stable thrust setting for significant periods. Alternatively, even if a problem was noted, it may have been attributed to a range of factors other than a fuel flow indication problem.

The reasons why the fuel flow gauges were underreading is also unclear. The operator's other Westwind aircraft did not appear to have similar problems, indicating there was not a systemic issue associated with the design of the fuel flow system, the maintenance task or maintenance practices.

Safety management and management oversight

Overview

As noted in previous sections, there were a number of limitations with the operator's risk controls for air ambulance flight operations across several areas. These including fuel planning, in-flight fuel management, flight crew training and proficiency checking, emergency procedures and fatigue management. Accordingly, the investigation examined the overall nature of potential reasons why these problems existed and had not been addressed.

Many of the problems involved the absence of suitable risk controls (such as specific fuel planning requirements for remote islands or isolated aerodromes, formalised training for planning flights to remote islands or international operations, procedures to cross-check fuel planning calculations or PNR calculations, and procedures for ensuring a life raft was in an appropriate location prior to ditching).

However, there were also other types of problems:

- risk controls specified in the OM that were not routinely used (for example, calculating PNRs and CPs before flight, assessing a pilot's ability to conduct flight/fuel planning during proficiency checks)
- risk controls that were present but generally not adequate for the purpose (for example, pre-flight safety briefings and the safety briefing card's description of how to use a life jacket)

- risk controls that were not formalised or documented and therefore potentially not consistently applied (for example, always departing with full fuel for certain types of flights, use of a how-goes-it chart to monitor PNRs during flight).

Overall, the risk controls were not adequate to assure that air ambulance operations would be consistently conducted to an appropriate standard. In most cases, the risk control problems appeared to have existed for a significant period of time. However, they had the potential to become more prevalent as pilot turnover increased.

A range of different factors may have contributed to one or more of the risk control problems. Three key areas that warrant discussion include:

- hazard identification processes
- risk assessment processes and responding to identified problems
- roles and responsibilities of key management personnel.

Hazard identification processes

The operator had a safety management system (SMS) in some form for several years prior to it being formally mandated in regulatory requirements for Australian RPT operators in 2009. Although ideally an SMS will allow an operator to identify and address hazards in its operations, the effectiveness of these processes can be affected by many factors.

The operator's processes to identify hazards in its flight operations relied heavily on flight crew submitting incident, hazard and fatigue occurrence reports. If a report was submitted, it could then be assessed and considered by personnel other than those involved in the relevant fleet's operations. However, the reporting culture within the operator was such that flight crew were generally only submitting reports when requested or for incidents that external parties had already reported. There were minimal voluntary or discretionary reports submitted. Although the available evidence indicates this situation was improving in the operator's other fleets during 2009, this did not appear to be the case in the Westwind fleet.

The effectiveness of incident reporting is also limited by the size of the operation (or number of flights) and the types of incidents that occur. In this case, there were few precursor incidents that could have triggered a detailed review of the operator's existing risk controls relating to problems identified during the investigation. For example, the two previous flights from Apia to Norfolk Island conducted by the captain (September 2009) and the Westwind standards manager (October 2009) were notable in that they both landed at Norfolk Island with insufficient fuel to divert to another aerodrome. However, both flights departed with full fuel, and the reported and actual weather conditions in both cases were not of significant concern. The operator would have reason to assume that, based on these and the operator's other flights, Westwind pilots were adopting a conservative approach to fuel planning and taking full fuel for long-distance flights to remote islands or isolated aerodromes.

Effective hazard identification requires the use of a range of activities in addition to incident and hazard reporting. Although the operator also had some proactive processes for identifying hazards, these had limitations. More specifically:

- Internal audits were limited in scope and number. Although these audits had identified some problems with the currency of training records and the operation of the FRMS, none of the audits had focussed on issues such as fuel planning, fuel management or the content of proficiency checks.
- External audits were limited in scope. An operator could potentially take some comfort that external reviews of its operations were conducted and that these reviews found minimal problems. However, in this case, the external audits were general in nature and did not examine in detail the types of risk controls relevant to long-distance, overwater air ambulance operations.
- There was minimal monitoring of the conduct of line operations. The Westwind standards manager provided support to flight crews for some tasks, including developing flight plans.

However, proficiency checks were not being conducted on normal line flights, and check pilots and supervisory pilots rarely flew with line captains after they were cleared for line operations. In addition, there appeared to have been minimal review of flight records and documentation after flights, and there was no independent monitoring of flights, either in terms of ramp checks or observational flights.

- There had been no structured surveys of flight crews since a survey relating to fatigue management in 2002, conducted at CASA's request. The operator had conducted a detailed review of the operator's flight crew training and checking activities in early 2008, following the issue of a CASA safety alert. However, the specific risk controls examined in the review were limited to the delivery of training courses and the maintenance of appropriate flight crew records.

The primary task of the Westwind fleet was traditionally night freight operations. It commenced air ambulance operations with the air ambulance provider in 2002, and the extent of these operations significantly increased from 2007 to 2009, and by 2009 it was the main activity undertaken by the Westwind fleet. During 2007–2009, the number of bases routinely conducting air ambulance operations increased from one to four, and there was a significant turnover of flight crew, particularly with the captains based in Sydney.

Despite these changes, the operator's formally-defined risk controls, particularly for training and checking, still appeared to be better suited to routine freight operations. There also appeared to be a significant reliance on the informal transfer of essential knowledge to flight crew regarding international operations and operations to remote islands, and an assumption flight crew would acquire the knowledge and skills appropriate for their tasks.

Given the expansion of the operator's air ambulance operations, and the inherent nature of international ad hoc air ambulance operations, there was a need for the operator to closely monitor and review the conduct of operations to assure itself they were being conducted to an appropriate standard, and that the implemented risk controls were suited to the nature of the tasks being conducted. As indicated above, the processes used to identify hazards and monitor operations were not adequate to achieve this purpose.

Safety management is an evolving discipline, and it is undoubtedly difficult for a relatively small air transport operator to conduct hazard identification activities to the standard expected of major airline operators. There were indications the operator was taking positive steps to improve its hazard identification processes during 2009. However, these efforts had limited effect on the Westwind fleet's operations up until the time of the accident.

In summary, the operator's processes for identifying hazards extensively relied on hazard and incident reporting, and it did not have adequate proactive and predictive processes in place. In addition, although the operator commenced air ambulance operations in 2002, and the extent of these operations had significantly increased since 2007, the operator had not conducted a formal or structured review of its risk controls for these operations. Overall, had the operator adopted more thorough proactive and predictive hazard identification processes, it is likely at least some of the inadequate risk controls associated with its air ambulance operations would have been identified, particularly in terms of flight/fuel planning and in-flight fuel management.

Risk assessment processes and responding to identified problems

Although the operator's Westwind pilots did not appear to formally report hazards, they did report some concerns to management. The most commonly reported concern was associated with extended periods of 24-hour standby. It appears the operator responded to this concern in 2002 and stated its intention to abolish the practice, however this position was reversed at a later stage. The problem became much more significant with the introduction of the Perth base in 2008 and the Cairns base in 2009, and the requirement for pilots at these bases to be on 24-hour standby for weeks at a time.

Although pilots reported concerns with this practice, including one pilot raising the matter with CASA, the operator did not appear to adequately assess and recognise the risk of this practice.

This may have been associated with an assumption the risk would be offset by the minimal amount of actual duty time conducted by these flight crew, and the limited research available about standby at that time. It may also have been reinforced as an acceptable practice following a meeting with CASA in March 2009 regarding a pilot's concerns with being rostered on 3 weeks standby, although the exact nature of what was discussed in that meeting was not able to be determined.

Another common pilot concern reported to management was the suitability of the flight planning software tools that were provided at the bases. It appears there were limitations with the suitability of the version that was provided to flight crew, however the exact nature of the problem and whether it was ever addressed was difficult to determine. Regardless of the suitability of the software tool, the more fundamental problem was that the lack of suitable policies and procedures for fuel planning was not identified or recognised.

After CASA issued the safety alert in March 2008 regarding the lack of FRMS training, the operator conducted an investigation into issues relating to the operator's flight crew training and checking. This review was detailed and systemic in nature, and it led to some significant changes in the operator's management of flight operations, including the appointment of a new chief pilot.

In addition to that review, the available evidence indicates that in 2009, if incidents or hazards were identified, they were being assessed and closely monitored by the operator's safety management group (SMG). The SMG also appeared to be functioning with a high level of involvement and support of key management personnel such as the chief pilot. Prior to this time there appeared to have been had been difficulties with resourcing and commitment issues with the functioning of the SMS.

In summary, there were some cases where problems had been raised or identified by management and these problems did not appear to have been adequately addressed. However, it also appeared the operator had made significant changes to its management personnel and the conduct of safety management activities in the 12 months prior to the accident, and the process of responding to reported incidents and hazards was being more effectively managed. As noted in the previous section, the more fundamental issue with the operator's safety management was the limited nature of its processes for identifying hazards.

Roles of key management personnel

After the new chief pilot was appointed in November 2008, the previous chief pilot became the Westwind standards manager. He was also the general manager for air ambulance and charter operations.

To ensure operations are effectively managed, it is important the roles and responsibilities of management personnel are clearly defined. In this case there was a significant potential for confusion as the roles and responsibilities of the positions of standard manager and general manager were not defined.

As indicated by the title, a standards manager should have an important role in monitoring, maintaining and managing operational and safety standards amongst the relevant fleet. However, if it is not clearly defined, there can be ambiguity and confusion between the duties and responsibilities of that position and other related positions, such as the chief pilot or head of training and checking (HOTC).

In this case, the potential significance of this problem was increased by other contextual factors:

- The chief pilot (and HOTC) had limited knowledge of the Westwind fleet and its operations, and therefore his ability to monitor operational and safety standards for the fleet without significant support from the standards manager or other experienced Westwind pilots was limited.
- The standards manager's general manager position involved a significant commercial role, creating a potential conflict between commercial and safety perspectives when making decisions.

- The standards manager had initiated and developed the operator's air ambulance operation over the previous 8 years, and therefore potentially had a strong personal sense of ownership and attachment to the operation and the way it was conducted. Although the ongoing involvement of a manager with significant experience of the operation was obviously beneficial, there was also the potential for a lack of objectivity when evaluating the effectiveness of the existing risk controls.
- The general manager role was at the same level in the organisational structure as the chief pilot role, creating potential confusion regarding the relative authority of the different roles and personnel.
- Both the chief pilot and the Westwind standards manager had high workloads.

In summary, the lack of clear definitions of roles and responsibilities had a significant potential to influence the extent to which operational and safety standards were being monitored, maintained and managed within the Westwind fleet after the new chief pilot commenced in November 2008.

However, the extent to which the lack of formal position descriptions led to a reduction in management oversight of the Westwind fleet is unclear. Although the standards manager reported he had less involvement in some activities after April 2009, he was still heavily involved in conducting and supporting day-to-day operations and interacting with the Westwind fleet's pilots. As far as could be determined, other than conducting less training and checking activities, his role in the operation was similar to what it was before April 2009.

Regulatory oversight

Overview

An operator with an Air Operator's Certificate (AOC) had a clearly defined responsibility under the *Civil Aviation Act 1988* to ensure the safety of its operations. The regulator, CASA, also had defined responsibilities for oversighting the activities of the operator, through the processes of approving AOC variations and other permissions, as well as conducting surveillance of the operator's activities.

AOC approval and surveillance processes will always have constraints in their ability to detect problems. In particular, there is restricted time and limited resources available for these activities. Regulatory surveillance is therefore a sampling exercise, and cannot examine every aspect of an operator's activities, nor identify all the limitations associated with these activities. Even when surveillance is conducted on some system elements, problems may subsequently develop as the nature and size of operators change over time.

In addition, to a large extent AOC approval and surveillance processes have to focus on regulatory requirements, which provide a minimum standard of safety, rather than safety management processes or other aspects that exceed these minimum standards. If regulatory requirements are not explicit, it will often be more difficult for inspectors to facilitate improvements.

Following the 18 November 2009 accident involving VH-NGA, CASA conducted a special audit of the operator and identified a significant number of problems, most of which had not been identified in previous surveillance. This was due to many factors, including:

- CASA conducted the special audit with substantially more resources over a longer period of time than previous audits of the operator (and other similar operators). Latent problems are present in all organisations (Reason 1997), and if more effort is used to look for them, then it is very likely more will be found.
- The scope of the special audit was largely determined by the circumstances of the accident, which resulted in CASA examining some system elements it had not examined in previous audits (most notably flight/fuel planning and in-flight fuel management).
- The audit involved interviewing a significant number of line pilots, which gave CASA access to a type of information it did not normally obtain during surveillance.

Given that CASA simply does not have the resources to conduct audits of this depth on a regular basis, the ATSB examined aspects of CASA's normal oversight processes which could have increased its ability to have detected the problems earlier. These aspects included:

- processes for approving changes to an operator's activities
- processes for determining surveillance priorities
- processes for scoping audits
- processes for conducting audits.

Processes for approving changes to an operator's activities

In terms of AOC approval processes, the operator had been approved to conduct international charter flights and RPT freight flights in Westwind aircraft for many years. Given these approvals occurred a long time prior to the accident, the ATSB investigation did not review them.

Nevertheless, the ATSB identified CASA had some opportunities to review the operator's procedures in areas such as flight/fuel planning and in-flight fuel management during subsequent approval activities. These activities included the rewrite of the operator's operations manual (OM) in late 2001, the addition of air ambulance operations to the operator's AOC in early 2002 and the merger of the operator's two AOCs in 2006. However, in each case it appears flight/fuel planning and in-flight fuel management procedures, which were particularly relevant to the Westwind fleet's operations, were not reviewed in detail.

In the 2006 case the limited consideration of fuel management aspects for the Westwind fleet was because the procedures had already been approved and the approval process only focussed on areas where there were changes. It is likely that a similar situation occurred on the two previous occasions. In addition, it is likely that, when the addition of air ambulance operations to the AOC was approved in February 2002, the fact the operator was already approved to do international passenger-carrying charter operations was a key consideration, particularly given passenger charter operations had a higher level of classification than air ambulance operations. It is also possible that resource considerations played a part in limiting the scope of CASA's assessments.

It is difficult to determine whether CASA would have detected any significant problems if it had conducted a more detailed review on any of these occasions. As already noted, the requirements for Australian remote islands only applied to passenger-carrying charter flights, and the operator rarely conducted these types of flights to such destinations. Therefore, requiring the operator to include remote island procedures in its OM may have only resulted in it including them for charter flights. At the time the addition of air ambulance operations was approved, CASA also did not appear to have much indication as to the range of destinations likely to be used by the operator in the future (other than Noumea).

In terms of other approval activities, CASA reviewed the operator's FMS manual in 2002 and its FRMS manual during 2005–2007. Its assessment of the operator's manuals was based on the knowledge it had at the time, involved the use of specialists and appeared to involve a significant amount of effort. Prior to each re-approval of the operator's exemption from CAO 48 (and approval to use its FMS or FRMS), CASA undertook some form of surveillance or review activity. Nevertheless, as discussed in *Fatigue and fatigue management*, there were still weaknesses with some aspects of the FRMS and the way it was being applied that CASA had not identified or anticipated, some of which may not have been apparent when the FRMS was finally approved (June 2007) or was last audited (October 2007). The March 2009 meeting, following a Westwind pilot's complaint, was an opportunity to examine aspects such as standby and the operator's processes for reviewing its FRMS. The evidence indicates CASA discussed such matters with the operator, but it did not identify any significant problems at that stage.

Up until the time of the accident, the operator was not required to have an SMS formally approved by CASA. The operator had RPT (freight) operations on its AOC, and therefore it was required to have submitted to CASA an implementation plan by July 2009 and an SMS manual (covering many but not all elements of an SMS) by February 2010. The operator submitted the documents as required, and CASA approved them. However, given the approval of the operator's SMS manual occurred after the accident, CASA's assessment processes for such manuals were not considered as part of this ATSB investigation. Further discussion about these assessment processes is provided in the audit by the Australian National Audit Office (ANAO) in 2010 (see *Audit of CASA's implementation of safety management systems (2010)*).

In summary, CASA's approval processes had not identified all the problems in the operator's manuals or systems that were subsequently identified by its special audit. There were some missed opportunities to conduct more detailed reviews, particularly in regard to flight/fuel planning and in-flight fuel management. Because these opportunities were not taken (and not required to be taken), CASA was relying on its subsequent surveillance processes to detect any problems.

Processes for determining surveillance priorities

Overall, CASA conducted audits of the operator more frequently than its stated requirement, which since 2005 was one scheduled audit every 3 years. The frequency of its other surveillance activities were broadly consistent with its published requirements, which included a safety trend indicator (STI) every 6 months, a small number of observations of proficiency checks, and in-flight surveillance and ramp checks done on an opportunity basis only. It could have conducted additional surveillance if it identified a need to do so, but it had not identified any such need until the accident occurred.

CASA considered a range of different types of information when evaluating surveillance priorities and deciding whether additional surveillance of an operator was warranted. However, there appeared to be at least two limitations with its process of doing these evaluations. Firstly, although CASA routinely obtained and received many different types of information about an operator, it was stored in a range of formats and in many different databases and locations. This lack of integration increased the difficulty for CASA personnel making decisions about surveillance priorities.

This type of problem has also been noted in other aviation regulators. For example, the Auditor General of Canada stated in 2008:[339]

> Transport Canada has several databases and systems that contain information related to aviation safety. However, these databases and systems do not provide an integrated view of the safety profile of an aviation company or industry sector. While data can be pulled together to create such a profile, several sources must be consulted. Integrated profiles would help in determining which companies should receive closer oversight. Without easily accessible safety profiles, inspectors need to rely on several sources of data as well as their own experience.

Secondly, to be most effective, the process of determining surveillance priorities required CASA to have a good understanding of the nature and extent of each operator's activities. In this case it was apparent CASA personnel were aware the operator's Westwind fleet were conducting international air ambulance operations (and international charter operations), but they had a very limited understanding of the extent of these operations. In particular, CASA was not aware of the extent that the operator was conducting flights to Australian remote islands and other remote aerodromes, and that by 2009 air ambulance operations were being conducted out of four bases and formed the majority of the Westwind fleet's operations.

There was no requirement for charter and aerial work operators to advise CASA of expansions or changes in their operations that were consistent with their OM and the conditions of their AOC.[340] Accordingly, CASA needed to ensure it had effective processes in place to gather relevant information about an operator's activities. However, none of the information it routinely collected

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[339] Report of the Auditor General of Canada to the House of Commons, Chapter 3: Oversight of air transportation safety-Transport Canada, May 2008.

[340] There was also no indication in this case that the operator withheld any information from CASA, or did not provide information about its operations that CASA requested.

about an operator included data on the frequency of operations of different types, and the frequency of operations to different destinations or on different routes.

To help improve its ability to assess surveillance priorities, CASA had developed the STI and used it for non-airline operators. The STI included questions on many relevant topics, including general questions such as the operator's primary type of operation and the percentage of passenger-carrying operations, as well as safety indicator questions on significant changes in operations or the addition of new routes. However, the STI questions probably would not detect gradual changes in the activities of an on-demand charter/aerial work operator.

In addition, to be most effective, the STI required the inspector completing the form to already have a significant amount of current knowledge about the operator and its activities. If the inspector did not have this knowledge, or could not readily obtain it from other CASA sources (such as a recent audit), they needed to contact the operator to obtain information. This provided a useful mechanism for maintaining ongoing contact with an operator. However, unless the inspector asked a broader set of questions than those contained in the STI, they would not become aware of the full nature of an operator's activities, and the answers to some of the safety indicator questions would have limited validity.

During the process of an audit or site visit, CASA inspectors had the opportunity to obtain detailed information about an operator's activities. However, there was no formal process for collecting or storing this information in a manner that allowed CASA to effectively compare operators with each other, or assess an operator's activities over time. The currency of the information would also often be limited given the normal frequency of audits.

In summary, although CASA collected or had access to many types of information about an operator, the information was not integrated to form a useful operations or safety profile of the operator. In addition, CASA's processes for obtaining information on the nature and extent of an operator's operations were limited and informal. These limitations reduced its ability to effectively prioritise surveillance activities.

Although having better processes for obtaining and integrating information about an operator would improve surveillance planning, and reduce risk, it is unclear to what extent better processes would have changed CASA's level of surveillance of the operator of VH-NGA. For example:

- The most notable increase in the air ambulance activities occurred during 2008–2009, and CASA had already recently conducted audits of the operator in October 2007 and March 2008.
- According to CASA policies (and regulatory requirements), passenger charter operations had a higher level of classification than aerial work activities with passengers (including air ambulance operations). If CASA had elected to do increased surveillance during 2009, it may have decided to focus on the expanding passenger-carrying operations in the operator's turboprop fleet.
- CASA already had a reasonable amount of interaction with the operator, both prior to and after the completion of its last audit in March 2008. Although the last audit resulted in a safety alert, CASA was satisfied with the operator's remedial and corrective action. It had expressed reservations to the operator regarding the chief pilot's attitude to regulatory compliance, and the operator had replaced the chief pilot. CASA appeared to be satisfied with the work conducted by the new chief pilot, and the involvement of the parent airline from late 2008 in facilitating the operator's safety management processes. Although CASA had become aware of various problems with the operator's activities during 2009, it was satisfied with the way the operator was responding to the problems.
- If CASA had developed better prioritising processes, this may have resulted in identifying higher priorities for surveillance in other operators in addition to the operator of VH-NGA.

Processes for scoping audits

As already noted, surveillance is a sampling exercise, and each audit cannot examine every aspect of an operator's activities. In addition, for charter and aerial work operators, CASA did not have the resources to audit each system element within a defined period of time. Therefore, CASA needed to have a sound approach for deciding what to examine in each audit.

With the introduction of the *Surveillance Procedures Manual* (SPM) in November 2003, CASA's procedures and guidance for scoping audits required inspectors to consider information such as the results of previous audits, known organisational changes and other known safety information (such as incident reports). All of these are highly-relevant types of information to consider, and the evidence indicates CASA's inspectors followed these requirements when scoping their audits of the operator during 2004–2008. This resulted in the audits examining several relevant system elements that applied to all of the operator's operations, most commonly flight crew training and checking and fatigue management.

However, the use of previous audit findings and incidents reports is largely a reactive approach. Considering organisational changes can be both reactive and proactive, depending on the nature of the change. Another proactive approach, not included in CASA's procedures and guidance, is to formally consider the nature of the operator's activities, the inherent threats or hazards associated with those activities, and the risk controls that were important for managing those threats or hazards.

For example, if an operator was conducting a significant amount of international, overwater operations, the inherent threats or hazards would include weather and fuel exhaustion, and important risk controls would include the procedures, training and proficiency checking for flight/fuel planning and in-flight fuel management. Therefore, it would be important to conduct some level of surveillance to assess the effectiveness of these risk controls.

This type of proactive, risk-based approach to scoping audits is not a novel concept. For example, during the development of the SPM manual, CASA commissioned external audits of its proposed surveillance approach. An external audit in May 2003 noted that, at that time, CASA inspectors were not provided with a standard audit planning tool. The audit report recommended a standard template be developed, which was subsequently introduced (as indicated above). In addition to aspects such as recent changes and issues associated with the operator, the external audit report suggested including:

- the operator's background and structure
- operations summary
- external factors affecting operations
- a summary of key operational risks.

CASA accepted the recommendation, but noted that given the variance and experiences within its general aviation offices, coverage of all the recommended inclusions 'may require a staged implementation'. However, such factors were not subsequently included on the planning form.

Even though the SPM provided no formal guidance to consider the nature of an operator's operations when scoping audits, it is possible CASA inspectors were informally considering such aspects. However, the inclusion of appropriate, formal guidance material about proactively scoping audits based on the inherent threats and hazards involved in an operation would provide additional assurance that audits focussed on the most relevant system elements.

Another aspect associated with CASA's scoping of audits for non-airline operators is the list of system elements. Although they covered all relevant aspects of an operator's operation in some form, some important aspects appeared to have minimal visibility. For example, flight/fuel planning was not clearly identified as a distinct system element. Nevertheless, the importance of flight/fuel planning would be recognised by CASA flying operations inspectors (FOIs), and it is likely that this minimal visibility would have had more influence on the inspectors' coding of the selected scope in CASA's audit database rather than on the development of the actual audit scope.

In summary, CASA's procedures and guidance for scoping an audit included several important aspects, but it did not formally include the nature of the operator's activities, the inherent threats or hazards associated with those activities, and the risk controls that were important for managing those threats or hazards.

In considering the potential relevance of this issue to the 18 November 2009 accident, a notable aspect of CASA's surveillance of the operator was that it conducted very little examination of the operator's processes for flight/fuel planning or in-flight fuel management of international air ambulance flights during 2002–2009. It would be reasonable to expect that, if CASA had formally included a proactive approach to scoping audits, it could have identified a need to consider further surveillance activity on these aspects at some stage. However, given the context, there was insufficient evidence to consider that an improved audit scoping process by itself would have had an influence in this case. More specifically:

- As already noted, CASA had a limited appreciation of the extent to which international air ambulance operations were being conducted, and the types of destinations involved. This could have reduced the potential for considering aspects of air ambulance operations within an audit scope, as would the classification of air ambulance operations as being a lower priority than charter flights.
- The only specific example of CASA surveillance of flight/fuel planning appeared to be following up a ramp check conducted by the French regulator at Noumea in July 2006. In that case, the previous flight had departed with a substantial amount of discretionary fuel and no problems were identified.
- Even if CASA had examined flight/fuel planning and in-flight fuel management during one of its audits, it is unlikely it would have identified all the problems it identified during the special audit in November 2009 (see also the next section). For example, if CASA had reviewed a sample of flight records for air ambulance and charter flights, it would probably have identified that pilots were almost always using a conservative approach to fuel planning.
- As already noted, even if CASA had identified the operator was conducting a significant number of flights to Australian remote islands, and it required or recommended the operator amend its OM to include specific procedures for such flights, the operator may have elected to do so for passenger-carrying charter flights only (consistent with the regulatory requirements). In other words, the limited nature of the regulatory requirements for fuel planning flights to remote islands and isolated aerodromes limited the potential effectiveness of any surveillance processes to effect change in the operator's procedures.

Processes for conducting audits

CASA's SPM advocated a systems-based approach to auditing. Consistent with the principles of safety management, this involved examining management systems when auditing any system element. The use of this approach significantly enhanced CASA's potential for identifying underlying problems with how an operator managed safety.

CASA's audits of the operator during 2004–2008 appeared to use this systems-based approach. However, the evolution of this approach in practice resulted in the audits of the operator (and other operators) primarily involving reviews of the operator's documentation and interviews with a small number of key personnel, such as the chief pilot or compliance/safety manager. This approach, particularly the reviews of an appropriate sample of documentation for a system element such as training and checking, involved a significant amount of resources.

CASA's audits of the operator generally identified problems with each system element it examined, and CASA was able to effect some improvement in the operator's processes. When it identified repeated problems, CASA was able to facilitate more substantial changes, as occurred following the March 2008 audit. However, although documentation and key personnel are important sources of information, they only provide a partial picture of operations. In particular, these sources do not necessarily provide much information on the extent to which many procedures are actually followed (or able to be followed) during line operations.

One method for CASA to obtain further information about how operations are conducted in practice is to conduct more frequent line observations and other 'product' inspections. However, such activities also involve significant resources, and they can be difficult for CASA to organise with appropriately-qualified FOIs for each aircraft type. In addition, it is logistically difficult to arrange and conduct line surveillance for ad hoc air ambulance or charter flights. Furthermore, the presence of a CASA inspector during a flight may change the way some aspects of a flight are planned and conducted.

Another method is for CASA to conduct interviews with line personnel. As well as obtaining information about how line operations are conducted in practice, such interviews can also help identify pilots' concerns with safety management aspects or the operational environment. CASA's experience with the special audit following the 18 November 2009 accident clearly demonstrated the usefulness of interviews with line pilots. However, part of that success was attributable to the fact many pilots were interviewed in some detail about a range of topics. In routine audits, smaller samples would only normally be available or practical, which could make it more difficult to provide assurances about confidentiality.

A third method is for CASA to ensure an operator has appropriate processes in place to monitor the conduct of its line operations. This is a fundamental aspect of SMS, and it was also clearly articulated in CASA's management systems model (under 'monitoring and improvement'). In the case of the operator of VH-NGA, CASA conducted a detailed evaluation of the operator's SMS in its October 2007 audit. Following this and other audits, it made recommendations to the operator about increasing the number and scope of internal audits. Despite these efforts, there was limited additional auditing conducted prior to the accident. CASA audits had also identified similar problems with other operators.

CASA had been actively encouraging operators for many years to develop SMSs, and its approach to surveillance in this area also appeared to be one of encouragement rather than enforcement. Its ability to force additional effort in this area was probably limited by the absence of explicit regulatory requirements regarding SMSs in general (or internal auditing in particular) in the period prior to the accident.

Until CASA can be assured an operator has a mature SMS and is conducting adequate internal monitoring of its own operations, there will always be a need for CASA to conduct some level of independent monitoring of line operations. Many previous reports, including the ANAO 2002 audit of CASA and the 2008 audit of Transport Canada (see *Processes for determining surveillance priorities*) have noted the need for an appropriate balance between examining systems and examining products, until the relevant SMSs are fully mature.[341]

In summary, consistent with widely-agreed safety science principles, CASA's approach to conducting surveillance of large charter and air ambulance operators had placed significant emphasis on systems-based audits. However, its implementation of this approach resulted in minimal emphasis on evaluating the conduct of line operations (or 'process in practice'). Although there are pragmatic difficulties with interviewing line personnel and conducting product surveillance of some types of operations, such methods are necessary to ensure there is a balanced approach to surveillance, particularly until CASA can be confident that operators have mature SMSs in place.

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341 In addition, see the Transportation Safety Board of Canada Aviation Investigation Report A13W0120, Engine failure after takeoff and collision with terrain, Buffalo Airways Ltd., Douglas DC-3C, C-GWIR, Yellowknife Airport, Northwest Territories, 19 August 2013. That report included the following finding: 'The current approach to regulatory oversight, which focuses on an operator's SMS processes almost to the exclusion of verifying compliance with the regulations, is at risk of failing to address unsafe practices and conditions. If [Transport Canada] does not adopt a balanced approach that combines inspections for compliance with audits of safety management processes, unsafe operating practices may not be identified, thereby increasing the risk of accidents.'

As already indicated, there are practical difficulties with implementing effective surveillance activities that involve product inspections or interviewing of line personnel for charter and aerial work operators. Consequently, it is difficult to assess the extent increased efforts in this area would have had on detecting some of the operator's safety issues, particularly in key areas such as flight/fuel planning. Nevertheless, increased effort in this area would be very likely to improve the effectiveness of CASA's surveillance.

Additional comments

Regardless of how regulatory surveillance is conducted, as already noted, it will fundamentally always be a sampling exercise and cannot identify all of an operator's problems, particularly when those problems change over time. After reviewing several accidents in many industries, Reason (1997) noted:

> Regulatory bodies worldwide seem to be hopelessly trapped in a mesh of double binds. Consider the following:
>
> - Workload has increased as resources have been slashed.
> - Regulators are regularly accused of lax oversight and overly collusive relationships with their clients, while the clients themselves often regard the regulators as intrusive, obstructive, threatening, rigid, out-of-date, ignorant and generally unsympathetic to their commercial pressures.
> - Accident inquiries find regulators guilty of not being fully acquainted with all of the details of their clients' operations and of missing important contributing factors, but the only means they have of obtaining this information is from the operators themselves or from periodic inspections and follow-ups. After an accident, these omissions take on a sinister significance, but for regulators, armed only with foresight, they are but one of many possible contributions to a future accident. As stated earlier, warnings are only truly warnings if we know what kind of an event the organization will suffer.
> - Front-line regulators are generally technical specialists, yet major accidents arise from the unforeseen–and often unforeseeable–interactions of human and organizational factors whose role is only now being acknowledged by health and safety legislators, and then in the most general terms.

To increase its ability to identify systemic problems in operators and other organisations, CASA introduced a new surveillance approach in 2003. The approach included many components, and appropriately emphasised the importance of examining management systems during surveillance. However, as indicated in the previous sections, there were some limitations with CASA's processes for planning surveillance, scoping audits and conducting audits.

During 2002–2009, CASA conducted a significant amount of oversight of the operator. However, a key concern is that, although the operator conducted a substantial number of international air ambulance tasks during this period, CASA conducted no detailed or focussed examination of these activities, particularly of potentially relevant aspects such as fuel planning, in-flight fuel management and emergency procedures. This was a very undesirable outcome.

Although it is difficult to conclude that addressing any one of the safety issues associated with planning surveillance, scoping audits or conducting audits would have prevented the accident, it is likely that addressing all of them, and raising the classification of air ambulance operations, would significantly improve CASA's capabilities for conducting effective surveillance of this type of operator.

During the investigation, the ATSB considered a number of other aspects of CASA oversight. These included:

- CASA's checklist for evaluating an operator's fuel policy was last revised in June 1999 and focussed on the contents of Civil Aviation Advisory Publication (CAAP) 234. It did not include a reference to the CAO 82.0 requirements for remote islands (first introduced in August 1999). This omission increased the likelihood of CASA personnel not considering this aspect when assessing an operator's fuel policy. Given the checklist did not appear to be used during assessments of the operator's fuel policy, this omission is unlikely to have influenced CASA's oversight in this case. Nevertheless, the use of checklists to guide inspectors' tasks is very useful, and CASA should take steps to ensure such checklists are updated to reflect changes in regulatory requirements.

- Multiple investigations and reviews have identified limitations with the training of CASA inspectors. Such personnel perform a wide range of tasks that require expert judgement, and providing more training for such personnel will always be beneficial. However, the limitations identified in CASA's oversight of the operator on this occasion appeared to be related to the design of the surveillance process rather than the individual skill levels of the personnel involved.
- CASA's internal review of its oversight following the 18 November 2009 accident identified problems with the acquittal of requests for corrective action (RCAs) without sufficient evidence of corrective action. The ATSB investigation did not identify a significant problem in this area, although there were examples of repeating problems with the conduct of some types of training. The more fundamental problem with CASA's oversight was the absence of surveillance on some system elements, rather than the limitations of the surveillance it did conduct.
- The default audit schedule for an operator conducting passenger-charter operations in large aircraft was one scheduled systems audit every 3 years. However, operators vary extensively in their size and complexity. If the operator had not merged its jet and turboprop operations into one AOC, it would probably have been subject to twice as many audits during the 2006–2009 period. Accordingly, it would seem appropriate for CASA to more overtly consider such aspects when developing future surveillance plans.
- Another approach to increasing CASA's ability to detect problems during surveillance is to simply conduct more surveillance, which would require more resources. Evaluating the extent to which CASA had adequate surveillance resources to conduct its tasks during the period up to 2009 is very complex, and ultimately was considered to be beyond the scope of the current investigation. In addition, until other mechanisms to improve the effectiveness of surveillance are considered, it would be difficult to justify. Following CASA's internal review of its oversight processes conducted after the 18 November 2009 accident, CASA introduced a range of changes to its surveillance approach, and these are discussed in *Safety issues and actions*.

Final comments and some key lessons

As with many accidents involving an air transport aircraft, this accident involved a combination of multiple safety factors. These included individual actions by the flight crew and air traffic services' personnel, local conditions influencing the flight crew, limitations in some of the operator's risk controls, and other safety issues associated with the operator's safety management processes and regulatory requirements. In addition, the investigation identified many other factors that increased safety risk, although there was insufficient evidence to conclude they contributed to this accident.

It is worth noting this accident also involved a combination of rare events. For example, weather conditions below the landing minima at Norfolk Island occurred 0.1 per cent of the time, the operator conducted a relatively small number of flights to Norfolk Island (or similar destinations) each year, and it was rare for any of the operator's long-distance flights to such islands to depart with less than full fuel (or the maximum available fuel load). It was also unlikely that both Nadi ATS and Auckland ATS would not provide all the relevant weather information to a flight crew, and then the crew would not request sufficient information at the appropriate time.

Even though each of these events may be rare or unlikely, they each increased risk, and in this case ultimately contributed to an accident. This highlights the importance for all operational (or front-line) personnel and organisations of minimising the occurrence of such actions and having sound practices, controls and processes in place to identify and manage such actions if they do occur.

Overall, the investigation found a large number (36) of safety factors, including 16 safety issues. This large number was due in part to the amount of information obtained by the reopened investigation and the depth to which it was analysed. Similar to CASA's special audit, the more effort or resources applied to a safety investigation, then generally the more problems will be found.

Accordingly, it is important for all flight crew, other personnel, operators, regulators and other organisations to review these findings and assess whether they provide useful lessons to their own activities.

Overall, the most fundamental lesson for all flight crew, operators and regulators is to recognise that unforecast weather can occur at any aerodrome. Consequently, there is a need for robust and conservative fuel planning and in-flight fuel management procedures for passenger-carrying transport flights to remote islands and isolated aerodromes.

Additional safety messages include:

- Flight crew should discuss and consider options to manage threats when there is time available to do so.
- Operators should ensure their flight crew proficiency checks assess the performance of all key tasks required of their flight crew.
- Operators should not rely on informal risk controls for managing the performance of safety-critical tasks, particularly when there is a significant turnover of pilots in a fleet.
- Operators of air ambulance flights should ensure medical personnel have clearly defined procedures and practical training for using the emergency equipment on board to ensure they can effectively assist a patient in the event of an emergency.
- All organisations in safety-critical industries should use proactive and predictive processes to identify hazards in their operations.
- Organisations that use a bio-mathematical model of fatigue (BMMF) as part of their fatigue risk management system should ensure they have a detailed understanding of the assumptions and limitations associated with such models.
- Regulators should develop effective methods for obtaining, storing and integrating information about operators and the nature of their operations so they can develop effective surveillance plans.

Finally, this investigation also highlights important lessons for safety investigation agencies, some of which were outlined in the Transportation Safety Board of Canada's review of the processes used by the ATSB in its original investigation of the 18 November 2009 accident (see *Background*). One important lesson is the importance of investigations obtaining detailed information about normal operations when assessing a flight crew's actions and the potential factors that may have influenced those actions.

Findings

From the evidence available, the following findings are made with respect to the fuel planning event, weather-related event and ditching of the Westwind 1124A aircraft, registered VH-NGA, which occurred 6.4 km west-south-west of Norfolk Island Airport on 18 November 2009. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance. A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- Contrary to the consistent practice of the operator's Westwind fleet, the long-distance flight to a remote island aerodrome departed without uploading the maximum possible amount of fuel prior to departure. Had the flight departed with the maximum amount of fuel, it is very likely the aircraft would have had sufficient fuel to divert from the top of descent or to hold at the remote island for a significant period of time.
- The captain's pre-flight planning did not include many of the elements needed to reduce the risk of a long-distance flight to a remote island or isolated aerodrome. Limitations included:
    - miscalculating the total fuel required for the flight under normal operations
    - not obtaining relevant forecasts of upper-level winds and, in the absence of such forecasts, underestimating the potential headwind component
    - not calculating the additional fuel required to allow for aircraft system failures
    - not obtaining a current aerodrome forecast and NOTAMs for potential alternate aerodromes
    - not calculating a point of no return (PNR).
- **The operator's Westwind pilots generally used a conservative approach to fuel planning, and the operator placed no restrictions on the amount of fuel that pilots uploaded. However, the operator's risk controls did not provide assurance that there would be sufficient fuel on board flights to remote islands or isolated aerodromes. Limitations included:**[342]
    - **no explicit fuel planning requirements for remote islands or isolated aerodromes**
    - **no formal fuel planning guidance for some relevant situations, such as a loss of pressurisation or flight below reduced vertical separation minimum (RVSM) airspace**
    - **no formal training for planning flights to remote islands or for international operations**
    - **no guidance information about potential hazards at commonly-used aerodromes**
    - **no procedure for a captain's calculation of the total fuel required to be checked by another pilot**
    - **little if any assessment during proficiency checks of a pilot's ability to conduct flight/fuel planning. [Safety issue]**

[342] Some of these specific limitations, if listed as a separate finding, would probably not meet the definition of a contributing factor.

- **Although passenger-carrying charter flights to Australian remote islands were required to carry alternate fuel, there were no explicit fuel planning requirements for other types of passenger-carrying flights to remote islands. There were also no explicit Australian regulatory requirements for fuel planning of flights to isolated aerodromes. In addition, Australia generally had less conservative requirements than other countries regarding when a flight could be conducted without an alternate aerodrome. [Safety issue]**
- **Although air ambulance flights involved transporting passengers, in Australia they were classified as 'aerial work' rather than 'charter'. Consequently, they were subject to a lower level of regulatory requirements than other passenger-transport operations (including in terms of requirements for fuel planning of flights to remote islands). [Safety issue]**
- The meteorological conditions were below the landing minima at the time the aircraft arrived at Norfolk Island (1003 UTC). This level of deterioration in the conditions was not indicated in the aerodrome forecast issued at 0437, prior to the departure of the flight (although an amended forecast issued at 0803 included conditions below the alternate minima).
- Although the Nadi international flight information service officer had provided the flight crew with the 0800 UTC special weather report (SPECI) (which included conditions below the alternate minima), he did not proactively provide the flight crew with the amended aerodrome forecast for Norfolk Island issued at 0803 (which forecast conditions below the alternate minima) or the SPECI issued at 0830 (which included conditions below the landing minima).
- After responsibility for the flight transferred to Auckland air traffic services at 0835 UTC, the Auckland air/ground operator did not confirm the flight crew had received the 0803 amended aerodrome forecast for Norfolk Island or the 0830 special weather report.
- The flight crew did not request sufficient weather information at an appropriate time prior to reaching the point of no return (PNR) to support effective decision-making. In addition, the captain's method for estimating the PNR to an off-track alternate aerodrome during a flight would generally not produce a specific, accurate time that could be used as an effective basis for deciding when to gather relevant weather information.
- The captain underestimated the risk associated with continuing the flight to Norfolk Island. This underestimation was probably associated with several contextual factors, including the limited weather information he had been provided during the flight, the limited information he had requested during the flight, and a strong though mistaken expectancy that the automatic weather station at Norfolk Island generally overestimated the amount of cloud that was present.
- **The operator's risk controls did not provide assurance that the operator's Westwind pilots would conduct adequate in-flight fuel management and related activities during flights to remote islands or isolated aerodromes. Limitations included:[343]**
    - **no formal guidance material about how to calculate a point of no return (PNR) for an off-track alternate aerodrome**
    - **no formal guidance material regarding what types of weather information to obtain during a flight and when to obtain the information**
    - **no procedure for a captain's calculation of the PNR to be checked by another pilot**
    - **little if any assessment during proficiency checks of a pilot's ability to calculate a PNR and conduct in-flight fuel management on long distance flights**
    - **no fitment of a satellite phone in most of the operator's Westwind aircraft. [Safety issue]**
- The flight crew were aware that the reported weather conditions were below the alternate minima before they briefed the first approach, and they were aware the reported conditions were below the landing minima before the top of descent. However, the crew did not discuss approach

[343] Some of these specific limitations, if listed as a separate finding, would probably not meet the definition of a contributing factor.

options, or effectively discuss contingencies if they could not successfully land off the first approach. After the first approach, the crew did not effectively review their fuel situation and consider alternate emergency options prior to ditching the aircraft.

- The flight crew experienced significant workload, time pressure and stress during the latter stage of the flight, which reduced their capacity to assess their situation, make effective decisions and conduct approaches.
- Associated with the limited time available following the decision to ditch, the flight crew did not refer to the emergency procedures checklist for ditching and some checklist items were not completed. In particular, the captain conducted the final approach at an airspeed significantly below the reference landing speed (V_{REF}), which reduced the aircraft's energy state and increased the descent rate just prior to impact.
- The ditching was conducted in dark night conditions, which resulted in the flight crew being unable to evaluate the direction of the main swell, as well as increasing the captain's difficulty in conducting the flare manoeuvre.
- The aircraft probably encountered forces during the impact sequence that were significantly greater than those the aircraft was designed to withstand. Although the survivable space within the cabin was maintained, the forces resulted in serious injuries, significant damage and rapid flooding of the aircraft.
- **Although the operator's safety management processes were improving, its processes for identifying hazards extensively relied on hazard and incident reporting, and it did not have adequate proactive and predictive processes in place. In addition, although the operator commenced air ambulance operations in 2002, and the extent of these operations had significantly increased since 2007, the operator had not conducted a formal or structured review of its risk controls for these operations. [Safety issue]**

Other factors that increased risk

- **The operator and air ambulance provider did not have a structured process in place to conduct pre-flight risk assessments for air ambulance tasks, nor was there any regulatory requirement for such a process. [Safety issue]**
- The aircraft's fuel quantity gauges were probably underreading by a total of about 260 lb during the flight. Although the flight crew were aware the fuel gauges were underreading, the captain became significantly concerned about the fuel situation when the indicated fuel remaining approached 0 lb.
- Following a pilot report of underreading fuel quantity gauges on VH-NGA on 9 October 2009, the gauges were probably not effectively calibrated.
- The aircraft's fuel flow gauges were probably underreading. The flight crew of the accident flight had not identified the problem, and flight crews of previous flights had not identified and/or reported the problem.
- **The available regulatory guidance on in-flight fuel management and on seeking and applying en route weather updates was too general and increased the risk of inconsistent in-flight fuel management and decisions to divert. [Safety issue]**
- **Although the operator provided its flight crew with basic awareness training in crew resource management (CRM), it was limited in nature and did not ensure flight crew were provided with sufficient case studies and practical experience in applying relevant CRM techniques. [Safety issue]**
- Prior to departing Apia, the flight crew did not conduct a pre-flight safety briefing for the aircraft's other occupants.
- **The operator's risk controls did not provide assurance that the occupants on an air ambulance aircraft would be able to effectively respond in the event of a ditching or similar emergency. Specific examples included:**

  - **insufficient information provided during the pre-flight demonstrations and on the passenger safety brief card to demonstrate how to use a life jacket**
  - **limited procedures and guidance regarding the relative roles, responsibilities and required actions of flight crew and medical personnel during emergencies, particularly with regard to the evacuation of a patient**
  - **no practical training or demonstrations for medical personnel on how to use the safety equipment on board the aircraft**
  - **no designated location for a stretchered patient's life jacket**
  - **no formal, specific procedures and limited training on how to secure life rafts in an appropriate, readily-accessible location prior to a ditching. [Safety issue]**

- Associated with limited preparation time before the ditching and the rapid ingress of water into the cabin after the ditching, the six occupants evacuated the aircraft with only three life vests and without the aircraft's life rafts.
- One of the lights on the three life jackets operated for less than 85 minutes, significantly less than the 8 hours required by the relevant design standard.
- The first officer did not advise the Norfolk Island Unicom operator of the runway being used for the fourth approach, and her subsequent advice that they were proceeding with the ditching did not include the intended location. As a result, the rescue services initially started proceeding to an incorrect search datum, potentially delaying the recovery of any survivors.
- Due to limited sleep in the previous 24 hours, the captain was probably experiencing a level of fatigue that has been demonstrated to adversely influence performance.
- **The operator's application of its fatigue risk management system overemphasised the importance of scores obtained from a bio-mathematical model of fatigue (BMMF), and it did not have the appropriate expertise to understand the limitations and assumptions associated with the model. Overall, the operator did not have sufficient risk controls in addition to the BMMF to manage the duration and timing of duty, rest and standby periods. [Safety issue]**
- **Guidance material associated with the FAID bio-mathematical model of fatigue did not provide information about the limitations of the model when applied to roster patterns involving minimal duty time or work in the previous 7 days. [Safety issue]**
- **Although the operator installed an enhanced ground proximity warning system (EGPWS) and traffic alert and collision avoidance system (TCAS) on VH-NGA in August 2009, it did not provide relevant flight crew with formal training on using these systems, or incorporate relevant changes into the aircraft's emergency procedures checklists. [Safety issue]**
- **The operator had not formally defined the roles and responsibilities of key positions involved in monitoring and managing flight operations, such as the standards manager for each fleet and the General Manager Flying Operations (Medivac and Charter). [Safety issue]**
- **Although the Civil Aviation Safety Authority (CASA) collected or had access to many types of information about a charter and/or aerial work operator, the information was not integrated to form a useful operations or safety profile of the operator. In addition, CASA's processes for obtaining information on the nature and extent of an operator's operations were limited and informal. These limitations reduced its ability to effectively prioritise surveillance activities. [Safety issue]**
- **The Civil Aviation Safety Authority's procedures and guidance for scoping an audit included several important aspects, but it did not formally include the nature of the operator's activities, the inherent threats or hazards associated with those activities, and the risk controls that were important for managing those threats or hazards. [Safety issue]**

- **Consistent with widely-agreed safety science principles, the Civil Aviation Safety Authority's approach to surveillance of larger charter operators had placed significant emphasis on systems-based audits. However, its implementation of this approach resulted in minimal emphasis on evaluating the actual conduct of line operations (or 'process in practice'). [Safety issue]**

Other findings

- In 2009, the amount of unforecast weather below the landing minima at Norfolk Island was similar to that for other remote islands and also for capital city airports in Australia.
- At the time the flight was planned, there were no weather-related or other operational requirements that affected the planning of the accident flight, or necessitated the nomination of an alternate aerodrome or the carriage of additional fuel to reach an alternate aerodrome.
- If the aircraft manufacturer's *1124A Westwind Operational Planning Manual* was used, the aircraft departed with sufficient fuel for the flight for normal operations. If the operator's specified fuel planning methods were used, the aircraft departed with insufficient fuel for the flight for normal operations. In either case, the flight departed with insufficient fuel to meet the regulatory requirements as there was insufficient fuel to allow for aircraft system failures.
- At the time of the accident, many emergency locator transmitters (ELTs) were not GNSS-equipped. Such ELTs were of limited effectiveness for impacts where the ELT was unable to continue sending signals for an extended period, such as in the case of a ditching or water-impact when the ELT and the associated aerial could not remain above the water for an extended period.
- In very difficult circumstances, the doctor and flight nurse did an excellent job evacuating the patient, and then assisting the patient and injured first officer in the water. Both the doctor and nurse had undertaken helicopter underwater escape training (HUET), which they reported had helped them prepare for the evacuation.
- The chance observation of the captain's torch by a firefighter redirected the search for the evacuees to the correct area and facilitated the timely arrival of the search vessel.

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions are repeated separately on the ATSB website to facilitate monitoring by interested parties. Where relevant the safety issues and actions will be updated on the ATSB website as information comes to hand.

The ATSB's reopened investigation into the 18 November 2009 accident involving VH-NGA used the investigation number AO-2014-190 for ATSB internal purposes. Accordingly, all of the safety issues and actions were allocated numbers associated with AO-2014-190 rather than the original investigation number AO-2009-072. There were two safety issues published in the original ATSB AO-2009-072 investigation report:

- Safety issue AO-2009-072-SI-02 (associated with the operator's oversight of the flight and its planning) was replaced by three safety issues: AO-2014-190-SI-01, AO-2014-190-SI-02 and AO-2014-190-SI-03.
- Safety issue AO-2009-072-SI-01 (associated with the regulator's guidance about fuel planning and en route decision-making) was replaced by two safety issues: AO-2014-190-SI-10 and AO 2014-190-SI-11.

Operator's risk controls for flight/fuel planning

Number:	AO-2014-190-SI-01
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's Westwind flight crew

Safety issue description:

The operator's Westwind pilots generally used a conservative approach to fuel planning, and the operator placed no restrictions on the amount of fuel that pilots uploaded. However, the operator's risk controls did not provide assurance that there would be sufficient fuel on board flights to remote islands or isolated aerodromes. Limitations included:

- no explicit fuel planning requirements for remote islands or isolated aerodromes
- no formal fuel planning guidance for some relevant situations, such as a loss of pressurisation or flight below reduced vertical separation minimum (RVSM) airspace
- no formal training for planning flights to remote islands or for international operations
- no guidance information about potential hazards at commonly-used aerodromes
- no procedure for a captain's calculation of the total fuel required to be checked by another pilot
- little if any assessment during proficiency checks of a pilot's ability to conduct flight/fuel planning.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-023

On 20 November 2009, the operator issued a notice to flight crew stating that all flights to Australian designated remote islands (Norfolk Island, Lord Howe Island and Christmas Island) must carry fuel for a suitable alternate aerodrome.

Following the accident, CASA carried out a special audit of the operator's operations between 26 November and 15 December 2009. The audit included an extensive assessment of the operator's Westwind operations and a number of the operator's organisational aspects. The operator voluntarily ceased its Westwind operations and collaborated with CASA during the special audit. A management action plan was developed to address a wide range of issues and provide the operator with confidence in the safety of its operations.

On 7 December 2009, the operator issued a notice to Westwind pilots that the Westwind standards manager would conduct the flight/fuel planning for all international air ambulance flights until the operator was able to install a standard flight planning software tool at all bases. In addition, the operator would provide all relevant weather information and NOTAMs to flight crews. Flight crew were able to conduct the flight planning for domestic flights, but only if they used the operator's approved fuel planning data.

In addition, on 7 December 2009, the operator issued a new Westwind 1124/1124A fuel policy and interim flight planning procedures. Following consultation with CASA, a revised policy and interim procedures was issued on 21 December 2009. The policy and procedures included specified fuel burn for different ranges of flight levels (including non-RVSM levels). It also included specified fuel figures for an instrument approach, alternate fuel, fixed reserve, holding fuel and taxi fuel.

In addition, the policy and procedures required:

- an alternate aerodrome be selected for all IFR flights unless the destination aerodrome was an isolated aerodrome, or the expected flight time was no more than 3 hours and there were two separate runways at the destination aerodrome and the forecast conditions indicated a VMC approach could be conducted
- flights to Australian remote islands carry an alternate aerodrome at all times
- remote islands only be used as a destination aerodrome (not used as a refuelling or technical stop)
- flights to isolated aerodromes be planned with taxi fuel, flight fuel, variable reserve fuel and additional fuel to fly for 2 hours after arriving overhead the aerodrome (including the fixed reserve).[344]

Additional safety actions related to fuel planning included:

- a requirement for both flight crew to review and cross check the flight plan before flight and acknowledge they had checked the fuel requirements were adequate for the flight
- a review of flight planning resources available at each base and replacement of computers and other resources where required
- introduction of a standard flight planning software tool, available at all bases, with operator-controlled figures and formal guidance for using the tool
- formal ground-based training for all flight crew on flight planning, fuel calculations, the new fuel policy and use of the flight planning software tool
- formal ground-based revision training for all flight crew on Westwind aircraft performance, Westwind aircraft systems, GPS principles, en route navigation, and IFR theory

[344] This requirement was subsequently amended in March 2010 to 90 minutes additional fuel with CASA approval.

- formal guidance to flight crew for operations in RVSM airspace
- a requirement for new captains to complete 10 international flight sectors before being recommended for a check to line
- introduction of standard flight plans and navigation logs for some commonly-used routes.

In mid-2010, the operator ceased its relationship with CareFlight, and therefore ceased air ambulance operations in Westwind aircraft. The operator advised that, if it restarted these operations, it would conduct a formal change management process.

In addition to the Westwind fleet, the operator also revised its fuel policy on the Learjet fleet.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB acknowledges that the operator undertook substantial safety action to address its risk controls regarding fuel planning on its Westwind fleet. Although not every item in the safety issue was specifically addressed, the overall level of action substantially reduced the risk of operations to remote islands and isolated aerodromes.

Operator's risk controls for in-flight fuel management

Number:	AO-2014-190-SI-02
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's Westwind flight crew

Safety issue description:

The operator's policies, procedures, training and guidance did not provide assurance that the operator's Westwind pilots would conduct adequate in-flight fuel management and related activities during flights to remote islands or isolated aerodromes. Limitations included:

- no formal guidance material about how to calculate a point of no return (PNR) for an off-track alternate aerodrome
- no formal guidance material regarding what types of weather information to obtain during a flight and when to obtain the information
- no procedures for a captain's calculation of the PNR to be checked by another pilot
- little if any assessment during proficiency checks of a pilot's ability to calculate a PNR and conduct in-flight fuel management on long distance flights
- no fitment of a satellite-phone in most of the operator's Westwind aircraft.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-024

On 7 December 2009, the operator issued a new Westwind 1124/1124A fuel policy and interim flight planning procedures. Following consultation with CASA, a revised policy and interim procedures was issued on 21 December 2009. The policy and procedures included:

- (for all flights exceeding 3 hours) a requirement for a how-goes-it chart to be completed to compare planned versus actual fuel burns
- (for all flights exceeding 3 hours) a requirement for weather updates to be obtained for the destination and en route alternate aerodromes no later than 90 minutes after departure, at each CP or PNR position and prior to top of descent (with acceptable weather updates in order of preference being a TTF, TAF and METAR)

- revised procedures for in-flight replanning.

Additional safety actions related to in-flight fuel management included:

- formal guidance and ground-based training for all flight crew on using a how-goes-it chart
- a requirement for flight crews to recalculate the fuel available if planned cruising levels were not provided (and to ensure these calculations were cross-checked)
- a requirement for new captains to complete 10 international flight sectors before being recommended for a check to line.

The operator also introduced portable satellite phones for its air ambulance operations, although these would have been usable from within an aircraft in only some situations.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB acknowledges that the operator undertook substantial safety action to address its risk controls regarding in-flight fuel management on its Westwind fleet. Although not every item in the safety issue was specifically addressed, the overall level of action substantially reduced the risk of operations to remote islands and isolated aerodromes.

Pre-flight risk assessments for air ambulance tasks

Number:	AO-2014-190-SI-03
Issue owner:	Pel-Air Aviation / CareFlight
Operation affected:	Aviation: Air transport
Who it affects:	Operator’s Westwind flight crew

Safety issue description:

The operator and air ambulance provider did not have a structured process in place to conduct pre-flight risk assessments for air ambulance tasks, nor was there any requirement for such a process.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-025

In December 2009, the operator issued a formal notice to its Westwind flight crew that aviation safety was the primary consideration regarding flight continuation, and the condition of the patient was a secondary consideration. The notice also included detailed requirements for pre-flight safety briefings with medical personnel (see *Operator’s emergency procedures and cabin safety*).

In addition, the operator also introduced a requirement for all air ambulance flights to depart with a portable satellite phone on board. A formal notice to pilots stated:

> The provision of this communication tool not only allows the Company to improve operational support to flight crew, but allows crews to advise the Company of departure times, delays, flight times, diversions, delayed arrivals (beyond 15 minutes), and actual arrival times, including intermediate stops.

The notice also outlined a format for text messages providing trip updates.

The operator also provided retraining for all Westwind flight crew in many areas, as outlined in the safety actions to the other safety issues.

Proactive safety action by CareFlight

Action number: AO-2014-190-NSA-026

In April 2015, CareFlight advised the ATSB that its medical directors normally scrutinised all missions for clinical risk and management of those clinical risks. Following the 18 November 2009 accident, they added fatigue to their scrutiny, with a view to postpone or push back timing so that it reduced the potential for fatigue (that is, if it were tasked on an mission that was deemed not urgent, it would push the mission back to align with daylight hours).

It also advised that it had a lowered threshold for overnighting crews rather than return to base when timing was marginal or overnight flights were required to position back to base.

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-027

In July 2013, CASA issued the Notice of Proposed Rule Making (NPRM) 1304OS (Regulations of aeroplane and helicopter ‘ambulance function’ flights as Air Transport operations). This NPRM is further discussed below in relation to safety issue AO-2014-190-SI-12. Annex A of the NPRM stated:

> An HMT or AMT operator will have outlined in their exposition a formal policy and standard operating procedures for compliance with Part 121,133 or 135 of CASR in regard to operational control. These documents will include:
>
> - a tasking dispatch risk assessment tool
> - an inflight risk assessment and management process (using operational decision point go / no go processes)
> - a flight-following procedure and capability that is able to update the pilot on operational matters during flight, if required by the risk management aspects of the operation, or at the next landing point if in flight updates are not required.

In September 2015, CASA issued the Notice of Proposed Rule Making (NPRM) 1519OS (*Aerial Work Operations*). The NPRM proposed a requirement for pre-flight risk assessments for aerial work operations (dependent on size and nature of operation).

In March 2017, CASA was asked whether requirements for pre-flight risk assessments would also be extended to air ambulance or medical transport flights, when such flights were no longer classified as aerial work. CASA advised:

> NPRM 1519OS is for the development of CASR Part 138 Aerial Work Operations. The risk, in an aerial work context, is particular to the specific operation and the environment in which it is being conducted. However, that does not preclude conducting an initial generic risk assessment before developing a tailored assessment for a particular task. With the classification of Medical Transport flights as Air Transport, CASR Part 138 is not applicable in a medical transport context.
>
> However, pre-flight risk in an air transport context is managed by the flight planning requirements which in essence are a formalised assessment of the hazards and associated risks of the flight. Please note that CASR Part 135 contains specific pre-flight planning requirements for flights to isolated aerodromes.

Current status of the safety issue

Issue status: No longer relevant

Justification: The ATSB notes the operator and air ambulance provider both took safety action to reduce the risk of this safety issue, and the operator also undertook broader safety action in relation to hazard identification processes that also potentially reduced the risk associated with this safety issue (see Safety issue AO-2014-190-SI-08). The ATSB also notes the operator ceased air ambulance operations with the air ambulance provider in mid-2010.

Operator's emergency procedures and cabin safety

Number:	AO-2014-190-SI-04
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's Westwind flight crew and medical personnel on air ambulance flights.

Safety issue description:

The operator's risk controls did not provide assurance that the occupants on an air ambulance aircraft would be able to effectively respond in the event of a ditching or similar emergency. Specific examples included:

- insufficient information provided during pre-flight safety demonstrations and the passenger safety brief card to demonstrate how to use a life jacket
- limited procedures and guidance regarding the relative roles, responsibilities and required actions of flight crew and medical personnel during emergencies, particularly with regard to the evacuation of a patient
- no practical training or demonstrations for medical personnel on how to use the safety equipment on board the aircraft
- no designated location for a stretchered patient's life jacket
- no formal, specific procedures and limited training on how to secure life rafts in an appropriate, readily accessible location prior to a ditching.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-028

In December 2009, the operator issued a formal notice to Westwind flight crew to state that prior to the commencement of an air ambulance flight, the captain had to brief the medical personnel about each person's role for that flight. The briefing should include:

- use of life rafts, life jackets and emergency exits
- any flight crew requirements regarding the patient's condition (for example, sea level cabin)
- information for the medical crew regarding the nature of the flight (including flight times, weather, likelihood of diversions, use of electronic equipment).

The notice also clearly stated to flight crew that aviation safety was the primary consideration regarding flight continuation, and the condition of the patient was a secondary consideration.

In December 2009, all Westwind flight crew completed another wet drills training course (delivered by an external specialist).

In October 2017, the operator advised the ATSB:

> Since the accident in 2009 new and comprehensive Safety Equipment and Emergency Procedures (SEEP) manuals were developed and published for the Westwind and Learjet aircraft.
>
> In relation to the Life Raft prior to a ditching, there is no advice given to crew, or briefed passengers, that the life raft should be removed from its secure location prior to ditching. In fact it is made clear that under no circumstances is the life raft, or survival kit, to be removed from stowage and placed unsecured on the floor for landing.
>
> The stowed location of the life raft is clearly explained and all advice to crew is that it is only to be removed after ditching…
>
> In relation to safety equipment and passenger briefings, more broadly it should also be noted that amendments were made to Part A of the Operations Manual and included, for example, a change to the brief to include shoulder harnesses that previously were not mentioned.

> This also led to an amendment of the Safety On Board cards…
>
> Additionally, every aircraft in the fleet was issued with a “DEMO” bag to ensure the full demonstration of the life jacket with all its safety features, a seat belt for buckle demo and an oxygen mask. Any medical crew today are briefed along with the passengers prior to flight…

Proactive safety action taken by CareFlight

Action number: AO-2014-190-NSA-029

Following the accident, the air ambulance provider introduced a number of changes to its international operations. These included:

- adding life jackets to the medical equipment carried on all missions at each base (so that medical crew had rapid access to life jackets at all times)
- adding individual EPIRBs to the medical equipment carried on all missions, so that medical crew had rapid access to EPIRBs at all times
- changed uniforms to include cargo style pants with extra pockets to facilitate the medical personnel carrying the life jackets and EPIRBs at all times.

CareFlight also advised it offered HUET training to all medical personnel engaged in air ambulance flights.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB notes the safety action undertaken by the operator to improve its emergency procedures following the November 2009 accident reduced the risk of this safety issue. The ATSB also acknowledges that the air ambulance provider also took safety action to reduce the risk of this safety issue.

Operator’s crew resource management training

Number:	AO-2014-190-SI-05
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator’s Westwind flight crew

Safety issue description:

Although the operator provided its flight crew with basic awareness training in crew resource management (CRM), it was limited in nature and did not ensure flight crew were provided with sufficient case studies and practical experience in applying relevant CRM techniques.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-030

In December 2009, the operator’s Westwind pilots completed a 2-day course titled ‘Introduction to airline human factors and crew resource management’. The course was delivered by the human factors coordinator from the operator’s parent airline as per that airline’s syllabus and included case studies from the operator’s operations. During the course, the pilots were also provided information on a behavioural markers’ assessment form to reinforce CRM observable safety behaviours.

In addition, the operator introduced a requirement for recurrent (biennial) classroom-based CRM training.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that the action undertaken satisfactorily addressed this safety issue.

Operator's fatigue management

Number:	AO-2014-190-SI-06
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's Westwind flight crew

Safety issue description:

The operator's application of its fatigue risk management system overemphasised the importance of scores obtained from a bio-mathematical model of fatigue (BMMF), and it did not have the appropriate expertise to understand the limitations and assumptions associated with the model. Overall, the operator did not have sufficient risk controls in addition to the BMMF to manage the duration and timing of duty, rest and standby periods.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-031

After the accident, the operator undertook a series of actions to improve its fatigue management practices. These included:

- revised the callout time for air ambulance tasks from 2 hours to 3 hours
- developed and introduced a face-to-face introductory course on fatigue management and revised the content of the computer-based training course
- developed a fatigue assessment form to be used to assess the likelihood of fatigue prior to the assignment of ad hoc charter flights to flight crew who were on standby (with the form including a small number of questions to obtain basic information about a pilot's recent sleep and rest)
- introduced a requirement to reduce the maximum period of 24 hour standby to 28 days (after which crew required a minimum of 8 days off duty)
- modified the FRMS to include longer required rest periods following duty periods involving large time-zone changes (more than 3 hours)
- conducted a workshop with a sample of the operator's managers and flight crew (across all fleets) to identify fatigue hazards and risk controls.

In October 2017, the operator advised the ATSB:

> Since the accident, continuous improvement and advancement has been made to the Pel-Air FRMS including the use of and understanding of the BMMF.
>
> The FRMS has also become an integral part of the Pel-Air and Group Safety Management System and is a standing item that is tracked and reviewed by the Safety Management Group (SMG).
>
> In addition to the existing recorded pro-active actions, other examples of development include;
>
> - A formal Risk Assessment completed in relation to duty across different time zones and a set of guide lines were published as a result and the document (Acclimatisation Guidelines for Trans-Meridian Operations) is available to crew via the Flight Crew Notices Webpage.
> - All Pel-Air crew, when submitting a report in the Safety Management System online reporting system, must select 'Yes' in relation to fatigue report, and submit all the required details, irrespective of whether or not fatigue is considered a contributing factor.

- Further review, research and improvements were made in relation to the Extension of Duty assessment process.
- Completion of an FRMS Crew Survey.
- Pel-Air is also ISO 9001:2015 certified and holds BARS Gold Accreditation both of which are heavily weighted on the Safety Management System which include the FRMS.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB notes the operator undertook several actions to address its risk controls regarding fatigue management on its Westwind fleet, and more broadly across its operations. Although not every aspect of the safety issue was specifically addressed, the overall level of action reduced the risk of this safety issue.

Operator's installation of new aircraft systems on VH-NGA

Number:	AO-2014-190-SI-07
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's Westwind flight crew

Safety issue description:

Although the operator installed an enhanced ground proximity warning system (EGPWS) and traffic alert and collision avoidance system (TCAS) on VH-NGA in August 2009, it did not provide relevant flight crew with formal training on using these systems, or incorporate relevant changes into the aircraft's emergency procedures checklists.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-032

Given the aircraft was the only one of the operator's aircraft fitted with either EGPWS or ACAS, there was no safety action the operator could introduce that would specifically address this safety issue.

Following the accident, the operator advised CASA that it would provide the training to flight crew for any other aircraft that were subsequently fitted with the systems.

In October 2017, the operator advised the ATSB:

> As foreshadowed in the report, complete and comprehensive training in the EGPWS and TCAS systems was subsequently provided to all crew.
>
> All crew during their induction courses attend a formal and programmed TCAS/GPWS course prior to commencement of flying duties. In addition to this face to face training for all, there is a Computer Based Training module for the B200 Air Ambulance pilots due to the different operating method related to integration with the Proline 21 avionics pack fitted.
>
> Since the accident, Flight Crew Operating Manuals (FCOM's) were developed for all aircraft types and all contain detailed information (both technical and operational) regarding both TCAS and EGPWS.
>
> Most importantly, in 2010, formal Change Management policy and procedure was implemented across the Rex Group of Companies as part of our *Group Safety Management System Manual* chapter 6…with specific and particular reference to Introduction or modification of new equipment.
>
> This has been an integral part of all our business units ever since.
>
> Although another example of the introduction of such equipment has not occurred since the accident, numerous formal Risk Assessments have been completed as part of this formal Change Management

> process including for example the introduction of and the operational use by crew of performance data derived from APG (Aircraft Performance Group).
>
> The issue that was identified in relation to the introduction of the new equipment has not reoccurred and cannot occur in the future...

Current status of the safety issue

Issue status: Adequately addressed

Justification: Given the aircraft was destroyed in the accident, the safety issue risk in relation to VH-NGA was no longer relevant. However, the ATSB is satisfied that the processes introduced by the operator satisfactorily reduced the risk of similar events in the future.

Operator's hazard identification processes

Number:	AO-2014-190-SI-08
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's flight crew and other operational personnel

Safety issue description:

Although the operator's safety management processes were improving, its processes at the time of the accident for identifying hazards extensively relied on hazard and incident reporting, and it did not have adequate proactive and predictive processes in place. In addition, although the operator commenced air ambulance operations in 2002, and the extent of these operations had significantly increased since 2007, the operator had not conducted a formal or structured review of its risk controls for these operations.

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-032

After the accident, the operator undertook a detailed review of its air ambulance operation and the associated risk controls. In addition, it conducted a series of actions to improve its hazard identification processes. These included:

- conducted a workshop with a sample of the operator's managers and flight crew (across all fleets) to identify fatigue hazards and risk controls
- implemented an internal audit schedule that focussed on the actions introduced following the 18 November 2009 accident (including audits of fuel policy and fuel planning, FRMS, operational support provided to flight crew, training and checking and defect reporting during January to March 2010)
- provided additional training on the operator's SMS to all Westwind pilots.

In October 2017, the operator advised the ATSB:

> In addition to the actions already contained in the report, significant change has occurred within Pel-Air in relation to Hazard Identification. Pel-Air's Safety Management System today is more sophisticated, mature and robust and Pel-Air is more proactive in identifying and assessing hazards and risks.
>
> Pel-Air achieved and has held Flight Safety Foundation - BARS Program Gold registration standard since 2013 and the Executive Summary of the last and recent Audit Report includes the following in relation to Quality and Safety Management;
>
> > Pel-Air utilises the Group's Quality Assurance and Safety Management structure that has direct communication with senior management and regular safety meetings and safety related bulletins ensure dissemination of all safety related information.

> The company demonstrated there is a strong Safety Management System, Quality Assurance and Control Systems and that it has a dedicated commitment to hazard and occurrence reporting. All of which are signs of a mature and robust organizational structure.

Pel-Air has also received similar comments from other external auditing organisations.

As advised in relation to Safety Issue [AO-2014-190-SI-07], in 2010, formal Change Management policy and procedure was also implemented across the Rex Group of Companies as part of our Group Safety Management System and Manual chapter 6… which particularly includes the need to identify and consider new hazards as a result of constant change.

This has been an integral part of all Rex Group business units ever since.

The Rex Group's risk management framework and principles of risk management are based on ICAO Annex 19- Safety Management and the associated Safety Management Manual (Doc 9859), the International Standard ISO 31000: 2009 Risk Management- Principles and Guidelines, and the Australian Transport Safety Bureau (ATSB) Safety Investigation Guidelines- Risk Analysis:2011.

Some specific examples of the Group risk and change management policies being followed within Pel-Air since the accident have been;

- Formal Change Management Plan for the Westwind and Learjet operation moving from defence activities to civilian operations.
- Development of a specific set of procedures and processes for the jet operation in Malaysia which were subsequently published in Part C of the Operations Manual.
- Formal Risk Assessment to change to aircraft based checks in the Jet operation.
- Formal Risk Assessment for the introduction of APG performance data and charts.
- Formal Risk Assessment for night operations to certain Authorised Landing Areas...
- Formal Risk Assessment for duties that involve flight across numerous time zones.
- Numerous formal Risk Assessments for dispatch of international flights to Manus Island, Christmas Island, Papua New Guinea and Wake Island.
- Formal Risk Assessment prior to operating the B200 King Air on narrow runways.

These processes are constantly reviewed and, for example, Change Management processes were further bolstered in June 2015 as part of the approval process for Rex to obtain an Area AOC.

Event Categories and Causal Factors have also since been introduced from investigation and audit findings which further assists with predictive analysis.

Hazard Identification and the Safety Management System was also a feature article in the August 2017 edition of the Group Safety Newsletter.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied the safety action undertaken by the operator to improve its hazard identification processes following the November 2009 accident reduced the risk of this safety issue.

Operator's roles and responsibilities of key personnel

Number:	AO-2014-190-SI-09
Issue owner:	Pel-Air Aviation
Operation affected:	Aviation: Air transport
Who it affects:	Operator's flight crew and other operational personnel

Safety issue description:

The operator had not formally defined the roles and responsibilities of key positions involved in monitoring and managing flight operations, such as the standards manager for each fleet and the General Manager Flying Operations (Medivac and Charter).

Proactive safety action taken by Pel-Air Aviation

Action number: AO-2014-190-NSA-034

In June 2010, the operator amended its operations manual to include a description of the role and accountabilities of a standards manager. The manual stated a standards manager was:

- accountable to the head of training and checking for the supervision of their fleet type, check pilots and supervisory pilots
- accountable for the implementation of training and checking programs within their fleet
- responsible for the development of operating procedures for the fleet
- responsible for communicating front line issues to senior management.

The OM also included a list of more specific accountabilities for a standards manager.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that the action undertaken satisfactorily addressed this safety issue.

Regulatory requirements and guidance for fuel planning of flights to remote islands and isolated aerodromes

Number:	AO-2014-190-SI-10
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation: Air transport
Who it affects:	All operators and flight crew who conduct flights to remote or isolated aerodromes

Safety issue description:

Although passenger-carrying charter flights to Australian remote islands were required to carry alternate fuel, there were no explicit fuel planning requirements for other types of other passenger-carrying flights to remote islands. There were also no explicit Australian regulatory requirements for fuel planning of flights to isolated aerodromes. In addition, Australia generally had less conservative requirements than other countries regarding when a flight could be conducted without an alternate aerodrome.

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-035

Following the 18 November 2009 accident involving VH-NGA, the Civil Aviation Safety Authority (CASA) conducted a special audit of the operator of VH-NGA, which involved a detailed examination of the operator's fuel policy and procedures.

In addition, during the reopened investigation, CASA advised the ATSB that, commencing in December 2009:

> CASA conducted checks of all of the [Australian air ambulance] operators with aircraft capable of operating to a remote island aerodrome to ensure that they had a fuel policy that met the requirements for the carriage of "minimum safe fuel"…
>
> CASA inspectors contacted operators or examined relevant operations manuals to ascertain whether there were any relevant issues or potential problems meriting further investigation and/or action by CASA. CASA has not been able to locate documentation recording the abovementioned checks but it is understood the checks did not reveal any issues…

During the original ATSB investigation into the 18 November 2009 accident, the ATSB and CASA had a number of meetings in respect of the general nature of the available fuel planning and fuel management guidance and its possible influence on the development of this accident.

Following these discussions, in July 2010, CASA issued the Notice of Proposed Rule Making (NPRM) 1003OS (*Carriage of Fuel on Flights to a Remote Island*). The purpose section of the NPRM stated:

> 3.1.1 The purpose of this NPRM is to consult on a proposed change to CAO 82.0 relating to the carriage of fuel for flights to remote islands. A 'remote island' is currently defined as Lord Howe Island; Norfolk Island; or Christmas Island.
>
> 3.1.2 Presently, CAO 82.0, subsection 3A requires all passenger-carrying charter flights in aeroplanes to a remote island to carry enough fuel for flight from the remote island to an alternate aerodrome, unless an operator's operations manual states otherwise. There are no similar provisions for passenger-carrying aerial work, regular public transport (RPT), private or cargo-only charter flights.
>
> 3.1.3 The NPRM proposes an amendment to the Order which will require the carriage of enough fuel for flight from a remote island to an alternate aerodrome for all passenger-carrying aerial work, charter and RPT flights in aeroplanes, unless CASA approves otherwise.
>
> 3.1.4 The NPRM also proposes to re-designate Cocos (Keeling) Island as a remote island for the purposes of CAO 82.0.

The NPRM also stated:

> 3.7.4 In addition to changes to the relevant CAO, CASA also intends to review Civil Aviation Advisory Publication (CAAP) 234-1 relating to fuel requirements. This review is being undertaken in two phases: the first to enhance the guidance for fuel planning and in-flight fuel-related decision making on flights to remote destinations (including remote islands); and secondly a holistic review of guidelines for fuel and alternate planning.
>
> 3.7.5 The Standards and Recommended Practices (SARPs) promulgated by the International Civil Aviation Organization (ICAO) in relation to fuel and alternate requirements are currently being revised by ICAO, with amendments expected in the next 2 years. CASA is considering these changes and where considered appropriate, will propose to amend the relevant regulations in accordance with the revised ICAO SARPs.

In August 2012, CASA published a new version of CAAP 215-1(1) – Guide to preparation of operations manuals. The CAAP outlined suggested headings for an operations manual section on fuel policy. This included a sub-heading titled 'conditions for flights to remote islands'.

In December 2014, CASA amended the fuel planning requirements in CAO 82.0 for operations to remote islands so that these requirements applied to RPT operations and aerial work operations involving air ambulance functions (regardless of whether a patient was carried) in addition to passenger-carrying charter flights. The list of remote islands was also amended to include the Cocos Islands.

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-037

In August 2009, CASA commenced a project to review the Australian requirements for fuel and alternates (Project OS 09/13 – Fuel and alternate requirements). The terms of reference noted that the ATSB database had provided evidence that fuel quantity issues were becoming problematic, and it was proposed to strengthen CAAP 234, and to change CAR 234 in order to encourage industry to follow the contents of the CAAP. It also noted proposed amendments to ICAO Annex 6 for fuel and alternate requirements for commercial air transport operations 'require CASA to explore this issue and identify any potential issues the proposed ICAO amendments may have within the Australian aviation operating environment'.

In addition to changes to the requirements relating to Australian remote islands (see Safety action AO-2014-190-NSA-035), this project has involved various activities in relation to fuel planning.

On 25 June 2012, CASA advised the ATSB that amendment 36 to International Civil Aviation Organization (ICAO) Annex 6, State Letter AN 11/1.32-12/10 detailed a number of new Standards and Recommended Practices (SARP) in regard to fuel planning, in flight fuel management, the selection of alternates and extended diversion time operations (EDTO). In this respect, CASA provided the following update:

> CASA intends to review Civil Aviation Advisory Publication (CAAP) 234-1 relating to fuel requirements. The ICAO fuel and alternate Standards and Recommended Practices (SARPs) are the basis of these changes and will be coordinated by CASA project OS09/13. While this project will focus specifically on passenger-carrying commercial flights the project will also be reviewing fuel requirements generally. The project will now be conducted in four phases. The first three phases will involve amendments to the relevant Civil Aviation Order (CAO) applicable Civil Aviation Advisory Publication (CAAP) 234-1 and Civil Aviation Regulation (CAR) 234. The project objectives are as follows:
>
> – Phase 1 will involve amendments to the relevant CAOs and a review of CAAP 234-1 for flights to isolated aerodromes in light of the ICAO amendments. This phase will encompass fuel and operational requirements for flights to isolated aerodromes and will also consider the provision for flight to an alternate aerodrome from a destination that is a designated isolated aerodrome. The CAAP 234-1 will also be expanded to provide guidance and considerations necessary for flights to any isolated aerodrome, in particular when, and under what circumstances, a pilot should consider a diversion.
>
> – Phase 2 will involve amendments to the relevant CAOs and further review of CAAP 234 in light of the ICAO amendments. This phase will encompass regulatory changes related to the implementation of general fuel planning, in-flight fuel management and the selection of alternate aerodromes. This review will include the methods by which pilots and operators calculate fuel required and fuel on-board.
>
> – Phase 3 will involve amendment to CAR 234 to specify that the pilot in command, or the operator, must take reasonable steps to ensure sufficient fuel and oil shall be carried to undertake and continue the flight in safety. In addition, for flights conducted in accordance with Extended Diversion Time Operations (EDTO), CAO 82 and CAR 234 shall be amended to require consideration of a "critical fuel scenario" taking into account an aeroplane system failure or malfunction which could adversely affect safety of flight. It is anticipated that the methods chosen by the pilot-in-command and operator will therefore be sufficient to meet the requirements of CAR 234 to enable a flight to be undertaken and continue in safety.
>
> – Phase 4 will involve the publication of internal and external educational material along with conducting briefings where necessary.

and that:

> The amendment to the ICAO Annex 6 standards will be considered, and where appropriate, incorporated into the relevant legislation/advisory publication. In addition it is anticipated that there will be guidance material for operators who can demonstrate a particular level of performance-based compliance. The intent is to provide a bridge from the conventional approach to safety to the

> contemporary approach that uses process- based methods and Safety Risk Management (SRM) principles.
>
> The ICAO Fuel and Flight Planning Manual are reflected in the SARP to Annex 6. Inclusion of the provisions of the Amendment 36 SARPs will be captured throughout this project. The ICAO SARP becomes effective from November 2012.
>
> CASA will endeavour to make the changes as soon as possible - subject to third party arrangements such as drafting and resource availability. However the timing of the CAR changes will be subject to a timetable that is not necessarily able to be controlled by CASA.

In January 2016, as part of the project commenced in August 2009, CASA issued Consultation Draft (CD) 1508OS – Fuel and oil quantity requirements. The CD included proposed amendments to CAR 234 and CAAP 234. The explanation of the changes stated:

> Regulation 234 of the Civil Aviation Regulations 1988 (CAR) requires the pilot-in-command of an aircraft to take reasonable steps to ensure that the aircraft carries sufficient quantities of fuel and oil for the proposed flight to be undertaken safely. The regulation also requires the operator of an aircraft to take reasonable steps to ensure that an aircraft does not begin a flight unless it is carrying sufficient fuel and oil to allow the flight to be conducted safely.
>
> Australian Transport Safety Bureau (ATSB) reports have revealed incidents and accidents directly related to carriage of insufficient quantities of fuel. CASA proposes to address this safety issue by amending regulation 234 of CAR to provide updated fuel and oil requirements.
>
> The current regulation 234 of CAR allows courts to consider any guidelines provided by CASA when determining whether sufficient fuel and oil were carried on a flight, which includes the guidelines provided in CAAP 234-1(1). While some of the information provided in the CAAP should be read as a requirement empowered by the current regulation 234, other information is advisory in nature. CASA intends to the make clearer the distinction between the regulatory requirements and the guidance material by transferring the requirements for determination of fuel and oil quantity from the CAAP to a proposed legislative instrument.

The CD proposed included fuel planning and fuel management requirements in an instrument, referenced by an amended CAR 234. The proposed instrument incorporated the definition of minimum safe fuel for a flight to a remote island from CAO 82.0. However, there were no other changes associated with remote islands or isolated aerodromes.

In March 2017, CASA advised the ATSB:

> CASA is continuing, as part of the standards development process for the development of CASR Part 91 (General Operating and Flight Rules), to consider how to address the generalities of the 'isolated aerodrome issue'. The specific operational parts for air transport (CASR 121/133/135) and aerial work (CASR 138) will subsequently consider whether additional constraints or conditions are needed, or if alleviation is available under certain conditions. These provisions, along with the fuel and alternate determination provisions will be subject to public consultation as part of the operational part suite…
>
> The application of 'isolated aerodrome' SARPs is a vexatious issue because it relies on the interaction of the various ICAO SARPs that underpin it. It is very difficult to apply exactly the requirements of one ICAO SARP whilst not applying exactly the others that support it. In this case, the isolated aerodrome SARP relies on the fuel and alternate SARPs. These provisions require, inter-alia, that an alternate be nominated in almost all cases and that fuel quantities be determined on that basis. The isolated aerodrome SARP then allows alleviation from that requirement under certain conditions, most notably, when the nearest alternate is beyond approximately 90 minutes flight time.
>
> Australian legislation has provisions that accommodate our unique infrastructure, particularly the absence of predominately independent runways at many aerodromes supporting air transport operations. The Australian rule set also allows for flights to be conducted without an alternate under certain operating conditions, such as weather above set criteria.

In August 2017 (after receiving the draft ATSB report for the reopened investigation), CASA advised the ATSB:

> As mentioned in the report, prior to this accident CASA had already commenced Project OS 09/13 - Fuel and Alternate Requirements – to develop improvements to CASA regulations and orders relating to fuel carriage, fuel guidance and isolated aerodromes policy in light of proposed ICAO changes.
>
> On 23 December 2014, CAO 82.0 was amended to require RPT passenger carrying operations and aerial work operations for ambulance functions or for functions substantially similar to ambulance functions to meet the same remote island requirements that had applied to charter passenger carrying operations at the time of this accident.
>
> As part of this Project, CASA extensively examined the ICAO concept of isolated aerodromes, the historical context that led to the CASA remote island policy in place at the time of the accident and reviewed these in light of technological changes and the scope of Australian aviation operations to the identified remote islands. CASA determined that the implemented policy - that all passenger carrying charter, RPT and aerial work ambulance flights must nominate and plan for an alternate for all remote island operations and that a nominated alternate cannot itself be a remote island - was more conservative than the ICAO isolated aerodrome concept.
>
> More generically, the policy regarding when a flight can be conducted without providing for an alternate aerodrome is being examined as part of Project OS 99/08 - CASR Part 91.

ATSB comment

The ATSB acknowledges CASA's safety action has reduced the risk associated with flights carrying passengers to Australian remote islands. The ATSB also notes that Australian major airlines which operate to isolated aerodromes (other than Australian remote islands) have risk controls in place that exceed the current minimum regulatory requirements.

Nevertheless, the ATSB is concerned other types of operators carry passengers on flights to isolated aerodromes both in Australia and internationally, and there are still limited Australian regulatory requirements that specifically address the hazards associated with such flights.

The ATSB acknowledges CASA is still considering changes to fuel planning requirements for isolated aerodromes as part of its project on fuel and alternates. The ATSB also acknowledges the complexity of specifying more detailed regulatory requirements in this area in line with ICAO requirements. Nevertheless, the ATSB is concerned that this matter still has not yet been addressed, and accordingly it issues the following recommendation.

ATSB safety recommendation to the Civil Aviation Safety Authority

Action number: AO-2014-190-SR-042

Action status: Released

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority continue its work in reviewing fuel planning requirements and guidance and address the limitations associated with requirements and guidance for fuel planning of flights for all types of passenger operations to isolated aerodromes in Australia and internationally.

Regulatory requirements and guidance for in-flight fuel management

Number:	AO-2014-190-SI-11
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation: Air transport
Who it affects:	All operators and flight crew, particularly those who conduct flights to remote or isolated aerodromes

Safety issue description:

The available regulatory guidance on in-flight fuel management and on seeking and applying en route weather updates was too general and increased the risk of inconsistent in-flight fuel management and decisions to divert.

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-036

As outlined in the safety action for AO-2014-190-SI-10, since 2009 CASA has conducted or initiated a number of actions to improve requirements and guidance for fuel planning and fuel management. These activities also addressed in-flight fuel management aspects.

In August 2012, the following text was added to AIP ENR 1.1 (based on requirements in ICAO Annex 6, see *Additional safety action regarding fuel planning and management*):

> 8.10.4 In-Flight Fuel Management
>
> 8.10.4.1 The pilot in command shall continually ensure that the amount of usable fuel remaining on board is not less than the fuel required to proceed to an aerodrome where a safe landing can be made with the planned fixed fuel reserve remaining upon landing.
>
> 8.10.4.2 The pilot in command shall request delay information from ATC when unanticipated circumstances may result in landing at the destination aerodrome with less than the fixed fuel reserve plus any fuel required to proceed to an alternate aerodrome or the fuel required to operate to an isolated aerodrome.

In August 2012, CASA published a new version of CAAP 215-1(1) – Guide to preparation of operations manuals. Annex B of the CAAP provided guidance on information to include in an operations manual regarding the calculation of a critical point (CP) and a point of no return (PNR). However, the guidance was applicable to situations where the destination aerodrome and alternate aerodrome were on the same track as the flight path from the departure aerodrome to the destination aerodrome.

In December 2014, CASA amended the fuel planning requirements in CAO 82.0 for operations to remote islands so that these requirements applied to RPT operations and aerial work operations involving air ambulance functions (regardless of whether a patient was carried) in addition to passenger-carrying charter flights (see Safety action AO-2014-190-NSA-035). In addition, the requirements included:

> …during the flight, the pilot in command carries out in-flight fuel management to ensure that the aeroplane is always carrying sufficient fuel to enable it to reach its destination aerodrome as planned, or its nominated alternate aerodrome if necessary, with the required minimum fuel reserves intact.

In January 2016, CASA issued Consultation Draft (CD) 1508OS – Fuel and oil quantity requirements. The CD included proposed amendments to CAR 234 and CAAP 234. The proposed instrument included specific requirements for in-flight fuel management. More specifically, section 5 included:

> In-flight fuel quantity checks

> (2) The pilot in command must ensure that fuel quantity checks are carried out in-flight at regular intervals and the usable fuel remaining is evaluated to:
>
> (a) compare planned fuel consumption with actual fuel consumption; and
>
> (b) determine that the usable fuel remaining is sufficient to complete the planned flight in accordance with subsection 4 (3) (if applicable) and subsection 4 (4); and
>
> (c) determine the expected usable fuel remaining on arrival at the destination aerodrome.
>
> (3) The relevant fuel quantity data evaluated in accordance with subsection 5 (2) must be recorded after each fuel quantity check.

Section 6 of the instrument included specific procedures to be used in the event a fuel quantity check identified the fuel quantity was below the required level.

The proposed version of CAAP 234-1(2) associated with the instrument included additional guidance on in-flight fuel quantity checks and in-flight fuel management. This proposed guidance included:

> 6.4.1 After a flight has commenced, in-flight fuel management is the practical means by which the pilot-in-command ensures that fuel is used in the manner intended during pre-flight planning, or in-flight re-planning.
>
> 6.4.2 In-fight fuel management does not replace pre-flight planning or in-flight re-planning activities, rather it acts to ensure continual validation of planning assumptions that influence fuel usage and required fuel reserves. Such validation serves as a trigger for re-analysis and adjustment activities that ultimately ensure that each flight is safely completed with the planned fixed fuel reserve on board at an aerodrome where a safe landing can be made.
>
> 6.4.3 The pilot-in-command should ensure that a critical point of last diversion to the final en-route alternate is identified during the pre-flight planning stage. This is particularly important when operating to a remote island. During the course of the flight, the critical point should be assessed and, if necessary, revised based upon actual fuel consumption and in-flight conditions.
>
> 6.4.4 The revised critical point then becomes the last point by which the pilot-in-command should obtain and assess updated destination information (i.e. meteorological conditions, traffic and other operational conditions at the destination aerodrome) in order to validate the destination planning assumptions and allow timely diversion to occur if necessary (i.e. the revised critical point is the final opportunity to assess options for preserving the required fuel reserves should the destination aerodrome no longer be available).

In August 2017 (after receiving the draft ATSB report for the reopened investigation), CASA advised the ATSB:

> Since the accident, ICAO published in 2015 a comprehensive guidance document in relation to in-flight fuel management - Doc 9976 **–** Flight Planning and Fuel Management Manual.
>
> CASA intends to update CAAP 234-1 (1) to incorporate similar concepts to those outlined in the ICAO Manual but on a more limited scale and scope as part of Project OS 09/13 (Fuel and Oil Quantity Requirements).

ATSB comment

The ATSB acknowledges CASA has undertaken work since 2009 to revise and improve requirements and guidance for in-flight fuel management. However, the ATSB is concerned that, as yet, this work has not resulted in many actual changes to the requirements and guidance. Accordingly, the ATSB issues the following recommendation.

ATSB safety recommendation to the Civil Aviation Safety Authority

Action number: AO-2014-190-SR-043

Action status: Released

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority continue its work to address the limitations associated with the requirements and guidance for in-flight fuel management.

Classification of air ambulance operations

Number:	AO-2014-190-SI-12
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation: Air transport
Who it affects:	All operators and flight crew that conduct air ambulance operations

Safety issue description:

Although air ambulance flights involved transporting passengers, in Australia they were classified as 'aerial work' rather than 'charter'. Consequently, they were subject to a lower level of regulatory requirements than other passenger-transport operations (including requirements for fuel planning flights to remote islands).

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-038

As outlined in the safety actions to address safety issue AO-2014-190-SI-10, in July 2010 CASA issued the Notice of Proposed Rule Making (NPRM) 1003OS (*Carriage of Fuel on Flights to a Remote Island*). The NPRM proposed amending Civil Aviation Order (CAO) 82.0 to require air ambulance flights to Australian remote islands to carry sufficient fuel for an alternate aerodrome. This change was implemented in December 2014.

In June 2012 (during the original investigation into the 18 November 2009 accident involving VH-NGA), CASA advised the ATSB of its intent to regulate air ambulance/patient transfer operations as follows:

- Air Ambulance/Patient transfer operations in the proposed operational Civil Aviation Safety Regulations (CASRs) will be regulated to safety standards that are similar to those for passenger operations.
- While CASR Parts 138/136 will be limited to domestic operations and, if CASA decides to retain Air Ambulance/Patient transfer operations in these rule suites, any such operation wishing to operate internationally will also be required to comply with CASR Part 119. If, however, CASA decides to move these operations into CASR Parts 121/135/133 they will already be required to comply with CASR Part 119. Either way, Air Ambulance/Patient transfer operations will be regulated to the same standard as Air Transport Operations (ATO). In relation to Norfolk and Lord Howe Islands, all ATO which include Air Ambulance/Patient transfer, will be required to carry mainland alternate fuel.
- CASR Parts 119/121/135/133 are expected to be finalised by the end of 2012 and are currently proposed to commence in June 2014. CASR Parts 138/136 are expected to be made by June 2013 and are proposed to commence in June 2014. Given that the drafting of these CASR Parts are subject to third party arrangements (Attorney-General's Department) and CASA and the industry's ability to effectively implement the new rule suite, these timelines are subject to change.

In July 2013, CASA issued the Notice of Proposed Rule Making (NPRM) 1304OS (Regulations of aeroplane and helicopter 'ambulance function' flights as Air Transport operations). With the release of the NPRM, CASA stated:

> The purpose of this NPRM is to advise the public and aviation community of CASA's intent to regulate, to the greatest extent practicable, ambulance function flights to the same safety standards that are currently applicable to AT operations. This will extend to adoption of AOC certification requirements, operating standards and maintenance standards.

> The NPRM outlines a new and updated policy that specifically categorises Medical Transport (MT) flights so that they operate under the requirements of an AT AOC (issued under Part 119 of CASR) and the applicable operational rule set (i.e. Part 133 of CASR for helicopter operations and either Part 121 or 135 of CASR for aeroplane operations).
>
> The proposed policy will ensure that appropriate mechanisms are included within the AT regulations to afford MT flights with:
>
> - sufficient operational flexibility
> - the safety benefits available under Part 119 of CASR.
>
> CASA considers that Part 119 of CASR, with its robust operator management systems, should be implemented by (and integrated into) these essential passenger transport services. This policy and change of classification is based on CASA's recognition that the focus of these operations is primarily passenger-carrying in nature, albeit in a highly specialised manner, and conforms more closely to international norms for the conduct of these operations.
>
> However, CASA acknowledges that, in some cases, applying all of the Air Transport Operations suite of standards to MT flights would not be practicable. Due to the highly specialised nature of some MT flights, some of the rules in these operational Parts will not apply and other requirements that are not characteristic of normal AT operations will be addressed specifically for MT flights.

In October 2014, CASA published a summary of responses to the NPRM. Its conclusion stated:

> From the responses received, CASA believes there is strong support for the movement of the current aerial work purpose 'ambulance functions' into the AT rule set under the CASR 1998 operational and certification rule structure.
>
> In this regard, CASA acknowledges the industry's desire for some possible amendments to the proposal and the need for close consultation throughout this regulatory change project and its ongoing development.
>
> CASA agrees with the industry feedback regarding fatigue management of flight and other crew members in MT operations. Without limiting the availability of access to an FRMS, a specific appendix for CAO 48.1 will be required. The development of this appendix will be part of a separate project to be managed by CASA Standards SMS and Human Factors Section subject matter experts.
>
> CASA will now commence compiling final policy and drafting instructions to move this project forward and will (when these are in a suitable form) organise a consultation meeting with the MT industry to review these developments.

In March 2017, CASA advised the ATSB:

> Drafting instructions have been issued to the Office of Parliamentary Counsel (OPC) to incorporate medical transport flights into the applicable Air Transport Parts.
>
> Initial drafts of CASR Parts 119, 133, and 135, with medical transport operations included, have been received from the OPC and reviewed by CASA. In addition, these drafts have been road tested by internal review teams. The results of these reviews are now being compiled into further instructions for the OPC.
>
> The continuing development of these amendments, together with the drafting of the MOS for each Part, is ongoing.

ATSB comment

The ATSB acknowledges CASA has introduced improved fuel planning requirements for air ambulance flights to Australian remote islands. The ATSB also acknowledges CASA has taken significant steps since 2012 to reclassify air ambulance (medical transport) operations as air transport operations. However, the ATSB is concerned that over 4 years since the NPRM, this change has not yet been introduced. Accordingly, the ATSB issues the following recommendation.

ATSB safety recommendation to the Civil Aviation Safety Authority

Action number: AO-2014-190-SR-044

Action status: Released

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority continue reviewing the requirements for air ambulance / medical transport operations and address the limitations associated with the current classification of these flights as aerial work rather than air transport.

Regulatory surveillance – surveillance planning

Number:	AO-2014-190-SI-13
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation: Air transport
Who it affects:	All operators

Safety issue description:

Although the Civil Aviation Safety Authority (CASA) collected or had access to many types of information about a charter and/or aerial work operator, the information was not integrated to form a useful operations or safety profile of the operator. In addition, CASA's processes for obtaining information on the nature and extent of an operator's operations were limited and informal. These limitations reduced its ability to effectively prioritise surveillance activities.

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-039

In August 2017 (after receiving the draft ATSB report for the reopened investigation), CASA advised the ATSB:

> CASA implemented a national approach to surveillance in 2012 with the introduction of the CASA Surveillance Framework which included the CASA Surveillance Manual (CSM) and a supporting software tool, Sky Sentinel. This provided a formal process and platform for capturing and integrating a range of information about the activities of authorisation holders and the capacity for CASA to regularly assess this information.
>
> Authorisation management teams are required to conduct regular formal discussions of each allocated authorisation holder, taking into consideration their current safety status and focusing on operational changes. The output of these formal discussions is a shared understanding of the operations of authorisation holders providing a picture of whether any significant change has occurred. Recorded notes of formal discussions are captured in Sky Sentinel.
>
> Authorisation Holder Performance Indicator (AHPI) assessments are also required to be completed at regular intervals for each authorisation holder by the responsible authorisation management team. AHPI assessments apply a questionnaire-based tool located in Sky Sentinel that focuses on a number of factors commonly recognised as affecting or relating to safety performance/behaviours, and are conducted to ensure the safety performance of all authorisation holders are appropriately examined on an ongoing basis.
>
> It is a requirement that information relevant to surveillance considerations is to be recorded in Sky Sentinel as comments against the relevant authorisation holder. This includes intelligence gathered from various sources both within and outside of an authorisation management team.
>
> Formal discussion notes, AHPI assessments and general comments—along with other relevant information such as outstanding findings history and time since last surveillance—are integrated in Sky Sentinel for consideration as part of the authorisation holder assessment process. This allows for the identification of areas of concern and the development of proposals for surveillance to be considered in a surveillance priority review.
>
> CASA is currently developing and implementing a National Surveillance Selection Process (NSSP), which will be an enhanced systematic approach to the prioritisation of CASA's surveillance activities. This will build upon existing authorisation holder risk and performance profiling capabilities, further

> improving the collection and integration of operational and safety information to support a consistent risk-based approach to surveillance prioritisation and planning on a national basis. The NSSP is expected to be fully deployed by June 2018.

ATSB comment

The ATSB acknowledges CASA's surveillance processes have undergone significant evolution since 2009, and that it is continuing to review and develop its surveillance processes. It should also be noted that the ATSB will review CASA's oversight processes since the introduction of the CSM in 2012 during the course of other investigations, including investigation AI-2017-100 (Case study: implementation and oversight of an airline's safety management system during rapid expansion).

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that CASA has undertaken action to address this issue since November 2009.

Regulatory surveillance – scoping of audits

Number:	AO-2014-190-SI-14
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation: Air transport
Who it affects:	All operators

Safety issue description:

The Civil Aviation Safety Authority's procedures and guidance for scoping an audit included several important aspects, but it did not formally include the nature of the operator's activities, the inherent threats or hazards associated with those activities, and the risk controls that were important for managing those threats or hazards.

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-040

In August 2017 (after receiving the draft ATSB report for the reopened investigation), CASA advised the ATSB:

> CASA implemented a national approach to surveillance in 2012 with the introduction of the CASA Surveillance Framework which is documented in the CASA Surveillance Manual (CSM). The CSM identifies possible systems and system elements for holders of each authorisation type, and necessitates that those elements relevant to a particular authorisation holder are identified when preparing for a surveillance event—including noting areas of potential system vulnerability.
>
> In the preparation process, inspectors are required to review a range of information—including the authorisation holder's policy and procedures manuals—and identify specific areas and risks to be assessed or reviewed. The information, data and history known about the authorisation holder assists in determining the scope and depth of each surveillance event.
>
> CASA has developed safety risk profiles for a number of sectors of the aviation industry, and is continuing to develop safety risk profiles for the remaining sectors. These sector safety risk profiles enable a shared understanding between CASA and industry of hazards that sector participants must address in order to manage their risks and enhance safety outcomes for the sector. CASA is working to enhance the use of sector safety risk data to inform the scoping of surveillance activities.
>
> CASA is currently developing and implementing a National Surveillance Selection Process (NSSP), which will be an enhanced systematic approach to the prioritisation of CASA's surveillance activities.

> This will include improved authorisation holder risk and performance profile capabilities, including integration of relevant sector information. The NSSP is expected to be fully deployed by June 2018.

ATSB comment

The ATSB notes the surveillance planning and scoping form provided by CASA to its inspectors is still the same as the form used from 2004–2009, and this form does not refer to the nature of the operator’s activities, the inherent threats or hazards associated with those activities, and the risk controls that were important for managing those threats or hazards.

Nevertheless, the ATSB acknowledges CASA’s surveillance processes have undergone significant evolution since 2009, and that it is continuing to review and develop its surveillance processes. It should also be noted that the ATSB will review CASA’s oversight processes since the introduction of the CSM in 2012 during the course of other investigations, including investigation AI-2017-100 (Case study: implementation and oversight of an airline's safety management system during rapid expansion).

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that CASA has undertaken action to address this issue since November 2009.

Regulatory surveillance – assessing process in practice

Number:	AO-2014-190-SI-15
Issue owner:	Civil Aviation Safety Authority
Operation affected:	Aviation: Air transport
Who it affects:	All operators

Safety issue description:

Consistent with widely-agreed safety science principles, the Civil Aviation Safety Authority’s approach to surveillance of larger charter operators had placed significant emphasis on systems-based audits. However, its implementation of this approach resulted in minimal emphasis on evaluating the actual conduct of line operations (or ‘process in practice’).

Proactive safety action taken by the Civil Aviation Safety Authority

Action number: AO-2014-190-NSA-041

In August 2017 (after receiving the draft ATSB report for the reopened investigation), CASA advised the ATSB:

> CASA implemented a national approach to surveillance in 2012 with the introduction of the CASA Surveillance Framework including the CASA Surveillance Manual (CSM). The CSM aims to ensure that 'process in practice' is given appropriate emphasis in CASA's surveillance approach. This was emphasised through the surveillance training delivered to all inspectors.
>
> 'Process in practice' is one of the four attributes of the Management System Model (MSM) described in the CSM as operating within an authorisation holder's organisation to provide effective control. The CSM requires that the evidence gathered during surveillance events must be framed around all four attributes of the Management System Model to determine the level of control the authorisation holder applies. 'Process in practice' includes assessment of compliance with procedures.
>
> In describing the process to conduct process verification during surveillance events, the CSM states that during verification inspectors should adequately confirm the 'process in practice' including outputs, and requires all levels of an authorisation holder's operation to be considered during sampling.

> The CSM also prescribes recommended frequencies for the conduct of various surveillance types. One such type is an 'operational check', which is focused on assessing the actual conduct of line operations, a product check that the system is operating as intended and is compliant with legislative requirements. For the surveillance of Air Operator's Certificates (AOC), recommended frequencies are prescribed for 'operational check' as well as for other surveillance types—for large charter operators, 'systems audit' and 'operational check' are the two surveillance types with associated frequencies. Other surveillance events and types in excess of those recommended in the CSM can also be proposed as considered appropriate, to ensure adequate assessment of line operations.

ATSB comment

The ATSB notes the recommended frequencies for various types of surveillance tasks included in the CSM since 2012 were similar to the recommended frequencies for such tasks prior to the introduction of the CSM.

Nevertheless, the ATSB acknowledges CASA's surveillance processes have undergone significant evolution since 2009, and that it is continuing to review and develop its surveillance processes. It should also be noted that the ATSB will review CASA's oversight processes since the introduction of the CSM in 2012 during the course of other investigations, including investigation AI-2017-100 (Case study: implementation and oversight of an airline's safety management system during rapid expansion).

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that CASA has undertaken action to address this issue since November 2009.

Guidance information on the limitations of FAID

Number:	AO-2014-190-SI-16
Issue owner:	InterDynamics
Operation affected:	Aviation: Air transport and general aviation
Who it affects:	All operators and flight crew

Safety issue description:

Guidance material associated with the FAID bio-mathematical model of fatigue did not provide information about the limitations of the model when applied to roster patterns involving minimal duty time or work in the previous 7 days.

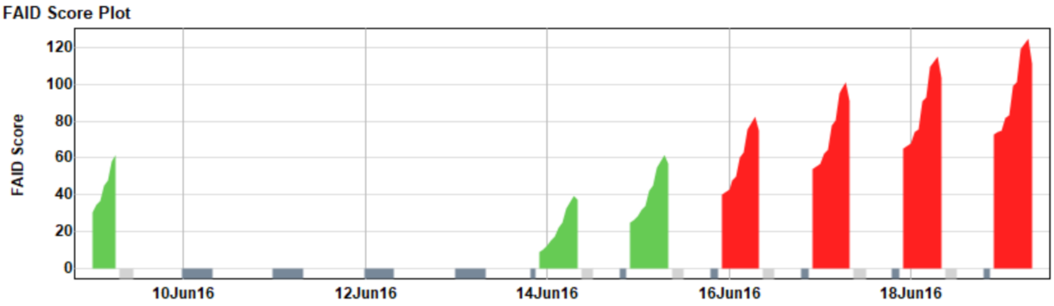
Proactive safety action taken by InterDynamics

Action number: AO-2014-190-NSA-045

In October 2017, InterDynamics (the provider of FAID) published a document titled BMM Warning' on its website (www.interdynamics.com). The document included the following statements:

> **Warning – know your biomathematical model and use it appropriately!**
>
> Not all biomathematical models are the same and will differ in their sensitivity to different work patterns and other parameters. The user of a biomathematical model should be familiar with how it works, what it is sensitive to, its strengths and weaknesses and suitability for evaluating the work context in question.
>
> **FAID**
>
> One of the strengths of the FAID biomathematical model is the inclusion of the accumulated contribution of work hours for the past 7 days. This component of the model is particularly helpful in

highlighting the increasing fatigue exposure over consecutive work periods, particularly night work, as shown below.



However, this is also a weakness when evaluating very intermittent work periods or work periods immediately after a long break. As shown above the first night shift after multiple days break has a low score.

The document also noted the usefulness of another biomathematical model (provided by the same company) for evaluating intermittent work or work after long breaks.

InterDynamics advised the warning document would also be provided to all new licence holders.

Current status of the safety issue

Issue status: Adequately addressed.

Justification: The ATSB is satisfied that the safety action will reduce the risk associated with this safety issue.

Additional safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence

Additional safety action regarding fuel planning and management

In July 2012, ICAO introduced additional provisions in Annex 6 Part 1, applying to destination alternate aerodromes (including flights to isolated aerodromes), in-flight fuel management, operations beyond 60 minutes to an en route alternate aerodrome and extended diversion time operations.

For flights to an isolated aerodrome, the amendment required that a point of no return (PNR) be determined for all flights to isolated aerodromes. Flights could not be continued beyond the PNR unless a current assessment of meteorological, traffic and other operational conditions indicated a safe landing could be made at the estimated time of use.

Provisions introduced for the in-flight management of fuel included ensuring the flight could proceed to an aerodrome and make a safe landing with the planned final reserve fuel intact. Those provisions included the contingency to notify air traffic control of a minimum fuel situation, where the pilot calculated that any change to the existing clearance might result in the aircraft landing with less than the planned final reserve fuel. Furthermore, if the pilot calculated that the aircraft would land with less than the planned final reserve fuel, they were required to declare a situation of fuel emergency.

Operators conducting flights beyond 60 minutes from a point on a route to an alternate aerodrome were required to identify en route aerodromes and provide the most up-to-date information including operational status and meteorological conditions. In achieving that outcome, operators were also required to take into account any provision for operational control and flight dispatch procedures, operating procedures and training programs.

In 2015, ICAO published the *Fuel Planning and Fuel Management (FPFM) Manual* (Doc 9976), providing operational guidance material to address the specific safety risks associated with alternate aerodrome selection, fuel planning and in-flight fuel management.

Additional safety action regarding fatigue management

In 2013, the International Civil Aviation Safety Organization (ICAO) modified the requirements in Annex 6 Part 1 to provide general requirements for a Fatigue Risk Management System (FRMS). Associated with these changes, it also issued the following guidance documents:

- Fatigue risk management systems (FRMS): Implementation guide for operators (released in 2011).
- Document 9966, Fatigue Risk Management Systems – Manual for Regulators (released in 2012)

In April 2013 the Civil Aviation Safety Authority (CASA) released revised fatigue management and flight and duty time requirements in Civil Aviation Order (CAO) 48.1 Instrument 2013. These requirements were to take effect for existing operators on 30 April 2016. This date was subsequently delayed.

The revised CAO 48.1 stated that, for air transport operations, an operator had to comply with a set of limits and requirements (dependent on the type of operation) or operate to a fatigue risk management system (FRMS), if that FRMS was approved by CASA. CASA provided detailed guidance for operators considering the use of an FRMS, in addition to a range of other guidance regarding fatigue management.

In addition, CASA released advisory publications regarding the use of bio-mathematical models of fatigue in 2010 and 2014.

Additional safety action by CareFlight

In October 2010, the air ambulance provider advised the ATSB that, following the 18 November 2009 accident, it implemented a policy of requiring a contracted safety audit of all of its air ambulance operators (in July and August 2010). Further audits were planned to take place annually.

In April 2015, the air ambulance provider advised it had reviewed its emergency response plan. It also introduced other changes, as discussed in *Pre-flight risk assessments for air ambulance tasks* and *Operator's emergency procedures and cabin safety*.

Additional safety action by the Bureau of Meteorology

In April 2010, the Bureau of Meteorology (BoM) released a flowchart outlined detailed guidance for forecasting low cloud at Norfolk Island. The flowchart comprised a series of questions for the forecaster to consider, including questions regarding anticipated source of moisture and the expected wind direction, the relative humidity and dewpoint depression. At around the same time, BoM had also introduced a flowchart outlining detailed guidance for forecasting low-level turbulence at Lord Howe Island.

As discussed in *Reliability of weather forecasting at Australian remote islands*, BoM regularly reviewed the reliability of its aerodrome forecasting processes using its TAF verification system. As indicated in Figure 30, the probability of TAFs accurately forecasting weather below the alternate minima increased during the period after 2009. However, because the false alarm ratio also increased, it was difficult to determine the extent to which the improvement was associated with improved forecasting models and practices and/or a more conservative approach to forecasting during this period.

As discussed in appendix J, the ATSB's review of weather information at Norfolk Island also indicated the amount of unforecast weather below the landing minima at Norfolk Island was lower in 2010–2014 compared to 2009. However, the extent that this was due to improved forecasting models and practices and/or a more conservative approach (as shown by false alarms) could not be determined.

The *Rural and Regional Affairs and Transport References Committee - Aviation accident investigations* report (published in May 2013) contained the following recommendation:

> That the relevant agencies review whether any equipment or other changes can be made to improve the weather forecasting at Norfolk Island. The review would include whether the Unicom operator should be an approved meteorological observer.

In response to that recommendation, during May 2014 the provision of weather services at Norfolk Island was reviewed. The review was conducted by BoM in consultation with Airservices Australia, the Department of Infrastructure and Regional Development and the Civil Aviation Safety Authority. The review examined:

- the existing meteorological equipment and service arrangements in support of aviation operations at Norfolk Island, including a comparative assessment against other locations
- opportunities to upgrade meteorological equipment at Norfolk Island to improve the support provided to aviation operations
- opportunities to improve existing weather observation and forecasting processes, services and outcomes at Norfolk Island, including consideration of the Unicom operator being an approved meteorological observer.

The review concluded that the existing meteorological equipment at Norfolk Island was comparable to equipment available at other similar aerodromes within Australia and was sufficient to support the current aviation activity. However, several potential developments were identified, with improved observational equipment becoming available during the next 2–3 years, providing enhanced services at locations where aviation forecasts were provided by BoM. These enhancements included:

- availability of output from the Japanese Himawari 8 satellite, providing significantly improved high resolution imagery with more available data channels, at more frequent intervals and access to an extended range of diagnostic products
- commissioning of a lightning detection service covering the Australian flight information regions
- trialling of weather cameras for installation at aerodromes and if successful, installation of a weather camera at Norfolk Island
- upgrading the resolution provided by the Norfolk Island weather radar and the introduction of GPS sonde technology, reducing the number of outages in the weather radar due to the tracking of weather balloons released at Norfolk Island
- reviews planned of BoM processes for forecasting fog and turbulence at Norfolk Island
- planned implementation of a data visualisation system for forecasters, to display and overlay combinations of meteorological observations, satellite imagery, weather radar and data from numerical weather prediction models.

The review group also considered if it was desirable that the Unicom operator should be a qualified weather observer. The group concluded that it was not necessary for the Unicom operator be an approved weather observer to transmit simple, factual statements about the weather. This included where the Unicom operator was reading out the observations from BoM's automatic weather station (AWS) on the Unicom frequency.

The review group also noted the airport operator could install a VHF transmitter to enhance the service provided by the existing automatic weather information service (AWIS), which would enable pilots to directly access observations made by the AWS over VHF radio.

In August 2016, BoM also advised the ATSB of additional updates regarding its forecasting processes applicable to Norfolk Island:

> From July 2015, the Bureau of Meteorology has been receiving satellite observational data from Himawari-8. Himawari 8 offers significant improvement in frequency, resolution and precision and is used extensively within the Bureau to assist in real-time analysis and forecasting. The information is also fed into the Bureau's numerical weather prediction (NWP) models… In addition, a low-cloud/fog enhancement and detection capability is now available to meteorologists, further increasing their situational awareness and supporting forecasting improvements for Norfolk Island.
>
> The weather camera trial has been finalised and a weather camera is expected to be installed and operational at Norfolk Island by the end of September 2016… [Note: The Norfolk Island weather camera became operational for BoM in September 2016. In addition, in May 2017 Airservices Australia provided public access to the network of BoM weather cameras on their website.]
>
> The spatial reporting resolution of the Norfolk Island weather radar was upgraded from two kilometres to 0.5 kilometres in 2014…
>
> GPS sondes have been used at Norfolk Island for more than a year now and have replaced the morning weather balloon flights to measure wind, temperature and relative humidity data. This has provided an opportunity to remove one of the 90 minute gaps in the radar weather watch coverage where the radar was previously unavailable to the meteorologists for that period as it was used to track the balloons…
>
> As part of its Quality Management System, the Bureau continues to review its forecasting methods. This includes improving forecasting capabilities at Norfolk Island. New fog climatology for Norfolk Island has now been made available to meteorologists. In addition, further work is in progress to improve fog and turbulence forecasting at the island.

In September 2014, BoM published their final report *Review of aerodrome forecast services for the aviation industry*. This review was commenced during 2009 in response to requests from the aviation industry for a review of the provision of aviation weather services and also as a quality management requirement to meet the service standards recommended by the International Civil Aviation Organization.

The objectives of the review were to:

- establish guidelines and requirements for TAF service changes for an aerodrome, including the introduction, modification and termination of a service;
- establish guidelines for the times of validity of a TAF service;
- establish a process for the regular review of TAF locations and service;
- establish the minimum requirements for observations in order to both issue and maintain a TAF service;
- establish guidelines for the provision and prioritisation of observational infrastructure to support a TAF service;
- establish a quality framework and validation process to ensure the quality and continuous improvement of the TAF service; and
- better align service with funding attribution and user needs, including the establishment of a process for the provision of a TAF on a contractual basis.

The review published 15 recommendations. Significant to the provision of aviation weather services at Norfolk Island, the review found that the meteorological equipment infrastructure at Norfolk Island continued to meet the requirements[345] for a Class A TAF. Although Norfolk Island fell below the passenger/aircraft movement threshold for provision of a TAF funded by the meteorological service charge, it retained its status as an airport where a Category A TAF would continue to be provided. This was due to Norfolk Island being an external territory international airport and the remote location of the aerodrome.

[345] For a Category A TAF, this included an automatic weather station making routine observations of surface wind, QNH, temperatures, precipitation, ceiling and visibility data, at least once every minute.

Additional safety action regarding advisory information about weather

Although not related to this accident, BoM commenced publishing climatological tables for Australian aerodromes on its website from August 2010. These included average data each month over many years for low cloud and visibility, low cloud, visibility, wind and temperature. In January 2013, additional data was provided for special weather phenomena (including phenomena such as fog, thunderstorms and haze). The information was made available at www.bom.gov.au/aviation/climate.

In 2013, BoM commenced publishing 'aviation weather hazards' online brochures that described the general meteorological conditions and hazards at selected aerodromes, including Norfolk Island, Christmas Island, Lord Howe Island and the Cocos Islands. These brochures were made available on the BoM website at www.bom.gov.au/aviation/knowledge-centre.

The *Rural and Regional Affairs and Transport References Committee - Aviation accident investigations* report (published in May 2013) contained the following recommendation:

> The committee recommends that the Aeronautical Information Package (AIP) En Route Supplement Australia (ERSA) is updated to reflect the need for caution with regard to Norfolk Island forecasts where the actual conditions can change rapidly and vary from forecasts.

The Australian Government response to the recommendation (March 2014) stated:

> The Government supports this recommendation in-principle.
>
> Variability of weather conditions from forecast is something for which flight crews should always anticipate and plan irrespective of which airport they operate to, including island destinations.
>
> There are however, some concerns with the Committee's recommendation.
>
> The specific identification of weather variability for a single location within the AIP could introduce its own risks. There is potential for a lack of such a statement at other locations to imply that weather is not variable, or forecasts are more accurate, at those other locations.
>
> Commentary or classification about the reliability of weather forecasts of susceptibility to weather changes should not be done in isolation at a single location unless the safety implications have been assessed by the relevant agencies. Accordingly, Airservices is consulting with the BoM and CASA to determine whether the current ERSA provisions should be updated for Norfolk Island. If agreed, changes will be incorporated into the next scheduled issue of ERSA.

In March 2017, Airservices advised the ATSB that the work package to change the ERSA entry for Norfolk Island had been completed but due to an oversight had not been processed. After identifying the problem the change was processed as a priority, with a NOTAM issued about the pending change on 27 March 2017. The amendment added the following note to the Norfolk Island ERSA entry (under the 'additional information' section), published on 17 August 2017:

> Actual weather conditions can change rapidly and vary from forecasts.

Airservices advised there was no indication that similar additions to the ERSA would be made for any other aerodromes.

Additional safety action by air traffic services providers

In February 2015, the Civil Aviation Authority of Fiji advised:

> Upon receipt of the [original investigation] Final report [in 2012] it was sent on to the Service Provider with emphasis on page 6 (error made by the IFISO on cloud height; 6000ft passed instead of 600ft) and the need to ensure officers were made aware of the report and to be more vigilant.
>
> The Service Provider issued the report and a safety alert to the operational staff.

In March 2015, Airservices Australia advised the ATSB that:

> Airservices shared the ATSB [original investigation report] report with both Fiji and New Zealand and highlighted the opportunity to review procedures/practices via formal communication… to the counterparts in Fiji and New Zealand in November 2012.

> Subsequently, the three agencies collaborated in reviewing the relevant AIP sections and established that there are no fundamental differences in the requirements to pass weather related information.
>
> The occurrence (including the sequence of events) was workshopped with attendees at the South West Pacific Safety Forum (SWPSF) in May 2013. The terms of reference for the SWPSF have been amended to include discussions by forum members on incidents within FIRs that can be useful to other forum members for lessons learnt.

The minutes from the 2013 SWPSF meeting included:

> Airservices through the chair provided a presentation on a Australian Transport Safety Bureau (ATSB) report where on the night of 18 NOV 2009, where a Westwind II VH-NGA operated by Pel-Air Aviation Pty Ltd ditched into the ocean in bad weather off Norfolk Island airport following several landing attempts. The objective of the presentation was to review the lessons learnt and the importance of the communication between boundaries FIR's and pilots. The presentation provided a review of a power point timeline of the incident and demonstrated this as a learning opportunity to review what happened, and incorporate the lessons learnt through staff refresher training program.
>
> Airservices recommend the standing agenda be amended to provide an opportunity where if a incident occurs within a FIR it could be discussed to provide lesson learnt opportunity.
>
> Fiji indicated they are undertaking refresher training and this incident will form the basis for this training.

Additional safety action regarding aircraft certification requirements for ditching

In March 2015, following the US Federal Aviation Administration (FAA) assigned the Aviation Rulemaking Advisory Committee (ARAC) a new task to provide recommendations regarding the incorporation of airframe-level crashworthiness and ditching standards into the US Federal Aviation Regulations part 25 and development of associated advisory material. As a result, ARAC developed the Transport Airplane Crashworthiness and Ditching Working Group.

Details of the tasking were outlined in the Federal Register in June 2015 (vol. 80, no. 107). The summary section included:

> The issue is during the development of current airworthiness standards and regulatory guidance, the FAA assumed that airframe structure for transport airplanes would be constructed predominantly of metal, using skin-stringer-frame architecture. Therefore, certain requirements either do not address all of the issues associated with nonmetallic materials, or have criteria that are based on experience with traditionally-configured large metallic airplanes. With respect to crashworthiness, there is no airframe level standard for crashworthiness. Many of the factors that influence airframe performance under crash conditions on terrain also influence airframe performance under ditching conditions. Past studies and investigations have included recommendations for review of certain regulatory requirements and guidance material to identify opportunities for improving survivability during a ditching event; consideration of these recommendations is included in this tasking.

The background section also included:

> Ditching: The FAA conducted several investigations on ditching and water-related impacts in the 1980s and 1990s. In conjunction with Transport Canada and the United Kingdom Civil Aviation Authority (UK CAA), the FAA recently investigated ditching/water-related impacts and ditching certification. One of the findings of these investigations is that current practices may not provide an adequate level of safety for the most likely ditching scenarios. From this research, a ditching event can be categorized as a specific type of emergency landing. Many of the factors (e.g., airframe energy absorption characteristics, structural deformation, etc.) that influence airframe performance under crash conditions on terrain also influence airframe performance under ditching conditions. Flight crew procedures, airplane configuration, safety equipment, and passenger preparedness also have a significant influence on survivability during a ditching event. Findings from these investigations include recommendations for review of certain regulatory requirements and guidance material related to the aforementioned factors to identify opportunities for improving survivability during a ditching event.

In early September 2017, the ATSB provided the FAA members of the ARAC with information from the draft ATSB report (reopened) on the 18 November 2009 accident involving VH-NGA so that this information could be used in the ARAC's considerations.

Additional safety action regarding emergency locator transmitters

Satellite detection of emergency locator transmitters

Although unrelated to the circumstances of this accident, during 2003 the International Cospas-Sarsat Programme had commenced developing the Medium-altitude Earth Orbiting Satellite System for Search and Rescue (MEOSAR). The system consisted of search and rescue signal repeaters installed on the Global Navigation Satellite Systems (GNSS) of Europe, Russia and the USA; complementing the existing Low-altitude Earth Orbit (LEO) and Geostationary Earth Orbit (GEO) satellites from the LEOSAR and GEOSAR systems.

Once fully operational, the MEOSAR system will be capable of near-real-time transmission of distress messages and if the distress beacon is within coverage of three or more GNSS SAR repeater-equipped satellites, an independently calculated position of the distress beacon location. With a full satellite constellation, it will be possible to calculate the location of the distress beacon within 10 minutes, 95 per cent of the time. The MEOSAR system will facilitate additional enhancements, such as a return-link-service to suitably equipped distress beacons acknowledging receipt of the distress message.

The Cospas-Sarsat MEOSAR system was not operational in 2009. A demonstration and evaluation phase commenced in 2013 and in late 2016, the system achieved an early operational capability for search and rescue agencies. Full operational capability of the MEOSAR system is anticipated during 2018.

Use of emergency locator transmitters

In May 2013, the ATSB published a research report titled *A review of the effectiveness of emergency locator transmitters in aviation accidents* (available from www.atsb.gov.au). The research report provided an overview of the use of emergency locator transmitters (ELTs) and provided basic quantitative evidence of their effectiveness. Analysis of ATSB's aviation occurrence database from 1993 to 2012 indicated ELTs functioned as intended in about 40–60 per cent of accidents in which their activation was expected. In addition, ELT activations accounted for the first notification to the Australian Maritime Safety Authority (AMSA) in about 15 per cent of incidents and ELT activations had been directly responsible for saving an average of four lives per year.

In accidents where ELTs did not work effectively (or not at all), it was found a number of factors could affect their performance. Those factors included incorrect installation, lack of water proofing, lack of fire proofing, disconnection of the co-axial antenna cable during impact, damage and/or removal of the antenna during impact and an aircraft coming to rest inverted following impact.

The safety messages highlighted in the research report included:

- pilots and operators of general aviation and low-capacity aircraft needed to be aware that a fixed fuselage mounted ELT cannot be relied upon to function in the types of accidents in which they were intended to be useful
- the effectiveness of ELTs in increasing occupant safety and assisting SAR efforts could be enhanced by using a GPS-enabled ELT, using an ELT with a newer 3-axis g-switch, ensuring it was correctly installed, ensuring the beacon was registered with AMSA and activating the beacon pre-emptively if a forced landing or ditching was imminent
- carrying a personal locator beacon (PLB) in place of (or as well as) a fixed ELT would most likely only be beneficial to safety if it was carried on the person, rather than being fixed or stowed elsewhere in the aircraft.

Additional information regarding distress beacons

AMSA's booklet *Distress Beacons and MMSI Information* contains important information and recommendations about the use of distress beacons and their use by persons in life threatening situations (available from www.amsa.gov.au). It provides information on the types of distress beacon and the advantages of beacons that are GNSS equipped. AMSA recommends the use of GNSS-equipped beacons because they provide the quickest and most accurate alerts.

Advice for using distress beacon includes that when in grave or imminent danger, two-way communication (such as phone or two-way radio) is the most effective means of communicating. If two-way communication is not available, then a distress beacon should be activated.

AMSA also recommended that personal locator beacons are physically carried on the person or within easy reach.

Additional safety action regarding instrument approach to land procedures at Norfolk Island

Although unrelated to the circumstances of the 18 November 2009 accident involving VH-NGA, increased implementation of Global Navigation Satellite System (GNSS) performance-based navigation (PBN) technologies has increased the availability of alternative instrument approach to land procedures. Such examples are the Required Navigation Performance (RNP) instrument approach and landing procedures.

For approved operators with suitably equipped aircraft and appropriately trained crew, a stand-alone GNSS RNP solution is achieved by the monitoring the accuracy of the navigation system, and if outside acceptable limits, an alert is provided to discontinue the approach. PBN and GNSS provides lateral navigation for runway aligned approaches with barometric vertical navigation. This type of approach requires advanced navigation, flight and cockpit control/display systems.

In 2012, RNP approaches were introduced for runways 11 and 29 at Norfolk Island. Those procedures could be flown by CASA-approved operators with appropriately trained crews in suitably equipped aircraft. The RNP procedure typically provided lower minimum descent altitudes and reduced visibility minima when compared to approaches using the ground-based navigation aids. For approved operations being conducted to final approach accuracy RNP 0.1 NM in August 2017, the minimum descent altitude was 690 ft for runway 29 or 324 ft above the runway threshold (requiring 1,800 m visibility), and 690 ft for runway 11 or 369 ft above the runway threshold (requiring 2,100 m visibility).

General details

Occurrence details

Date and time:	18 November 2009 – 1026 UTC	
Occurrence category:	Accident	
Primary occurrence type:	Fuel management event	
Location:	6.4 km WSW of Norfolk Island	
	Latitude: S 29° 03.270’	Longitude: E 167° 52.416’

Aircraft details

Manufacturer and model:	Israel Aircraft Industries (IAI) Westwind 1124A	
Year of manufacture:	1983	
Registration:	VH-NGA	
Operator:	Pel-Air Aviation Pty Ltd.	
Serial number:	387	
Total Time In Service	21,528 airframe hours	
Type of operation:	Air ambulance (aerial work)	
Persons on board:	Crew – 2	Passengers – 4
Injuries:	Crew – 1	Passengers – 4
Damage:	Destroyed	

Sources and submissions

Sources of information

The main sources of information during the investigation included:

- the flight crew and other aircraft occupants
- the aircraft's cockpit voice recorder and flight data recorder
- the operator (Pel-Air Aviation) and a number of flight crew, management personnel and safety personnel who worked for the operator in the period prior to the accident
- the air ambulance provider (CareFlight)
- the Civil Aviation Safety Authority (CASA) and a number of personnel who worked for CASA in the period prior to the accident
- the Bureau of Meteorology (BoM)
- a number of staff at the Norfolk Island Airport
- the Civil Aviation Authority of Fiji
- Airways New Zealand
- Airservices Australia
- the Australian Maritime Safety Authority (AMSA)
- the aircraft manufacturer (Israel Aircraft Industries)
- the life jacket manufacturer (EAM Worldwide) and the Australian authorised service agency for EAM life jackets
- a number of operators and flight crew involved in similar operations.

References

Arthur W, Bennett W, Stanush PL & McNelly TL 1998, 'Factors that influence skill decay and retention: A quantitative review and analysis', *Human Performance*, vol. 11, pp.57–101.

Battelle Memorial Institute 1998, *An overview of the scientific literature concerning fatigue, sleep, and the circadian cycle*, Report prepared for the Office of the Chief Scientific and Technical Advisor for Human Factors, United States Federal Aviation Administration.

Bes F, Jobert M & Schulz H 2009, 'Modeling napping, post-lunch dip, and other variations in human sleep propensity', *Sleep*, vol. 32, pp. 392–398.

Burian BK, Barshi I & Dismukes K 2005, *The challenge of aviation emergency and abnormal situations*, National Aeronautics and Space Administration Technical Memorandum NASA/TM-2005-213462.

Casner SM, Geven RW, Recker MP & Schooler JW 2014, 'The retention of manuals flying skills in the automated cockpit', *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 56, pp. 1506–1516.

Climent H, Benitez L, Roisich F, Rueda F & Pentecote N 2006, *Aircraft ditching numerical simulation*, Proceedings of the 25th Congress of the International Council of the Aeronautical Sciences (ICAS), Hamburg.

Civil Aviation Safety Authority 2010, *Biomathematical modelling in civil aviation fatigue risk management: Application guidance*. Available from www.casa.gov.au.

Civil Aviation Safety Authority 2014, *Biomathematical fatigue models*. Available from www.casa.gov.au.

Dawson D & McCulloch K 2005, ‘Managing fatigue: It’s about sleep’, *Sleep Medicine Reviews*, vol. 9, pp. 365–380.

Dawson D, Noy YI, Härmäc M, Åkerstedtd T & Belenkye G, 2011, ‘Modelling fatigue and the use of fatigue models in work settings’, *Accident Analysis and Prevention*, vol 43., pp. 549–564.

Dismukes RK, Berman BA & Loukopoulos LD 2007, *The limits of expertise: Rethinking pilot error and the causes of airline accidents*, Ashgate Aldershot UK.

Federal Railroad Administration 2010, *Procedures for Validation and Calibration of Human Fatigue Models: The Fatigue Audit InterDyne Tool*, Department of Transportation Technical Report DOT/FRA/ORD-10/14.

Flight Safety Foundation 2003, ‘Waterproof flight operations: A comprehensive guide for corporate, fractional, on-demand and commuter operators conducting overwater flights’, *Flight Safety Digest*, vol. 22–23.

Groff LS & Price JM 2006, ‘General aviation accidents in degraded visibility: A case control study of 72 accidents’, *Aviation, Space, and Environmental Medicine*, vol. 77, pp. 1062–1067.

Hall SJ, Ferguson SA, Turner AI, Robertson SJ, Vincent GE & Aisbett B 2017, ‘The effect of working on call on stress physiology and sleep: A systematic review’, *Sleep Medicine Reviews*, pp. 79–87.

Harrison H & Horne JA 2000, ‘The impact of sleep deprivation on decision making: A review’, *Journal of Experimental Psychology*, vol. 6, pp. 236–249.

Independent Transport Safety Regulator 2010, *Transport Safety Alert 34 - Use of bio-mathematical models in managing risks of human fatigue in the workplace*. Available from www.transportregulator.nsw.gov.au.

International Civil Aviation Organization 1998, *Human factors training manual*, Doc 9683-AN/950.

International Civil Aviation Organization 2011, *Fatigue risk management systems (FRMS): Implementation guide for operators*.

Johnson RA 1984, *Study on transport airplane unplanned water contact*, US Department of Transportation Technical Report DOT/FAA/CT-84/3.

Kahneman D 2011, *Thinking, fast and slow*, Allen Lane London.

Lauber JK 1984, ‘Resource management in the cockpit’, *Air Line Pilot*, vol. 53, pp. 20–23.

Lindenau O & Rung T 2009, *Review of transport aircraft ditching accidents*, paper presented at the 6th International Krash Users’ Seminar (IKUS6), Stuttgart.

McCulloch K, Fletcher A & Dawson D 2003, *Moving towards a non-prescriptive approach to fatigue management in Australian aviation: A field validation*, Report prepared for the Civil Aviation Safety Authority.

Monk TH 2005, ‘The post-lunch dip in performance’, *Clinical Sports Medicine*, vol. 24, e15–e23.

Nicol A & Botterill JS 2004, ‘On-call work and health: A review’, *Environmental Health: A Global Access Source*, vol. 3:15.

O’Connor P, Campbell J, Newon J, Melton J, Salas E & Wilson K 2008, ‘Crew resource management training effectiveness: A meta-analysis and some critical needs’, *International Journal of Aviation Psychology*, vol. 18, pp. 353–368.

O'Hare D, & Smitheram T (1995). ‘"Pressing on" into deteriorating conditions: An application of behavioral decision theory to pilot decision making’, *The International Journal of Aviation Psychology*, vol. 5, pp. 351–370.

Orasanu JM 2010, ‘Flight crew decision-making’, in BG Kanki, RL Helmreich & J Anca (Eds.) *Crew resource management*, Elsevier Amsterdam, pp. 147–179.

Orasanu J, Martin L & Davison J 2001, 'Cognitive and contextual factors in aviation accidents', in E Salas and G Klein (Eds.) *Linking expertise and naturalistic decision making*, Lawrence Erlbaum Mahwah NJ, pp. 209–226.

Patel AA & Greenwood RP 1996, *Transport water impact and ditching performance*, US Department of Transportation Technical Report DOT/FAA/AR-95/54.

Provine R 2005, 'Yawning', *American Scientist*, vol. 96, pp. 532–539.

Reason J 2007, *Managing the risk of organizational accidents*, Ashgate Aldershot UK.

R.G.W. Cherry & Associates Limited 2015, *Review and assessment of transport category airplane ditching standards and requirements*, US Department of Transportation Technical Report DOT/FAA/TC-14/8.

Salas E, Burke CS, Bowers CA, & Wilson KA 2001, 'Team training in the skies: Does crew resource management (CRM) training work?', *Human Factors*, vol. 43, pp. 641–674.

Salas E, DiazGradados D, Klein C, Burke CS & Stagl KC 2008, 'Does team training improve team performance?', *Human Factors*, vol. 50, pp. 903–933.

Salas E, Wilson KA, Burke CS & Wightman D 2006, 'Does crew resource management training work? An update, an extension, and some critical needs', *Human Factors*, vol. 48, pp. 392–412.

Salas E, Wilson KA, Burke CS, Wightman DC & Howse WR 2006, 'A checklist for crew resource management training', *Ergonomics in Design*, vol. 14, pp. 6–15.

Staal MA 2004, *Stress, cognition, and human performance: A literature review and conceptual framework,* National Aeronautics and Space Administration Technical Memorandum NASA/TM-2004-212824.

Thomas MJW & Ferguson SA 2010, 'Prior sleep, prior wake, and crew performance during normal flight operations', *Aviation, Space, and Environmental Medicine*, vol. 81, pp. 665–670.

To PT 1986, A study of the structural integrity of the Canadair challenger at ditching, Proceedings of the 15th Congress of the International Council of the Aeronautical Sciences (ICAS), London.

Wickens CD & Hollands JG, 2000, *Engineering psychology and human performance*, 3rd edition, Prentice-Hall International Upper Saddle River, NJ.

Wiegman DA, Goh J & O'Hare D 2002, 'The role of situation assessment and flight experience in pilots' decisions to continue visual flight rules flight into adverse weather', *Human Factors*, vol. 44, pp. 189–197.

Williamson A, Lombardi DA, Folkard S, Stutts J, Courtney TK & Connor JL 2011, 'The link between fatigue and safety', *Accident Analysis and Prevention*, vol. 43, pp. 498–515.

Wisher RA, Sabol MA & Ellis JA 1999, *Staying sharp: Retention of military knowledge and skills, US Army Research Institute*, Special Report 39.

Zilli I, Giganti F & Uga V 2008, 'Yawning and subjective sleepiness in the elderly', *Journal of Sleep Research*, vol. 17, pp. 303–308.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the flight crew, the medical personnel and passenger on the aircraft, the operator (and some former personnel from the operator), CareFlight, CASA, BoM, Airservices Australia, the Civil Aviation Authority of Fiji, Airways New Zealand (via the Transport

Accident Investigation Commission of New Zealand) and Israel Aircraft Industries (via the Israel Ministry of Transport and Road Safety). Sections of the draft report were also provided to other organisations, including the Norfolk Island Regional Council (current operator of the Norfolk Island Airport), the former manager of the Norfolk Island Airport, the Australian Maritime Safety Authority (AMSA), EAM Worldwide and InterDynamics.

Submissions with comments were received from the captain, the flight nurse, the operator, CASA, BoM, InterDynamics, AMSA, the Norfolk Island Regional Council and the former manager of the Norfolk Island Airport. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A – Cockpit voice recorder information

Recorder details

The aircraft was equipped with a L3 Communications solid-state cockpit voice recorder (CVR). Maintenance documentation provided by the operator gave the following details for the CVR fitted to VH-NGA:

- model – FA2100
- part number – 2100-1020-02
- serial number – 000542403.

These details matched those from the CVR recovered from the aircraft wreckage during November 2015.

An example of a FA2100 CVR is shown in Figure A1. The CVR unit recovered from VH-NGA is shown in Figure A2 and the crash-survivable memory unit, as removed from the CVR chassis, is shown in Figure A3.

Figure A1: Comparison (undamaged) FA2100 CVR - exterior

Source: L3 Aviation Recorders

Figure A2: Recovered CVR at the ATSB laboratories in Canberra, 16 November 2015

Source: ATSB

Figure A3: CVR crash-survivable memory unit, 16 November 2015

Source: ATSB

Data download

The CVR memory download was conducted by a team of ATSB specialists and two officers with flight recorder expertise from the Directorate of Defence Aviation and Air Force Safety (DDAAFS). The entire data download process was performed during 16–20 November 2015. The DDAAFS officers were part of the team for the entire data recovery period.

The steps involved in the CVR data download included:

- On 16 November, a disassembly plan for the recorders was discussed by the team.
- The CVR was disassembled during the morning of the 16 November in accordance with the CVR manufacturer's documentation. When the crash-survivable memory unit (CSMU) was opened there was no sign of water ingress. Visual inspection under a microscope did not reveal any signs of corrosion to the memory board.
- The CVR memory board was securely stored, with desiccant bags, in a fireproof safe while the flight data recorder (FDR) was disassembled.
- During the afternoon of 17 November work was resumed on the CVR memory board. Due to the possibility of damage/corrosion to the memory board cable, it was cut off in accordance with the manufacturer's procedures. A new cable was soldered onto the stub of the original cable and impedances were checked to ensure the solder connections were conductive.
- A 'known good' CVR chassis, compatible with the recovered accident CVR configuration, was used as the download platform. Before attempting to recover the data from the accident memory module, the 'known good' CVR was downloaded using the manufacturer's portable interface (PI) unit. As expected, a compressed data file of size 59,168 KB was obtained. This download was successful.
- The 'known good' download chassis was then reconfigured to match the part number and modification status of the CVR from VH-NGA. The reconfiguration was performed using Version 2.5 of the computer interface communications cable (CICC) loader software. A '2100-1020-xx (AIK, 120 min HQ-ONLY CVR, MD7)' load file was selected and the 'known good' CVR was successfully reconfigured.
- The accident CVR's memory board was connected to the 'known good' CVR chassis and was downloaded using a PI. During the download process, all indications on the PI were normal. As expected, a compressed download file (NGA2.CVR) of size 112,776 KB was obtained.

CVR system

CVR recordings contain flight crew speech but they may also capture other relevant sounds, such as sounds relating to engine operation, flight control and navigation systems and environmental conditions such a rain on the windscreen.

The CVR system installed on an aircraft comprises the CVR unit, a control unit, an area microphone and microphones at each flight crew position. The CVR unit is capable of simultaneously recording four channels of information. The CVR system fitted to aircraft operated in a two-crew configuration, such as the Westwind 1124A, has a separate channel dedicated to each flight crew position audio system and another for signals detected by the cockpit area microphone (CAM). The function of the CAM is to capture the audio environment in the cockpit. An additional channel is also available and can be used to record audio from the public address system or an additional crew position.

The CVR control unit, located in the cockpit, provides testing and monitoring functions of the CVR unit through the TEST and ERASE switches. A meter provides cockpit indication of the CVR unit monitor signals and a headset jack allows monitoring of the audio being recorded. The meter can also provide an indication of the serviceability of the CVR unit when the TEST function is activated.

A channel associated with a flight crew position would be expected to contain signals relating to crew conversation regarding the operation and management of the flight, communication with air traffic services (ATS) and any activation of aural alerts relating to aircraft systems (for example, landing gear unsafe or fire warning). The CAM channel would be expected to provide a record of the cockpit audio environment, such as sounds relating to engine/propeller operation, operation of switches and levers, activation of the landing gear and weather such as rain or hail.

Aircraft installation

The CVR in VH-NGA was installed in the unpressurised tail cone section of the aircraft, aft of the FDR. Recording commenced when the No. 2 AC bus was powered and the avionics master switch was ON.

The CAM was situated on the CVR control panel, which was on the centre pedestal console between the two crew seats.

Maintenance records showed that at some time between 29 September 2008 and 29 January 2009 the CVR unit was changed from an L3 model A100A to the FA2100 model that was fitted at the time of the accident. The A100A model used magnetic tape as the recording medium, providing a 30-minute recording duration and lesser crashworthiness when compared to the FA2100.

The wiring interface connector for the CVR[346] was examined by ATSB and found to conform to the CVR manufacturer's A100A installation wiring diagram.

CVR channel format and recording duration

The recording specifications and modification status of the CVR fitted to VH-NGA indicated each of the four channels on the CVR was capable of recording at least 120 minutes of 'high quality' audio.

The manufacturer's specification indicated allocation of channel 1 was for audio output from the third crewmember or public address system, channel 2 for the first officer, channel 3 for the captain and channel 4 for the CAM. The CVR recordings were made in the form of a continuous loop, with the older data being continuously erased/overwritten by new data.

The characteristics of the recorded data were:

- channels 1, 2, 3 – 24 kbps, audio bandwidth of 150–3,500 Hz
- channel 4 – 48 kbps, audio bandwidth of 150–6,000 Hz.

The intelligibility or 'quality' of the recorded audio signals was a combination of the fidelity of the CVR system components, which included the microphones, radio equipment, audio selection and distribution equipment, as well as the recording unit itself.

The CVR download file was decompressed using the CVR manufacturer's audio utility software. The size of the decompressed audio file for channels 1, 2 and 3 was 116,470 KB and for channel 4 was 232,939 KB. The following allocation of channels was detected for the CVR installed in VH-NGA:

- channels 1, 2 and 3 – flight crew audio
- channel 4 – CAM.

Examination of the audio output from the CVR showed the recorded duration was 124 minutes and 7 seconds.

Timing correlation

The CVR did not record UTC time. However, correlation of the CVR recording to ATS transmissions[347] enabled the UTC time of the CVR recording to be established. This technique also enabled the data from the FDR to be synchronised with the CVR recording by using the ditching impacts. These impacts were clearly audible on the CVR recording and evident in the vertical acceleration data recorded by the FDR. The correlation between the FDR, CVR and the UTC time is expected to be within ± 1 second.

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[346] The wiring connector interface was removed with the CVR recording unit during the recovery.

[347] ATS communications are recorded and encoded with a timestamp.

The recovered audio covered the period of the flight from 0821:55 UTC, when the aircraft was in cruise at FL 390, until the end of recording during the ditching.

CVR audio quality

The ATSB used the CVR quality rating scale as developed by the US National Transportation Safety Board (NTSB). That rating scale characterised the quality of the CVR recording using a five-point scale. Figure A4 is an extract from an NTSB Group Chairman's factual report with the quality rating scale.[348]

Figure A4: NTSB CVR quality rating scale

CVR Quality Rating Scale

The levels of recording quality are characterized by the following traits of the cockpit voice recorder information:

Excellent Quality	Virtually all of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate only one or two words that were not intelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.
Good Quality	Most of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate several words or phrases that were not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.
Fair Quality	The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the CVR system that distorts or obscures the audio information.
Poor Quality	Extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to-noise ratio) or by a mechanical or electrical failure of the CVR system that severely distorts or obscures the audio information.
Unusable	Crew conversations may be discerned, but neither ordinary nor extraordinary means made it possible to develop a meaningful transcript of the conversations. This type of recording is usually caused by an almost total mechanical or electrical failure of the CVR system.

Source: NTSB

The channel allocation on the CVR from VH-NGA did not conform to the channel allocation specified in the CVR manufacturer's maintenance manual, although the signals were connected to recording unit inputs with corresponding audio channel bandwidth characteristics.

The amplitude of the recovered crew channel audio was either extremely low level or extremely high. This caused significant interference and distortion and increased the complexity of the

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348 This rating scale was downloaded from 'https://dms.ntsb.gov/public/58000-58499/58493/588826.pdf'.

analysis of information recorded by the CVR. In some cases pertinent crew conversation was not able to be clearly discerned.

Signals recorded on channel 1 related to flight crew conversation and radio communication. These signals were of poor quality. Sounds and conversation were able to be analysed but required significant amplification and filtering techniques to make the information interpretable.

Signals recorded on channel 2 were considered unusable. Sounds and conversations were able to be discerned but, despite significant amplification and filtering to clarify the audio, no significant conversational narrative was able to be transcribed. The only signals able to be identified were related to the 400 Hz AC power supply.

Signals recorded on channel 3 related to flight crew conversation and radio communication. The recorded amplitude of the radio communications was high when compared to the flight crew conversation, resulting in some of the crew conversations being masked by received radio communication and background static and noise, particularly when the HF radio was selected as a crew audio input. These signals were of fair quality, sometimes reducing to poor quality during radio transmissions.

Signals recorded on channel 4 related to the cockpit area microphone and these signals were of fair quality.

Despite the limitations with the recordings, the investigation team was able to transcribe all of the transmissions between the flight crew and other parties and almost all of the operationally-relevant conversations between the flight crew. Both flight crew listened to sections of the CVR and provided clarification of some phrases on the CVR.

CVR maintenance

Periodic maintenance was required for all CVR equipment. This maintenance included inspection at 12-monthly intervals (or 2,000 flying hours, whichever occurs first). The operator’s system of maintenance (SOM) also required the operation of the CVR be checked at 400-hourly intervals.

However, the test procedure contained in the operator’s SOM was not appropriate for A100A or FA2100 recorders and it was not possible to verify the correct operation of the CVR channels using that procedure.

A maintenance and rectification sheet recorded that the FA2100 CVR fitted to VH-NGA had failed a test during scheduled maintenance during January 2009 and the CVR was replaced and ‘checked OK’. However, the rectification sheet did not detail any alternate procedure used to accomplish the successful test. Similarly, on 26 August 2009 a complete systems check was conducted on the CVR as part of the annual maintenance requirements and nil defects were found.

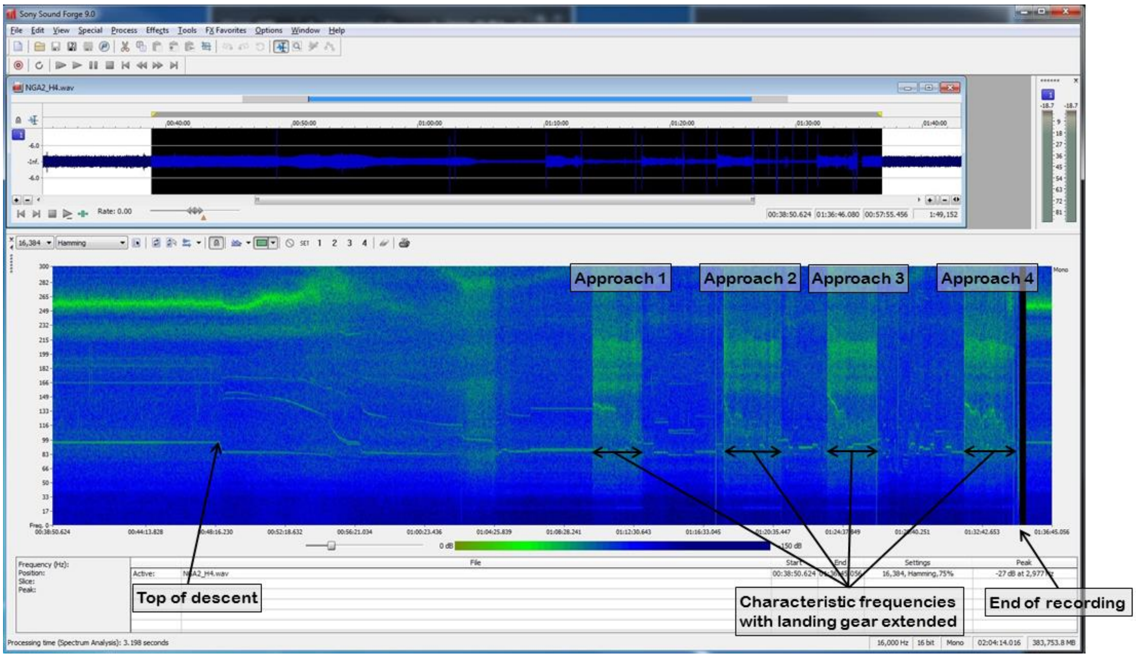
The ATSB was unable to establish how long the issues with the quality of some of the CVR channels had existed. However, these issues would have been detected using the appropriate test procedure for that model of recorder.

Background sounds relating to landing gear position

The crew configured the aircraft for landing during the various approaches and then reconfigured the aircraft during the subsequent missed approaches. As only basic flight trajectory information was recorded by the FDR system, the CVR recording was examined to detect information relating to the landing gear and flap configuration at various stages of the approaches.

The CAM recording channel contained information relevant to the aircraft configuration. Figure A5 shows an audio frequency spectra plot of aircraft operation from top of descent to the end of the recording.

Figure A5: Audio frequency spectra plot of signals recorded by the cockpit area microphone



Source: ATSB, from analysis of the continuous-loop recording from the CVR.

Characteristic frequency patterns were identified on the CAM channel, associated with aircraft operation with the landing gear extended. These frequencies included the airflow noise associated with the extended landing gear and fairings.

The landing gear system was also fitted with an alerting system to assist the flight crew to detect an incorrect aircraft configuration during approach and landing. This system comprised a landing gear warning horn and an annunciator light. For VH-NGA, aircraft serial number 387, the landing gear warning horn operated when:

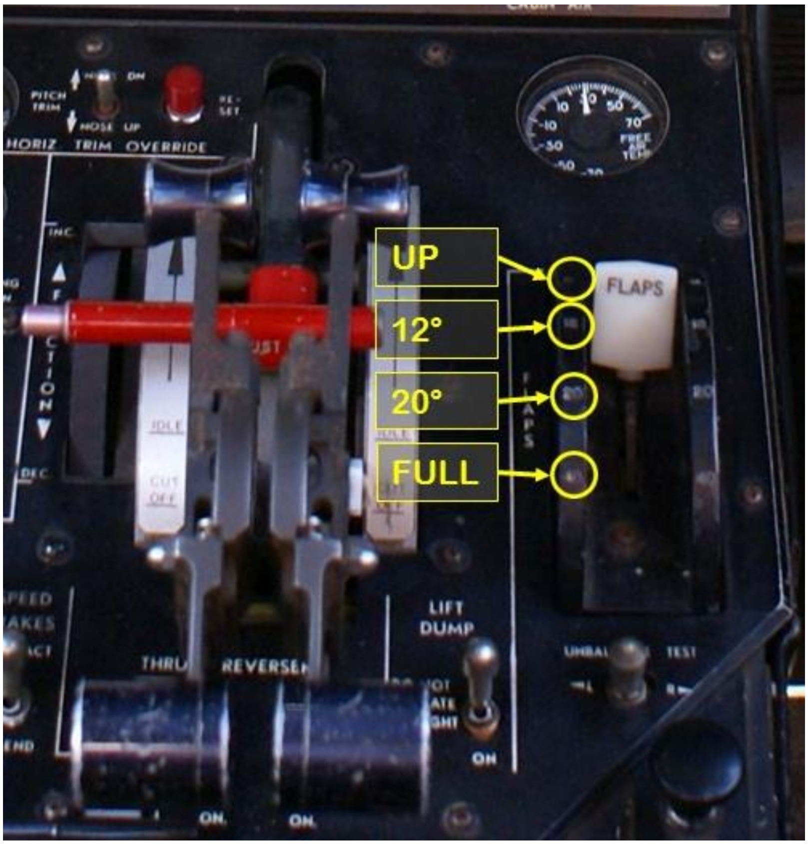
- any of the landing gear was not down and locked, the thrust levers were in the idle position and the airspeed was less than 150 kt
- any of the landing gear was not down and locked and the flaps were extended to 40°, irrespective of airspeed.

An aural alert warning with a fundamental frequency of 596 Hz briefly activated during the second missed approach (to runway 29) and the third missed approach (to runway 11). This warning appeared to activate as landing gear retraction was announced by the crew (with the retraction of the landing gear commencing before changing the flap setting from 40°). The warning also activated when the landing gear was selected UP about 15 seconds prior to ditching (with the flap setting remaining at 40°).

Background sounds relating to flap operation

The trailing edge flaps fitted to the Westwind 1124A had four positions - UP (0°), 12°, 20° and FULL (40°). The flaps were activated by a flap selector on the centre pedestal (see Figure A6) and each flap selection position was associated with a physical detent, such that any movement of the flap lever resulted in an audible click on the CAM recording channel.

Figure A6: Photograph of flap selector mounted on centre pedestal and showing flap positions



Source: Cockpit photograph Pel-Air, modified by ATSB.

A review of the CAM channel identified there were distinctive click sounds that corresponded to almost all known flap setting changes. The only two exceptions occurred during the start of the second and third missed approaches, when potential sounds were masked by the activation of the landing gear warning warn. Table A1 provides further details. As indicated in Table A1, there was no indication the flight crew selected full flap during the fourth approach.

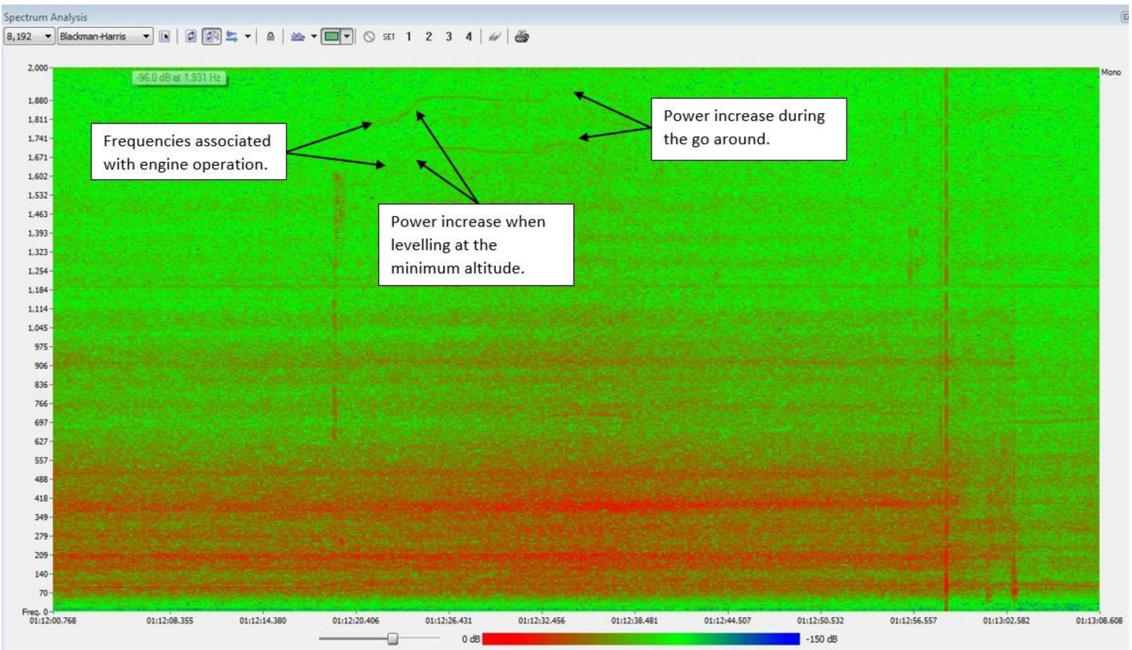
Table A1: Flap operation and activation of landing gear warning horn

Time of flap setting change (HHMM:SS)	Click (Yes/No)	Flight crew callout (Yes/No)	Flap position from/to	Comment
0955:20	Yes	Yes	Extension from UP to 12°	First approach runway 29
0955:29	Yes	Yes	Extension from 12° to 20°	
1002:36	Yes	Yes	Extension from 20° to FULL	
1004:08	Yes	Yes	Retraction from FULL to 20°	Following missed approach
1004:24	Yes	Yes	Retraction from 20° to 12°	
1004:35	Yes	Yes	Retraction from 12° to UP	
1007:53	Yes	Yes	Extension from UP to 12°	Second approach runway 29
1008:04	Yes	Yes	Extension from 12° to 20°	
1009:58	Yes	Yes	Extension from 20° to FULL	
1012:15	No	No	Retraction from FULL to 20°	Following missed approach. Sounds potentially masked by activation of the landing gear warning horn.
1012:24	Yes	No	Retraction from 20° to 12°	
1012:30	Yes	Yes	Retraction from 12° to UP	
1012:59	Yes	Yes	Extension from UP to 12°	Third approach runway 11
1014:38	Yes	Yes	Extension from 12° to 20°	
1016:01	Yes	Yes	Extension from 20° to FULL	
1017:45	No	No	Retraction from FULL to 20°	Following missed approach. Sounds potentially masked by activation of the landing gear warning horn.
1017:56	Yes	No	Retraction from 20° to 12°	
1018:23	Yes	Yes	Retraction from 12° to UP	
1018:59	Yes	Yes	Extension from UP to 12°	Fourth approach runway 29
1021:31	Yes	Yes	Extension from 12° to 20°	Remainder of approach conducted at Flap 20°
1025:00	No	No	Extension from 20° to FULL	Final descent for ditching

Background sounds relating to engine speeds

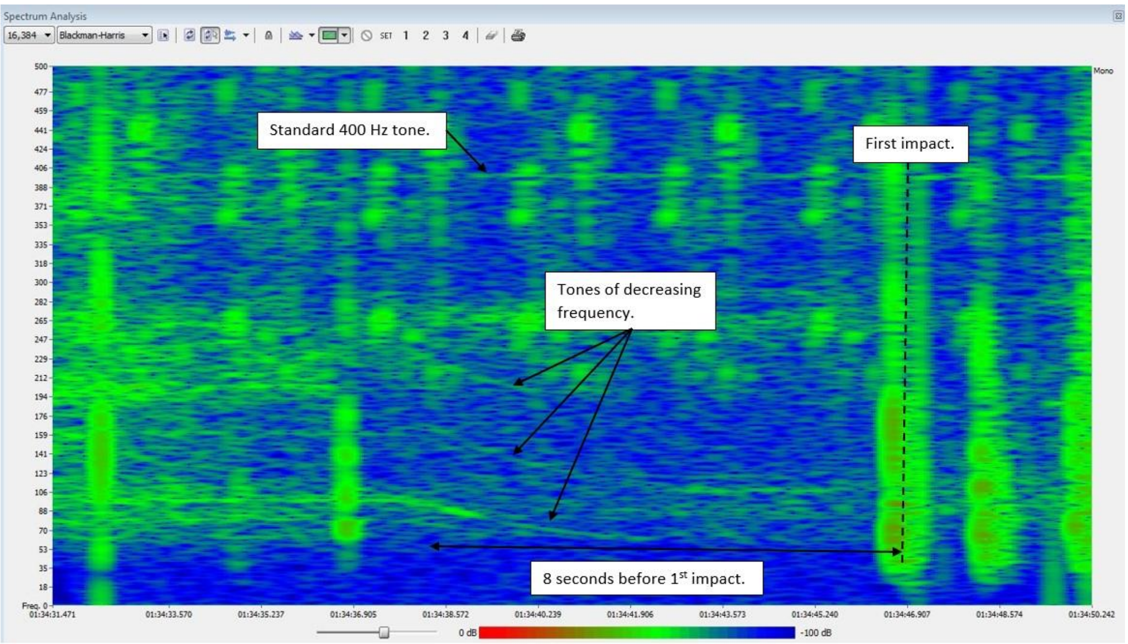
Analysis of the CVR recording did not identify any tones or frequency spectra that could be positively identified with engine operation. During the approaches there were frequencies detected that were possibly associated with engine speed, with those frequencies only detectable during high-power engine operation (Figure A7). There were also a series of background tones that were observed to decrease in frequency about 8 seconds prior to the first impact (Figure A8). When compared to other approaches and the aircraft at the top of descent, these tones could possibly be associated with a power reduction prior to impact.

Figure A7: Frequency spectra plot during the first approach



Source: ATSB, from analysis of the continuous-loop recording from the CVR.

Figure A8: Frequency spectra plot during the approach to ditching showing tones of decreasing frequency



Source: ATSB, from analysis of the continuous-loop recording from the CVR.

Additional aural alerts related to aircraft operation

Pitch trim activation

A single tone audio signal with a frequency of 2,785 Hz was detected on many occasions throughout the recording. The signal tone was active for differing periods of time, which was consistent with the operation of the aircraft's electric pitch trimming system.

Altitude alert

A single tone audio signal with a frequency of 2,697 Hz was detected on a number of occasions throughout the recording. The signal activated for the same time period on each occasion and corresponded with the crew announcing proximity to various altitudes. This signal was consistent with the operation of the aircraft's altitude alerting system.

Unidentified warning horn

A warning horn type sound with a fundamental frequency of 644 Hz activated during the ditching, about 1.3 seconds after the second impact was recorded. Correlation with the FDR indicated the airspeed was about 76 kt when the warning activated. The aircraft was not fitted with an audible stall warning system. The source of the tone could not be identified.

Appendix B – Flight data recorder information

Recorder details

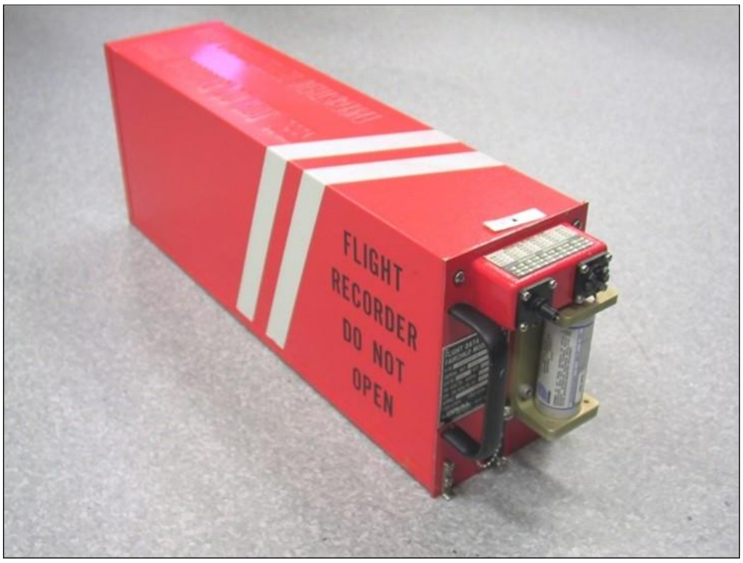
The aircraft was equipped with a Loral Data Systems solid-state flight data recorder (FDR). Maintenance documentation provided by the operator gave the following details for the FDR fitted to VH-NGA:

- model – F1000
- part number – S703-1000-0
- serial number – 00484.

These details matched those from the FDR recovered from aircraft wreckage during November 2015.

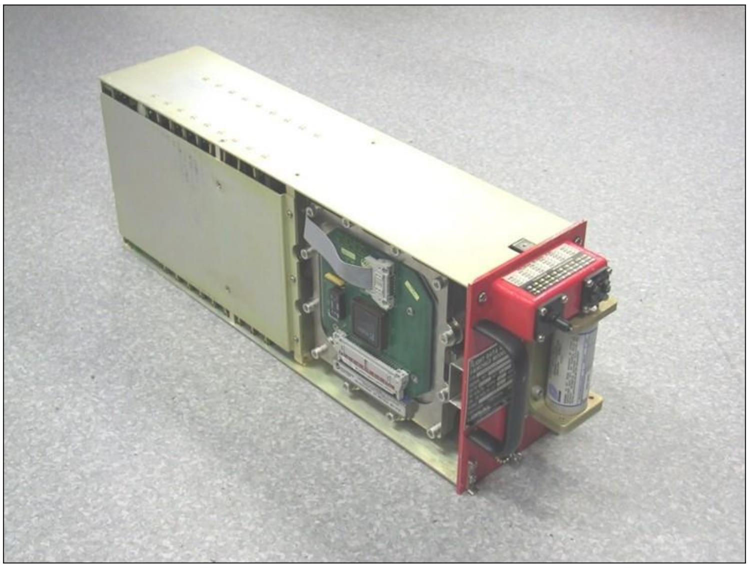
An example of an F1000 FDR is shown in Figure B1 and B2. Figure B3 shows the FDR recovered from VH-NGA.

Figure B1: Comparison (undamaged) F1000 FDR - Exterior



Source: ATSB

Figure B2: Comparison (undamaged) F1000 FDR - Interior



Source: ATSB

Figure B3: FDR at the ATSB laboratories in Canberra (16 November 2015)

Source: ATSB

Data download

The FDR data download was conducted by a team of ATSB specialists and two officers with flight recorder expertise from the Directorate of Defence Aviation and Air Force Safety (DDAAFS). The entire data download process was performed during 16–20 November 2015. The DDAAFS officers were part of the team for the entire period.

The steps involved in the FDR data download included:

- On 16 November, a disassembly plan for the recorders was discussed by the team.
- The FDR was disassembled during the afternoon of the 16 November in accordance with the FDR manufacturer's documentation. When the crash-survivable memory unit (CSMU) was opened some hissing was evident indicating the interior of the module had become pressurised as a result of water ingress while underwater (at a depth of 48 m). Visual inspection showed evidence that a small amount of water had entered the CSMU.
- The FDR memory board (Figure B4) was washed and gently brushed in distilled water. The water was removed with isopropyl alcohol and mild air pressure. To ensure any residual moisture was removed, the memory board was placed in a temperature-controlled oven overnight at a temperature of 65°C.
- On 17 November, due to the possibility of corrosion, the original connector was removed and a new connector was crimped onto the memory board cable in accordance with the manufacturer's procedures.
- A 'known good' FDR chassis was used as the download platform. An electronic component (described as Q1 on the Flash/Store Interface card) was removed from the 'known good' FDR to prevent any possibility of writing to the memory board. The 'known good' FDR was downloaded using an Avionica ruggedized service unit (RSU) and normal indications were

observed during the download. As expected, a compressed data file of size 8,193 KB, was obtained. This download was successful.

- The accident FDR's memory board was downloaded using the RSU and normal indications were observed during the download. As expected, a compressed data file of size 8,193 KB was obtained. Examination of the data showed that it gave 'unreasonable' results.
- A second download was performed using a Flight Data Systems hand-held multi-purpose interface (HHMPI) unit. During the download the HHMPI 'hung' and the download process did not complete successfully.
- On 18 November, the FDR memory board was placed in a temperature-controlled oven for 48 hours at a temperature range of 60–80°C in preparation for any re-working.
- On 20 November, the FDR memory board was retrieved from the oven and a portion of the cable including the connector was removed. A new connector was crimped on to the shortened cable.
- A download was performed using a HHMPI unit. The download gave normal indications and an 8,192 KB file was produced ('NGA1.fdt').
- This file was decompressed using the manufacturer's decompression software. The decompressed file was 52,290 KB in size ('NGA.UPK').
- This file was transferred to the ATSB flight recorder specialist's laptop computer and analysed using Insight Analysis version 4.5.0.503. Analysis showed the download was successful and that data from the accident flight had been recovered. The FDR data covered 116 hours of aircraft operation.

Figure B4: FDR memory module (16 November 2015)

Source: ATSB

FDR removal/installation history

FDR maintenance records supplied by the operator are summarised in Table B1.

The accident occurred on 18 November 2009, so FDR SN 00484 was installed on VH-NGA 15 days before the accident flight. During that period the aircraft was operated on four flights totalling about 12 hours of aircraft operation. The remainder of the 116 hours of downloaded data related to the operation of another of the operator's Westwind aircraft.

Table B1: Flights of NGA where flight data was available

Date	Part number	Serial number	ON/OFF	Reason
23 Dec 2008	980-4100-FWUS	2581	OFF	Removed for a functional check and data download.
23 Dec 2008	S703-1000-00	00557	ON	Replacement.
15 Oct 2009	S703-1000-00	00557	OFF	Due FDR fail light continuously flashing.
15 Oct 2009	S703-1000-00	02147	ON	Replacement (removed from another aircraft).
03 Nov 2009	S703-1000-00	02147	OFF	Removed for a functional check and data download.
03 Nov 2009	S703-1000-00	00484	ON	Replacement (removed from another aircraft).

As the previous FDR installed on VH-NGA (FDR SN 02147) had been removed for a functional check, the service provider was contacted to see whether the download file had been archived. The file had been archived and a copy was obtained by the ATSB for analysis. Accordingly, the ATSB had FDR data from an additional 13 flights from 16–30 October 2009.

Aircraft installation

The FDR was installed in the unpressurised tail cone section of the aircraft, forward of the CVR. Power was supplied to the FDR from the No. 2 AC bus via the Avionics Master Switch No. 2. The flight crew normally selected the Avionics Master Switches ON after starting the first engine.

The observed pin connections were consistent with the expected FDR installation for a Westwind aircraft.

FDR data format

The FDR produces a data stream which is time division multiplexed, with parameter identification established by means of position or time (word) slot addresses in the data stream. The data stream is a continuous sequence of 4-second data frames. Each frame consists of four subframes of 46 x 12 bit words with the first word containing a unique 12-bit synchronization (sync) word identifying it as subframe 1, 2, 3 or 4. The data stream is 'in sync' when successive sync words appear at the correct intervals.

The F1000 P/N S703-1000 FDR assembles 46 (12 bit) words per second and then compresses the data before it is recorded. When the data is recovered, the raw compressed data file needs to be decompressed before it is imported by the analysis software. The decompression software 'pads out' the 46 word per second data so that it conforms to the standard 64 word per second format expected by the analysis software.

Parameters can be recorded as multi-bit engineering parameters (for example, pressure altitude) or single-bit discrete parameters (for example, microphone keying).

FDR parameters (overview)

Civil Aviation Order (CAO) 20.18 (Aircraft equipment – basic operational requirements) outlined the types of aircraft that required an FDR to be fitted. CAO 103.19 (Equipment standards – flight data recorders) outlined the required parameters. For an aircraft with a maximum take-off weight of less than 29,000 kg (including VH-NGA), six parameters were required to be recorded. The F1000 recorded these parameters and sampled them at the required frequency. Details of the parameters are listed in Table B2. In addition, four FDR status parameters were recorded (Table B3).

Table B2: FDR parameters

Parameter name	Units	Sampling interval (seconds)
Elapsed time[349]	hh:mm:ss	1
Pressure altitude[350]	ft (reference 1013.2 hPa)	1
Indicated airspeed (IAS)	kt	1
Magnetic heading	º magnetic	1
Vertical acceleration	g	0.125
Microphone keying	discrete (keyed/not keyed)	1

Table B3: FDR status parameters

Parameter name	Units	Sampling interval (seconds)
A/D fault[351]	discrete (no fault/fault)	1
S/D fault[352]	discrete (no fault/fault)	1
Altitude/airspeed source	discrete (pneumatic/electric)	1
FDR fault	discrete (no fault/fault)	1

The data for the first five parameters in Table B2 were found to be serviceable. The data for microphone keying was not serviceable. Further details of each of the parameters are provided below.

Pressure altitude

Table B4: Pressure altitude details

Signal source	FDR pneumatic transducer
Signal type	Pneumatic
Bits used	14
Word location	26 (most significant word) 34 (least significant word)
Resolution	2 ft
Sampling interval:	1 second

A printed circuit board inside the FDR contains the pneumatic transducer and associated electronics for sensing and digitising altitude and airspeed data.[353] The transducer measures the difference between static pressure, captured through one or more static port(s), and a reference pressure. The reference conditions for the transducer are standard pressure and temperature (that is, 1013.25 hPa and 15ºC). The static ports are located on the exterior of the aircraft, at locations chosen to detect the prevailing atmospheric pressure as accurately as possible (that is, without any disturbance from the passage of the aircraft).

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349 Elapsed time from power-up of the FDR, incremented once per second.

350 Pressure altitude and IAS are sensed from a transducer package fitted to the FDR. The recorded values may differ from those observed by the crew.

351 Analogue to Digital (A/D) conversion fault – this signal is generated by the FDR.

352 Synchro to Digital (S/D) conversion fault – this signal is generated by the FDR.

353 The pneumatic board in FDR SN 00484 was replaced in October 2009 when the FDR was sent to an authorised repair agency for repair and a functional check.

The sensor is typically connected to the first officer's static system. The raw recorded altitude data is converted to engineering units (that is, altitude in ft) by a standard polynomial equation supplied by the FDR manufacturer.

The recorded altitude data was processed using the manufacturer's standard polynomial conversion equation.

Air traffic services (ATS) recordings and transcripts provided the assigned cruise altitudes and these values were compared with the recorded altitudes (Table B5). As a result of the differences shown in Table B5, small corrections were made to the standard conversion equation, as listed in Table B6.

Table B5: Pressure altitude data

		Elevation (ft)	Recorded altitude (ft)	QNH (hPa)[354]	QNH correction (ft)[355]	Difference (ft)
Take-off	**Sydney**	21	13	1012	-30	-38
Cruise	FL 370		37,350			+350
Landing	**Norfolk Is**	371	420	1010	-90	-41
Take-off	**Norfolk Is**	371	470	1009	-120	-21
Cruise	FL 350		Avg. 35,340			+340
Cruise	FL 370		Avg. 37,370			+370
Cruise	FL 390		Avg. 39,310			+310
Landing	**Apia**	58	94	1010	-90	-54
Take-off	**Apia**	58	155	1011	-60	+37
Cruise	FL 310		Avg. 31,370			+370
Cruise	FL 390		Avg. 39,310			+310
Impact	**Sea-level initial 'g' spike**	0	-8	1014[356]	12	20

Table B6: Pressure altitude corrections

Altitude[357] (ft)	Corrected altitude (ft)
0	0
31,000	30,650
40,000	39,690

Indicated airspeed (IAS)

Table B7: IAS details

Signal source	FDR pneumatic transducer
Signal type	Pneumatic
Bits used	12
Word location	42
Resolution	1 kt
Sampling interval	1 second

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354 The QNH was sourced from the relevant aerodrome METAR/SPECI, which rounds down the QNH to the nearest hPa.
355 This correction is based on the QNH and the standard pressure, both rounded down to the nearest hPa.
356 The actual QNH at the time of the ditching was 1013.9 hPa.
357 Corrections for intermediate altitudes were linearly interpolated.

Pneumatic indicated airspeed (IAS) data is sensed by a transducer inside the FDR. The transducer measures the difference between static pressure captured through one or more static port(s), and dynamic pressure captured through a pitot tube. The static ports are located on the exterior of the aircraft, at locations chosen to detect the prevailing atmospheric pressure as accurately as possible (that is, without any disturbance from the passage of the aircraft). The pitot tube accumulates 'ram air' (that is, air forced against the opening of the tube by the passage of the aircraft). Pitot tubes face forward in the direction of flight.

The sensor is typically connected to the first officer's pitot-static system. The raw recorded airspeed data is converted to engineering units (IAS in kt) by a standard polynomial equation supplied by the FDR manufacturer.

The recorded IAS data was processed using the manufacturer's standard polynomial conversion equation.

All measurements from physical systems have some inaccuracies. The FDR from VH-NGA contained internal pneumatic sensors to compute airspeed and altitude data. Pitot and static lines were connected from the FDR to the aircraft's pitot/static plumbing.

The required accuracy for IAS is ± 10 kt and the FDR manufacturer stated a typical tolerance of ± 3 kt at 200 kt.[358]

Methods of validating the recorded IAS data were considered. One independent source of data was engine trend monitoring data that was manually recorded by flight crews. Flight crews typically recorded this data once every day at a time when the aircraft was in stable cruise flight. This manually recorded data was able to be compared with IAS values recorded by the FDR for several previous flights. As the time the trend monitoring data was recorded is unknown, this is an imprecise technique. It cannot generally be used to fine tune the derived FDR parameters of Mach and TAS, but it is useful as a reasonableness check.

Overall, the examination showed the IAS values recorded by the FDR were in good general agreement with known cruise IAS values obtained from trend monitoring records.[359] In addition, recorded IAS values were also consistent with values stated by the flight crew during the approaches. Therefore, no correction was required.

Magnetic heading

Table B8: Magnetic heading details

Signal source	**Gyrocompass**
Signal type	Synchro
Bits used	12
Word location	9
Resolution	0.09º
Sampling Interval	1 second

Magnetic heading data is typically sensed from the captain's gyrocompass.

The standard scaling equation for magnetic heading was used and no corrections were applied.

A reasonableness check was conducted using the magnetic heading recorded during take-off and landing against the known magnetic runway heading obtained from the relevant aeronautical information publications and the results are shown in Table B9.

358 Note that ± 3 kt is for IAS, values of ± 5 kt for TAS and ± 0.01 for Mach would be reasonable.

359 For example, on one flight the aircraft was at FL 370 for 30 minutes and the flight crew had recorded the engine trend data during that period. They had recorded a value of 220 kt, and the FDR values recorded during that period were 216–225 kt.

Table B9: Magnetic heading data for recently recorded flights in VH-NGA

		Published magnetic runway heading (degrees)	FDR recorded runway heading (degrees) at 100 kt	Difference (degrees)
Take-off	Nowra	212	209.5	-2.5
Landing	Sydney	155	155.4	+0.4
Take-off	Sydney	155	154.2	-0.8
Landing	Norfolk Island	287	288.4	+1.4
Take-off	Norfolk Island	287	285.5	-1.5
Landing	Apia	078	079.1	+1.1
Take-off	Apia	078	079.6	+1.6

Examination of the results showed that the magnetic heading values were in reasonable agreement with known values. No consistent offset was identified and no correction was made to the standard scaling equation.

Vertical acceleration

Table B10: Vertical acceleration details

Signal source	Single-axis accelerometer
Signal type	AC voltage
Bits used	12
Word location	4, 12, 20, 28, 36, 44, 52 & 60
Resolution	0.003 g
Sampling Interval	0.125 second

The accelerometer provided acceleration information in the aircraft vertical (Z) axis. The standard scaling equation for vertical acceleration was used and no corrections were applied.

Accelerometers can sometimes have a fixed bias (offset) from the actual acceleration value. Acceleration values were checked when the aircraft was stationary on the ground at Apia and at Norfolk Island on the outbound flight. A small bias of +0.045 g was observed. As a result, 0.045 g was subtracted from nominal acceleration values.

Microphone keying

Examination of the wiring connector for FDR verified that a wire was connected to pin J1A-46, a microphone keying input. Signals from this input are recorded in bit 3 of word 11 and it is described as the Binary 2 or COM 2 input. The recorded data from word 11 was examined for all four flights when FDR SN 00484 was fitted to VH-NGA. No activity consistent with microphone keying data was observed for any of the flights. Data from FDR SN 02147, when it had been earlier fitted to VH-NGA, was also examined. Again, no activity consistent with microphone keying data was observed. As a result, the failure to record microphone keying data was considered to be due to an airframe issue rather than the recorder itself.

Microphone keying is used to correlate FDR data with CVR audio. When magnetic tape was used as the CVR recording medium, it was common to see evidence of tape speed fluctuations during recording and microphone keying data was important in compensating for those fluctuations. With the advent of solid-state memory, the CVR recording time-base has become very accurate and the microphone keying parameter has become less important. The CVR from VH-NGA used solid-state memory.

In summary, the microphone keying parameter was unserviceable, most likely because of a wiring discontinuity within the airframe of VH-NGA. However, the absence of this parameter did not affect the investigation.

Timing correlation

Time in UTC was not recorded by the FDR. However the FDR records an elapsed time counter, which begins when power is applied to the recorder and is incremented once per second. When power is removed and later re-applied this counter is reset to zero and begins incrementing again.

The FDR data was synchronised with the CVR recording by using the three impacts recorded during the ditching. These impacts were evident in the vertical acceleration data recorded by the FDR and were clearly audible on the CVR recording. The CVR audio was correlated with UTC using ATS transmissions.

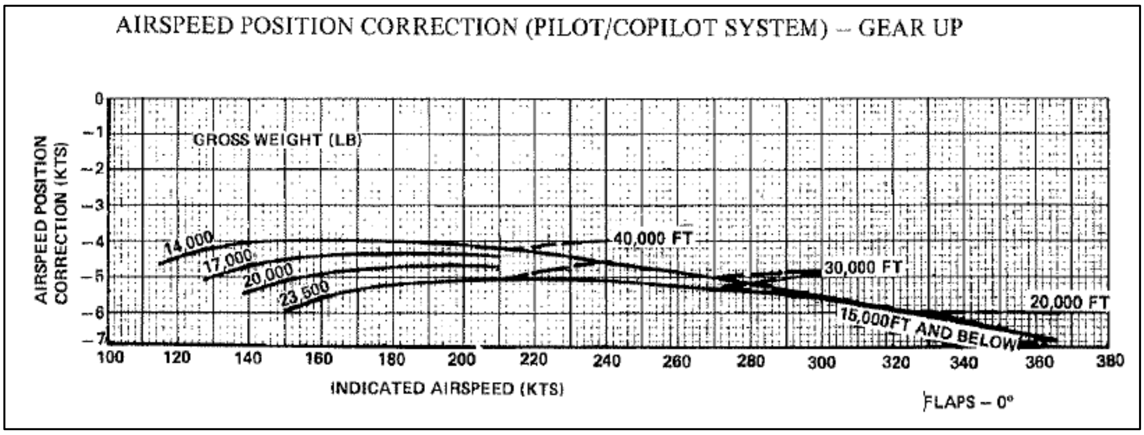
The FDR/UTC correlation is expected to be within ± 1 second.

Determination of Mach and true airspeed

Mach and true airspeed (TAS) were not recorded by the FDR. These parameters were calculated as follows:

- IAS was converted to calibrated airspeed (CAS) using static source correction tables from the Westwind 1124A Airplane Flight Manual (AFM) (Figure B5)
- Mach was calculated from CAS using a standard equation
- TAS was calculated from Mach allowing for temperature variations from ISA conditions using a standard equation.

Figure B5: Graph from the AFM to convert IAS to CAS



Source: Israel Aircraft Industries Westwind 1124A AFM.

Bureau of Meteorology data indicated temperatures during cruise for the accident flight were approximately ISA+2.0°C. The conversion of Mach to TAS allowed for this correction.

Determination of the aircraft ground track

The aircraft ground track was not recorded by the FDR. An aircraft ground track can be determined directly from FDR parameters when they are available (for example, latitude and longitude or ILS parameters). When an aircraft is under radar coverage its ground track can also be determined from radar data recorded on the ground.

In the absence of this information, as was the case with VH-NGA, the ground track must be determined indirectly and requires the following information:

- TAS

- groundspeed
- aircraft track angle
- a ground fix somewhere along the track.

Groundspeed was not recorded by the FDR. TAS was converted to groundspeed by allowing for wind speed, wind direction and aircraft magnetic heading. Wind speed and direction were obtained from meteorological agencies and magnetic heading was directly recorded by the FDR. For the approaches at Norfolk Island, a wind speed and direction of 9 kt at 170°T was used in the calculations of aircraft ground track.

Aircraft track angle was not recorded by the FDR. Track angle was estimated by using recorded magnetic heading and converting it to true heading by allowing for the published magnetic variation (15° E) at Norfolk Island. True heading was converted to track angle by allowing for wind speed and direction.

The wreckage location was used as the basis for the ground fix. An adjustment of 36 m north and 96 m east was made as the wreckage location on the sea floor would not have coincided exactly with the aircraft's position at the time that the FDR stopped recording. The adjustment reflects a deceleration in the direction that the aircraft was moving at the end of recording.

The ground track was calculated for the four approaches at Norfolk Island starting from 0953:28 UTC (descending through 5,000 ft) until 1026:01 UTC (end of recording for the FDR).

Error in the derived ground track generally increases with time (that is, as the length of time for which the ground track is derived increases, the error in aircraft position will increase). In this case adjustments were made to the ground track to validate it against DME distance and VOR radial call outs that were made by the crew and sourced from the CVR recording.

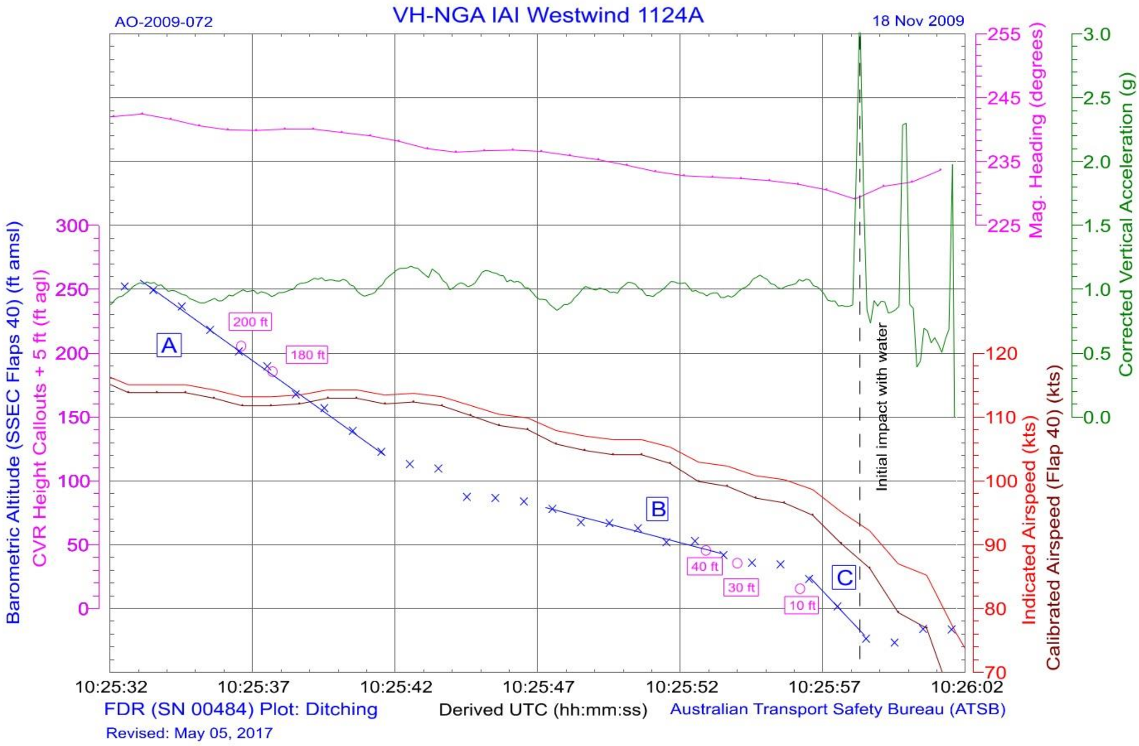
Determination of descent rate during the approach to ditching

Figure B6 shows data from the FDR for the last 30 seconds of the flight. The data includes the recorded airspeed, vertical acceleration, magnetic heading and altitude.

The CAS data was derived and extrapolated from charts in the manufacturer's *1124A-Westwind Operational Planning Manual* (OPM). Three periods were identified and annotated on the plot as A, B and C:

- Period A – the aircraft was in a stable descent with a descent rate of 950 ft/minute and an IAS of about 114 kt.
- Period B – the descent rate decreased to about 360 ft/minute and the IAS began to steadily decrease at a rate of about 1 kt per second. This was consistent with a change in the aircraft state at about 1025:42. This could be due to one or a combination of a change in engine thrust, flap setting, gear position and/or pitch attitude.
- Period C – during the final 2 seconds of flight the descent rate increased and the IAS reduced at an increased rate of about 3 kt per second.

Figure B6: Data from the FDR showing the last recorded 30 seconds



Source: ATSB, based on analysis of data on the FDR

The inherent limitations of barometric pressure sensing, particularly over short time periods and also close to the ground/water, meant that pressure altitude alone could not be reliably used to estimate the descent rate at impact.

An analysis was performed, for the 2-second period immediately prior to impact, using pressure altitude data and vertical acceleration data. Changes in pressure altitude were used to provide an initial descent rate and vertical acceleration data (recorded 8 times a second) was then integrated to estimate how the descent rate changed from that point onwards. Tolerances in the recorded parameters, as well as assumed parameters (such as pitch attitude), meant that the estimated descent rate at impact would cover a range of values. The results of the analysis were:

- the descent rate was increasing immediately prior to impact
- the descent rate at impact was likely about 500–600 ft/minute (or 8–11 ft/second) and very likely to be about 400–700 ft/minute (or 7–12 ft/second).[360]

The CVR recording included callouts of radio height by the first officer of 40 ft, 30 ft and 10 ft. A descent rate could be derived from these callouts and the (audible) time of the first impact. In particular, the time between the 10-ft callout and the first impact was 2.1 seconds, indicating the average descent rate during this period was 285 ft/minute. However, there were potential problems with this approach and several aspects needed to be considered, including:

- Radio height was displayed to the nearest 10 ft, such that 10 ft would be displayed as the aircraft descended through 15 ft radio height and until the aircraft reached 5 ft.
- The radio altimeter's readings would have been affected by the swell and wave height, such that it would typically be displaying values higher than mean sea level.[361]

360 The estimates were rounded to the nearest 100 ft/minute or nearest 1 ft/second.

361 As discussed in *Meteorological information – Sea surface conditions*, the effect of moderate waves on a moderate swell could vary the height of the moving surface measured by the radio altimeter by 10-20 ft.

- As indicated above, the vertical acceleration data indicated the descent rate was increasing during this 2-second period, and therefore the rate at the time of impact would have been higher than the average rate over the period.
- There would be a delay between the first officer identifying that 10 ft was displayed and calling this out. However, given the context, it is likely the first officer's attention was focussed on the display and she had a high level of expectation of the value changing, so the delay would have been minimal.

After considering these factors, the descent rate at impact based on the CVR callouts was considered to be consistent with the figures stated above.

During the ditching, the initial contact with the water occurred at 1025:58 UTC, coinciding with a vertical acceleration spike of 3.24 g, an IAS of 92 kt (CAS of 86 kt) and a magnetic heading of 229°. During the next 4 seconds, two further spikes in vertical acceleration were recorded (2.30 g and 1.98 g) before the end of recording at 1026:02 UTC.

For comparison purposes, key parameters from the previous three flights are provided in table B11. As indicated in the table, the approach speed was much lower for the ditching than the three normal landings. Although the average descent rate was similar over the last 30 seconds, it should be noted that during a normal landing the actual descent rate on touchdown is relatively low due to the flare being conducted just prior to touchdown.

Table B11: Approach comparison

Approach	Maximum vertical acceleration (g)	IAS decrease in last 30 seconds (kt)	IAS at touchdown (kt)	Average descent rate in last 30 seconds (ft/minute)
Previous landing at Sydney	1.78	3	110	610
Previous landing at Norfolk Island	1.15	10	118	600
Previous landing at Apia	1.43	14	116	580
Accident	3.24	24	92	590

Appendix C – Meteorological forecasts and reports for Norfolk Island during 17 and 18 November 2008

Norfolk Island aerodrome forecasts

Table C1 presents the aerodrome forecasts (TAFs) relevant for the outbound flight from Sydney to Norfolk Island on 17 November 2009 and the flight from Apia to Norfolk Island on 18 November 2009.

The TAFs are provided in their original format. An explanation of how to interpret them can be found at http://www.bom.gov.au/aviation/data/education/awp-taf.pdf.

Parts of a forecast below the alternate minima are highlighted in yellow.

Table C1: Aerodrome forecasts relevant for flights on 17–18 November 2009

Date, time and context	Aerodrome forecast
17 November 2009, 1017 UTC (used for planning flight from Sydney to Norfolk Island)	TAF YSNF 171017Z 1712/1806 34010KT 8000 HZ BKN005 FM172200 30015KT 9999 HZ SCT015 RMK T 19 18 18 21 Q 1012 1010 1010 1012
18 November 2009, 0437 UTC (provided by Brisbane flight service for planning flight from Apia to Norfolk Island)	TAF YSNF 180437Z 1806/1824 26008KT 9999 SCT020 FM181500 16012KT 9999 -SHRA SCT010 BKN020 RMK T 21 19 18 18 Q 1010 1013 1013 1012
18 November 2009, 0803 UTC (amended TAF issued halfway through the flight from Apia to Norfolk Island)	TAF AMD YSNF 180803Z 1808/1824 26008KT 9999 BKN010 FM181500 16012KT 9999 -SHRA BKN010 RMK T 21 18 18 17 Q 1012 1013 1013 1013
18 November 2009, 0958 UTC (amended TAF issued at about time of aircraft's arrival at Norfolk Island)	TAF AMD YSNF 180958Z 1810/1824 26008KT 9999 -SHRA BKN010 FM181500 16012KT 9999 -SHRA BKN010 TEMPO 1810/1824 4000 SHRA BKN005 RMK T 19 18 17 18 Q 1013 1013 1012 1014

Norfolk Island aerodrome weather reports

Table C2 presents the weather reports for Norfolk Island airport relevant for the flight from Sydney to Norfolk Island on 17 November, and Table C3 presents the weather reports relevant for the flight from Apia to Norfolk Island on 18 November 2009.

The reports are provided in their original format. An explanation of how to interpret aerodrome weather reports can be found at http://www.bom.gov.au/aviation/data/education/awp-metarspeci.pdf.

The reports are colour-coded for ease of understanding as follows:

- green reports indicate observed weather above the alternate minima

- yellow reports indicate observed weather less than the alternate minima but greater than the landing minima
- red weather reports indicate observed weather below the landing minima.

Table C2: Weather reports at Norfolk Island relevant for outbound flight on 17 November 2009

Date, time and context	Weather report
17 November 2009, 1230 UTC (departed Sydney at 1242)	SPECI YSNF 171230Z AUTO 33011KT 9999 BKN005 OVC009 20/19 Q1011 RMK RF00.0/000.0
17 November 2009, 1300 UTC	SPECI YSNF 171300Z AUTO 33008KT 9999 OVC005 20/19 Q1011 RMK RF00.0/000.0
17 November 2009, 1330 UTC	SPECI YSNF 171330Z AUTO 32009KT 9999 BKN004 OVC007 20/19 Q1011 RMK RF00.0/000.0
17 November 2009, 1400 UTC (SPECI provided to crew)	SPECI YSNF 171400Z AUTO 33011KT 9999 BKN005 OVC008 20/19 Q1011 RMK RF00.0/000.0
17 November 2009, 1430 UTC	SPECI YSNF 171430Z AUTO 33011KT 9999 BKN004 OVC029 20/19 Q1010 RMK RF00.0/000.0
17 November 2009, 1500 UTC (landed Norfolk Island at 1458)	SPECI YSNF 171500Z AUTO 34012KT 9999 BKN006 OVC010 20/19 Q1010 RMK RF00.0/000.0
17 November 2009, 1530 UTC (departed Norfolk Island at 1545)	SPECI YSNF 171530Z AUTO 33009KT 9999 OVC004 20/19 Q1009 RMK RF00.0/000.0
17 November 2009, 1600 UTC	SPECI YSNF 171600Z AUTO 33011KT 9999 OVC005 20/19 Q1009 RMK RF00.0/000.0

Table C3: Weather reports at Norfolk Island relevant for flight from Apia to Norfolk Island on 18 November 2009

Date, time and context	Weather report
18 November 2009, 0430 UTC (flight plan submitted at 0445)	METAR YSNF 180430Z 29014KT 9999 FEW008 22/18 Q1010 RMK RF00.0/000.0 HZ
18 November 2009, 0500 UTC	METAR YSNF 180500Z 29014KT 9999 FEW015 22/18 Q1010 RMK RF00.0/000.0 HZ
18 November 2009, 0530 UTC (departed Apia at 0545)	METAR YSNF 180530Z 29013KT 9999 FEW010 22/18 Q1011 RMK RF00.0/000.0 HZ
18 November 2009, 0600 UTC	METAR YSNF 180600Z 31011KT 9999 FEW008 BKN025 21/19 Q1011 RMK RF00.0/000.0 HZ
18 November 2009, 0630 UTC (Nadi IFISO provided to crew, although FEW006 misread as FEW060)	METAR YSNF 180630Z 30009KT 9999 FEW006 BKN024 21/19 Q1011 RMK RF00.0/000.0 CLOSE TILL 1930UTC
18 November 2009, 0700 UTC	METAR YSNF 180700Z AUTO 29011KT 9999 BKN017 BKN024 21/19 Q1011 RMK RF00.0/000.0
18 November 2009, 0730 UTC	METAR YSNF 180730Z AUTO 29010KT 9999 OVC013 21/19 Q1012 RMK RF00.0/000.0
18 November 2009, 0739 UTC	SPECI YSNF 180739Z AUTO 29010KT 9999 OVC011 21/19 Q1012 RMK RF00.0/000.0
18 November 2009, 0800 UTC (Nadi IFISO provided to crew, TAF amended 0803)	SPECI YSNF 180800Z AUTO 29008KT 9999 OVC011 21/19 Q1012 RMK RF00.0/000.0

18 November 2009, 0830 UTC (below landing minima, not provided to crew)	SPECI YSNF 180830Z AUTO 22007KT 9999 BKN003 OVC009 20/19 Q1013 RMK RF00.0/000.0
18 November 2009, 0856 UTC	SPECI YSNF 180856Z AUTO 21007KT 9999 SCT005 SCT012 OVC015 20/19 Q1013 RMK RF00.0/000.0
18 November 2009, 0900 UTC	METAR YSNF 180900Z AUTO 20007KT 8000 SCT005 OVC015 20/19 Q1013 RMK RF00.0/000.0
18 November 2009, 0902 UTC (Auckland A/G provided to crew; occurred at about the time of the PNR)	SPECI YSNF 180902Z AUTO 20007KT 7000 SCT005 BKN011 OVC015 20/19 Q1013 RMK RF00.0/000.0
18 November 2009, 0925 UTC (Norfolk Unicom provided almost identical information to crew at 0929, cloud was reported as broken)	SPECI YSNF 180925Z AUTO 20008KT 6000 BKN003 BKN008 OVC011 20/19 Q1013 RMK RF00.0/000.0
18 November 2009, 0930 UTC (provided by Auckland A/G to crew)	SPECI YSNF 180930Z AUTO 20007KT 4500 BKN002 BKN006 OVC011 20/19 Q1013 RMK RF00.2/000.2
18 November 2009, 1000 UTC (arrived at Norfolk Island at 1003, TAF amended at 0958)	SPECI YSNF 181000Z AUTO 18009KT 4500 OVC002 19/19 Q1013 RMK RF00.2/001.0
18 November 2009, 1030 UTC (ditching at 1026)	SPECI YSNF 181030Z AUTO 16009KT 3000 OVC002 19/18 Q1013 RMK RF00.4/002.4
18 November 2009, 1053 UTC	SPECI YSNF 181053Z AUTO 16009KT 5000 BKN002 BKN009 OVC014 18/18 Q1014 RMK RF00.0/002.4
18 November 2009, 1100 UTC	SPECI YSNF 181100Z 14008KT 5000 -SHRA BR BKN005 BKN014 18/18 Q1014 RMK RF00.4/002.8
18 November 2009, 1111 UTC	SPECI YSNF 181111Z AUTO 15006KT 3200[362] SCT003 BKN008 OVC014 19/18 Q1014 RMK RF00.2/003.0
18 November 2009, 1128 UTC	SPECI YSNF 181128Z AUTO 15008KT 7000 SCT005 BKN012 OVC017 19/18 Q1014 RMK RF00.0/003.0
18 November 2009, 1134 UTC	SPECI YSNF 181134Z 15008KT 8000 FEW006 BKN015 19/17 Q1014 RMK RF00.0/003.0 BR
18 November 2009, 1200 UTC	SPECI YSNF 181200Z 15009KT 9999 FEW008 BKN013 19/17 Q1014 RMK RF00.0/003.0

362 The visibility of 3,200 m was less than the landing minima for the runway 29 VOR approach (3,300 m) but more than the landing minima for the runway 11 VOR approach (3,000 m).

Aerodrome forecasts and aerodrome weather reports for Noumea, New Caledonia

Table C4 provides the TAF for Noumea relevant for planning the outbound flight from Sydney to Norfolk Island on 17 November, and the TAFs relevant for the flight from Apia to Norfolk Island on 18 November. Table C5 provides the weather reports that would have been potentially relevant.

Table C4: Aerodrome forecasts for Noumea relevant for flights on 17–18 November 2009

Date, time and context	Aerodrome forecast
17 November 2009, 1035 UTC (valid when planning flight from Sydney to Norfolk Island)	TAF NWWW 171035Z 1712/1812 VRB02KT 9999 –RA FEW010 SCT040 BECMG 1722/1724 18010KT TEMPO 1712/1724 6000 RA FEW 010 SCT020TCU BKN040
17 November 2009, 2238 UTC (valid when captain planned flight from Apia to Norfolk Island)	TAF NWWW 172300Z 1800/1824 20012KT 9999 SCT060 PROB30 TEMPO 1802/1808 7000 SHRA FEW030TCU SCT045 BECMG 1809/1812 VRB02KT BECMG 1821/1823 16012KT
18 November 2009, 0500 UTC (valid during period of accident flight)	TAF NWWW 180500Z 1806/1906 20012KT 9999 SCT060 BECMG 1809/1812 VRB02KT BECMG 1821/1823 16012KT
18 November 2009, 1100 UTC	TAF NWWW 181100Z 1812/1912 VRB02KT 9999 FEW040 BECMG 1822/1824 16010KT BECMG 1907/1909 VRB02KT=

Table C5: Weather reports for Noumea potentially relevant for the flight from Apia to Norfolk Island on 18 November 2009

Date, time and context	Weather report
18 November 2009, 0430 UTC (flight plan submitted at 0445)	METAR NWWW 180430Z AUTO 20009KT 9999NDV NCD 31/18 Q1011=
18 November 2009, 0500 UTC	METAR NWWW 180500Z AUTO 19011KT 9999NDV NCD 30/18 Q1011=
18 November 2009, 0530 UTC (departed Apia at 0545)	METAR NWWW 180530Z AUTO 20009KT 9999NDV NCD 29/18 Q1011
18 November 2009, 0600 UTC	METAR NWWW 180600Z AUTO 13011KT 9999NDV NCD 28/18 Q1011=
18 November 2009, 0630 UTC	METAR NWWW 180630Z AUTO 15009KT 9999NDV NCD 27/18 Q1011=
18 November 2009, 0700 UTC	METAR NWWW 180700Z AUTO 15007KT 9999NDV NCD 26/19 Q1012=
18 November 2009, 0730 UTC	METAR NWWW 180730Z AUTO 15007KT 9999NDV NCD 24/19 Q1012=
18 November 2009, 0800 UTC	METAR NWWW 180800Z AUTO 16005KT 9999NDV NCD 23/19 Q1012=
18 November 2009, 0830 UTC	METAR NWWW 180830Z AUTO 00000KT 9999NDV NCD 22/19 Q1013=
18 November 2009, 0900 UTC	METAR NWWW 180900Z AUTO 14003KT 9999NDV NCD 22/19 Q1013=
18 November 2009, 0930 UTC	METAR NWWW 180930Z AUTO 00000KT 9999NDV NCD 22/18 Q1014=
18 November 2009, 1000 UTC	METAR NWWW 181000Z AUTO 00000KT 9999NDV NCD 22/18 Q1014=
18 November 2009, 1030 UTC	METAR NWWW 181030Z AUTO 16001KT 9999NDV NCD 21/18 Q1014=
18 November 2009, 1100 UTC	METAR NWWW 181030Z AUTO 14001KT 9999NDV NCD 21/19 Q1014=
18 November 2009, 1130 UTC	METAR NWWW 181130Z AUTO 14001KT 9999NDV NCD 20/18 Q1014=
18 November 2009, 1200 UTC	METAR NWWW 181200Z AUTO 15002KT 9999NDV NCD 19/17 Q1014=

Aerodrome forecasts and weather reports for Nadi, Fiji

Table C6 provides the TAFs for Nadi relevant for the flight from Apia to Norfolk Island on 18 November. Table C7 provides the weather reports that would have been potentially relevant.

Table C6: Aerodrome forecasts for Nadi relevant to the flight from Apia to Norfolk Island on 18 November 2009

Date, time and context	Aerodrome forecast
18 November 2009, 0430 UTC (valid when captain planned flight from Apia to Norfolk Island)	TAF NFFN 180430Z 1806/1906 VRB03KT 9999 SCT030 BKN050 BKN110 BECMG 1821/1823 10012KT TEMPO 1808/1900 5000 TSRA BKN012 FEW018CB
18 November 2009, 0915 UTC (issued towards end of accident flight)	TAF NFFN 180915Z 1812/1912 VRB03KT 9999 SCT030 SCT050 BKN110 BECMG 1821/1823 10012KT TEMPO 1818/1900 5000 TSRA BKN012 FEW018CB

Table C7: Aerodrome weather reports for Nadi potentially relevant to the flight from Apia to Norfolk Island on 18 November 2009

Date, time and context	Weather report
18 November 2009, 0400 UTC (flight plan submitted at 0445)	METAR NFFN 180400Z 28012KT 45KM SCT028TCU SCT050 BKN110 28/23 Q1009 NOSIG RMK RR NIL TCU TO N=
18 November 2009, 0500 UTC	METAR NFFN 180500Z 27009KT 45KM SCT028TCU SCT050 BKN110 28/24 Q1009 NOSIG RMK RR NIL TCU TO N=
18 November 2009, 0600 UTC (departed Apia at 0545)	METAR NFFN 180600Z 00000KT 45KM SCT028 SCT050 BKN110 28/24 Q1010 NOSIG RMK RR NIL=
18 November 2009, 0700 UTC	METAR NFFN 180700Z 00000KT 40KM SCT028 SCT050 BKN110 27/24 Q1010 NOSIG RMK RR NIL=
18 November 2009, 0800 UTC	METAR NFFN 180800Z 14004KT 40KM SCT028 SCT050 OVC110 26/24 Q1011 NOSIG RMK RR NIL=
18 November 2009, 0900 UTC	METAR NWWW 180900Z 00000KT 40KM SCT028 SCT050 BKN110 26/24 Q1012 NOSIG RMK RR NIL=
18 November 2009, 1000 UTC	METAR NFFN 181000Z 00000KT 40KM SCT028 SCT050 OVC110 26/24 Q1013 NOSIG RMK RR NIL=
18 November 2009, 1100 UTC	METAR NFFN 181100Z 00000KT 40KM SCT028 SCT050 BKN110 25/24 Q1012 NOSIG RMK RR NIL=
18 November 2009, 1200 UTC	METAR NFFN 181200Z 00000KT 40KM SCT028 SCT050 BKN110 25/24 Q1012 NOSIG RMK RR NIL=

Aerodrome forecasts and weather reports for Auckland, New Zealand

Table C8 provides the TAFs for Auckland relevant for the flight from Apia to Norfolk Island on 18 November. Table C9 provides the weather reports that would have been potentially relevant.

Table C8: Aerodrome forecasts for Auckland relevant for the flight from Apia to Norfolk Island on 18 November 2009

Date, time and context	Aerodrome forecast
17 November 2009, 2326 UTC (valid when captain planned flight from Apia to Norfolk Island)	TAF NZAA 172326Z 1800/1824 30015KT 9999 SCT020 TEMPO 1800/1801 4000 +SHRA FEW020CB BECMG 1804/1806 23018KT BECMG 1812/1814 22008KT=
18 November 2009, 0453 UTC (issued before take-off)	TAF NZAA 180453Z 1806/1906 23018KT 9999 SCT020 BECMG 1810/1812 22008KT BECMG 1900/1902 24018KT=
18 November 2009, 1104 UTC	TAF NZAA 181104Z 1812/1912 23018G30KT 9999 SCT020 BECMG 1910/1912 23008KT=

Table C9: Aerodrome weather reports for Auckland potentially relevant for the flight from Apia to Norfolk Island on 18 November 2009

Date, time and context	Weather report
18 November 2009, 0400 UTC (flight plan submitted at 0445)	METAR NZAA 180400Z 26012KT 9999 FEW015 SCT020 BKN025 18/15 Q0999 NOSIG
18 November 2009, 0500 UTC	METAR NZAA 180500Z 25011KT 9999 VCSH FEW013 SCT020 BKN025 17/15 Q1000 NOSIG=
18 November 2009, 0600 UTC (departed Apia at 0545)	METAR NZAA 180600Z 24014KT 9999 SHRA SCT011 BKN018 17/15 Q1000 BECMG NSW=
18 November 2009, 0700 UTC	METAR NZAA 180700Z 23018KT 9999 SCT011 BKN018 15/14 Q1002 NOSIG RMK=
18 November 2009, 0800 UTC	METAR NZAA 180800Z 22025KT 9999 FEW011 BKN016 15/13 Q1003 NOSIG RMK=
18 November 2009, 0900 UTC	METAR NZAA 180900Z 22025KT 9999 FEW011 BKN020 15/12 Q1005 BECMG FM1000 22015KT=
18 November 2009, 1000 UTC	METAR NZAA 181000Z 22023KT 9999 FEW011 BKN020 15/13 Q1006 NOSIG=
18 November 2009, 1100 UTC	METAR NZAA 181100Z NIL=
18 November 2009, 1200 UTC	METAR NZAA 181200Z 22014KT 9999 FEW011 SCT020 15/13 Q1007 NOSIG

Appendix D – Review of winds and aircraft speeds for flights on 17 and 18 November 2009

Overview

The International Civil Aviation Organization (ICAO) established the World Area Forecast System (WAFS) in 1982, to provide aeronautical meteorological en route forecasts in a standardised format. World Area Forecast Centre (WAFC) London, UK and WAFC Washington, US were designated by ICAO to prepare and issue significant weather and upper air forecasts in digital form and on a global basis. Those centres produced upper air forecasts (from 5,000 ft to FL 530) in a gridded binary code form using global grid point numerical weather prediction models.

The initial conditions for the global forecasts were based on observed data (including satellites, ground observations, radar, reports from aircraft, wind profilers, radiosonde balloons) and a background field from previous model runs. The global grid point forecasts were produced four times a day: at 0000, 0600, 1200 and 1800 UTC. Each issue of the grid point forecast comprised six forecast steps, valid at fixed 6-hourly intervals between T+06 and T+36 hours. The grid was 1.25° by 1.25° (approximately 140 km by 140 km at the equator), with the grid thinned towards the poles.

The Bureau of Meteorology (BoM) was responsible for preparing the meteorological data used for civil aviation operations in Australia.

The upper air products issued by BoM were prepared using gridded data provided by WAFC London. These products included:

- significant weather (SIGWX) forecast charts
- grid point wind and temperature (GPWT) forecast charts
- route sector winds and temperatures (RSWT) forecasts[363]
- upper air (wind and temperature) forecast charts.

The GPWT, RSWT and upper air charts produced by BoM were at a significantly lower resolution than the WAFS 1.25° by 1.25° dataset, with the depicted data averaged over larger areas. This was a function of the surface area covered by the BoM charts, making display of data at higher resolutions impractical.[364]

National Aeronautical Information Processing System

The Airservices Australia National Aeronautical Information Processing System (NAIPS) disseminated meteorological information prepared by BoM to aviation users. NAIPS was a computerised aeronautical information system that processed and stored meteorological and NOTAM information and provided briefing products and services to pilots.

NAIPS could also provide meteorological and NOTAM information relevant to departure, destination and en route locations in a Specific Pre-Flight Information Bulletin (SPFIB), including the wind and temperature profile for the planned route. An expanded profile also provided wind and temperature information between each turning point, including the headwind or tailwind component and the cross track wind.

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363 The RSWT messages were prepared for frequently used domestic air routes and provided wind and temperature information for six levels. Those forecasts were issued twice daily (approximately 0800 and 2000 UTC), for three validity times at each issue (0800 issue – valid 1200, 1800 and 0000; 2000 issue – valid 0000, 0600 and 1200). The validity period for RSWT are ± 3 hours of the validity time.

364 Some charts are now produced by BoM for aircraft operations below FL 140 at 1.25° x 1.25° resolution.

NAIPS used the 1.25° by 1.25° native resolution[365] of the grid point forecast data to produce the SPFIB wind and temperature profiles.

ICAO forecast areas

Flights from Sydney to Apia were within in ICAO forecast Area F. In addition to data contained in any SPFIB prepared by Airservices Australia, BoM also prepared routine wind and temperature charts for various levels, valid at 6-hourly intervals during the forecast period.

Forecasts and analysis charts

A number of wind and temperature, GPWT and significant weather charts were obtained during the original ATSB investigation. Those charts covered large surface areas and were of relatively low resolution. The original investigation did not obtain a copy of the NAIPS SPFIB generated prior to the flight departing Sydney and nor had a SPFIB been prepared for the flight from Apia to Norfolk Island.

Due to the time elapsed since the accident, the original WAFS dataset used to generate the en route forecasts, charts and SPFIB was no longer available. Although WAFC London could regenerate the data, changes to the computer hardware and software since that time, meant the data output, although close to the original, could not be confirmed as being identical. Similarly, the NAIPS operating system had been subject to hardware and software upgrades and any outputs generated using regenerated data would have similar caveats applied.

The reopened investigation analysed a significant number of flight records and identified a number of additional flights for which en route forecast and analysis wind information was required.

Availability of alternative model data

A significant amount data is routinely archived by the United States' National Oceanic and Atmospheric Administration's, National Centers for Environmental Prediction (NCEP). That included data outputs and forecast model runs from the Global Forecast System (GFS). An evaluation of data derived from the GFS outputs compared favourably with other independent sources of information (such as available GPWT and wind and temperature forecasts prepared by BoM, and information derived from analysis of data from the FDR).

In addition to the data contained in the GFS forecasts and analysis products, the NCEP Final Operational Global Analysis data (FNL) and the NCEP Climate Forecast System Reanalysis (CFSR) products were also examined. The FNL analysis used the same model as the GFS, but was prepared about an hour after the initialisation of the GFS analysis and incorporated more observational data. The CFSR was a global reanalysis of all available conventional and satellite observations, designed to provide the best estimate of the coupled atmosphere-ocean-land surface-sea ice system.

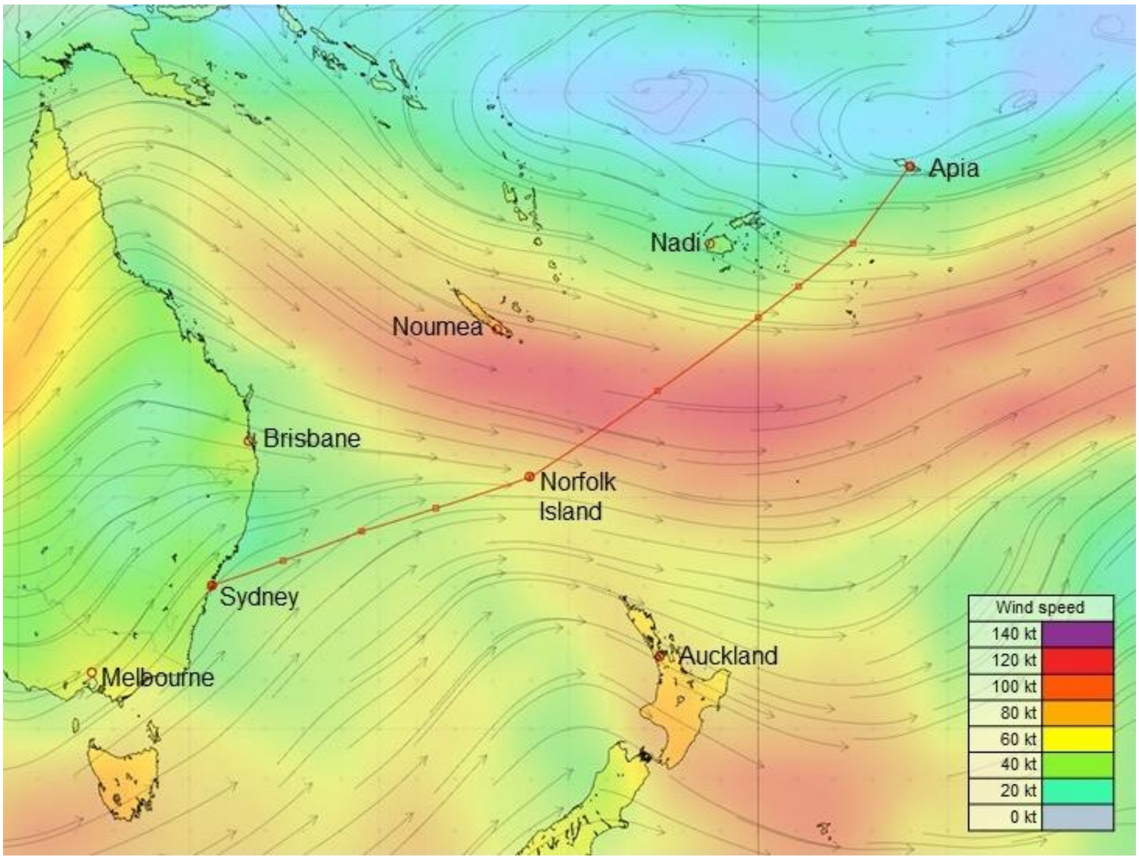
Summary of GFS data, outbound flight conducted 17 November 2009

The GFS forecast valid 1200 UTC on 17 November 2009 indicated a moderate tailwind at cruise altitudes for the outbound flight from Sydney to Norfolk Island.

For the flight from Norfolk Island to Apia on 17 November, a sub-tropical westerly jetstream to the north of Norfolk Island increased the strength of the cruise altitude tailwind for the first part of the flight, but reducing as the flight progressed (Figure D1).

365 The grid is spaced at 1.25° by 1.25° at the equator, with the number of points at a given latitude decreasing as the latitude approaches the poles.

Figure D1: GFS 200 hPa analysis 1800 UTC, 17 November 2009



This chart shows the wind direction and strength at FL 385 along the route at 1800 UTC, the day prior to the accident. This corresponds with the time the aircraft was approximately 2/3 of the distance between Norfolk Island and Apia.

Source: NCEP GFS GRIB data, decoded and rendered using 'LuckGrib' software, annotated by ATSB

The average wind component was calculated for the flight from Sydney to Norfolk Island and from Norfolk Island to Apia at FL 340 and FL 385 (Table D1). In addition, the data contained on the FDR was used to estimate an average wind component affecting the flight. That calculation was based on the derived true airspeed (using forecast temperature) and calculation of the number of air nautical miles flown. That result was then compared to the ground nautical miles flown to estimate an average wind component. This technique included the climb and descent, but ignored the effect of any cross track wind. The calculated average tailwind component for the full flight from Sydney to Norfolk Island was about 35 kt, and from Norfolk Island to Apia about 45 kt.

The GFS forecast for both outbound sectors was generally consistent with the subsequent GFS analyses and the CFSR reanalysis and similarly, when allowing for the reduced strength of wind during climb and descent, the estimation of average wind based on analysis of data from the FDR. The forecasts, analyses and estimates using data from the FDR were also consistent with the recollections of the captain, provided soon after the accident.

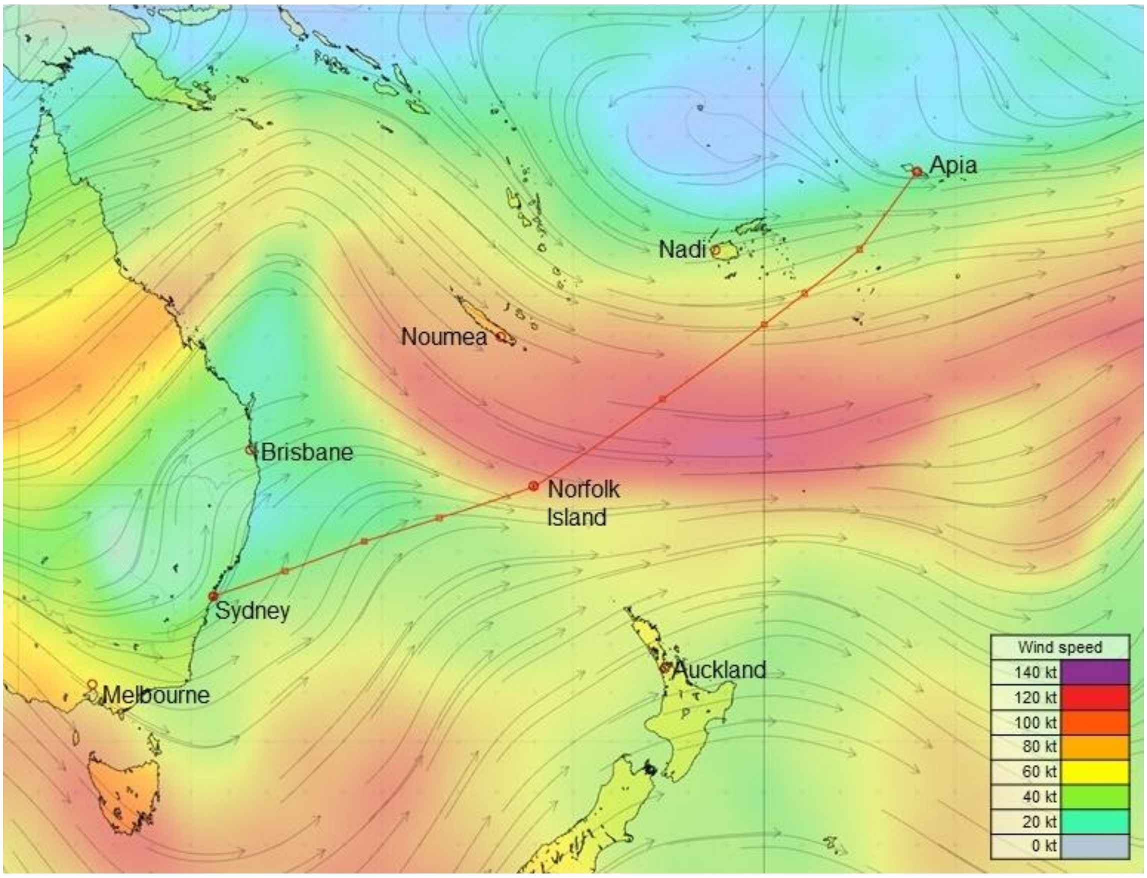
Summary of GFS data, inbound flight conducted 18 November 2009

For the return flight to Norfolk Island, the GFS forecasts indicated a slight strengthening of the jetstream when compared to the outbound flight the night before (Figure D2). When considered in conjunction with the wind direction, that resulted in a slight overall increase in the average headwind component for the return flight (Table D2). The GFS forecast for the accident flight was consistent with the subsequent GFS analyses and similarly, the estimation of average wind strength based on analysis of data from the FDR.

Table D1: Summary of derived average wind component[366] for outbound flights, 17 November 2009 at FL 340 and FL 385

Date/time valid	For flight sector	GFS forecast wind component FL 340/FL 385	GFS analysis wind component FL 340/FL 385	NCEP FNL analysis wind component FL 340/FL 385	NCEP CFSR reanalysis wind component FL 340/FL 385
17 Nov 2009 1200 UTC	Sydney to Norfolk Island	45/45 kt (based on 0600 UTC analysis)	50/45 kt	50/45 kt	50/45 kt
17 Nov 2009 1500 UTC	Norfolk Island to Apia	45/45 kt (based on 1200 UTC analysis)	-	-	45/50 kt
17 Nov 2009 1800 UTC	Norfolk Island to Apia	45/50 kt (based on 1200 UTC analysis)	45/50 kt	45/50 kt	40/45 kt

Figure D2: GFS 200 hPa analysis 1200 UTC, 18 November 2009



This chart depicts the westerly jetstream at FL 385 north of Norfolk Island and is the closest GFS analysis to the final hour of the flight and the time of ditching.

Source: NCEP GFS GRIB data, decoded and rendered using 'LuckGrib' software, annotated by ATSB

366 All forecast and analysis wind components in this section have been rounded to the nearest 5 kt.

Table D2: Summary of derived average wind component for accident flight, 18 November 2009

Date/time valid	For flight sector	GFS forecast wind FL 340 and FL 385	GFS analysis wind component FL 340 and FL 385	NCEP FNL analysis wind component FL 340 and FL 385	NCEP CFSR reanalysis wind component FL 340 and FL 385	Estimate of wind based on analysis of FDR data[367]
18 Nov 2009 0600 UTC	Apia to Norfolk Island	-45/-55 kt (based on 0000 UTC analysis)	-45/-60 kt	-45/-55	-45/-55 kt	-
18 Nov 2000 0900 UTC	Apia to Norfolk Island	-50/-60 kt (based on 0600 UTC analysis)	-	-	-45/-55 kt	-55 kt
18 Nov 2009 1200 UTC	Apia to Norfolk Island	-45/-60 kt (based on 0600 UTC analysis)	-50/-60 kt	-50/-60 kt	-45/-60 kt	-

Validation of forecast, analysis and reanalysis winds with data derived from the FDR and aircraft position reports

The forecast, analysis and reanalysis winds were compared with data derived from the aircraft's FDR at a series of reporting points, while the aircraft was maintaining FL 390. That comparison was to check the correlation between the wind estimate affecting the accident flight and other independent sources of information (Table D3). For the purpose of those calculations, the time of arrival at the reporting point was assumed accurate to the nearest minute and that the crew used the GPS to provide ATS the estimate for the next position.

The accuracy of the effective wind component derived from analysis of data from the FDR was subject to minor errors, including:

- rounding of times to the nearest minute
- accuracy of indicated airspeed recorded by FDR (nominally ± 5 kt)
- temperature deviation from forecast/assumed temperature at cruise altitude.

There was a good overall correlation between the data derived from the FDR/aircraft position reports and the forecast, analysis and reanalysis winds.

In addition, during the CVR replay, there were position reports passed by an opposite direction aircraft. Those reports included:

- waypoint DUNAK at 0853, FL 370 and wind 270/70 kt (representing a 55 kt tailwind for that aircraft)
- waypoint APASI 0911, FL 390 and wind 265/60 kt (representing a 50 kt tailwind for that aircraft).

Overall, the winds obtained from the GFS analysis, the NCEP FNL analysis and CFSR reanalysis were generally ± 5 kt of the effective wind component derived from the data on the FDR.

367 Estimate includes wind during climb and descent, but ignores the effect of any cross track wind.

Table D3: Correlation between forecast, analysis and reanalysis winds with FDR from the accident flight and allowing for the effect of drift due cross track wind

Time (UTC)	Waypoint (reporting point)	GFS forecast wind	GFS analysis wind (FL 385)	NCEP FNL analysis wind (FL 385)	CFSR reanalysis wind (FL 385)	Effective wind based on FDR data
0709	APASI	-55 kt (0600 UTC, based on 0000 data)	-60 kt (0600 UTC)	-60 kt (0600 UTC)	-45 kt (0600 UTC)	-63 kt[368]
0736	DUNAK	-70 kt (0900 UTC, based on 0600 data)	-60 kt (0600 UTC)	-60 kt (0600 UTC)	-65 kt (0900 UTC, based on 0600 data)	-60 kt[369]
0839	DOLSI	-85 kt (0900 UTC, based on 0600 data)	-90 kt (0600 UTC)	-90 kt (0600 UTC)	-90 kt (0900 UTC, based on 0600 data)	-84 kt[370]

Effect of cross track wind

The track of the aircraft across the ground is usually affected by the wind. The desired ground track is maintained by pointing the nose of the aircraft slightly into wind. As the strength of the cross track wind increases, the drift angle increases and, with the nose of the aircraft displaced away from the desired ground track, there is an increasing effect on the aircraft's effective true airspeed. This is due to the vector resolution of the aircraft and wind velocities, with the aircraft's heading displaced from the desired ground track. In that circumstance, the effective true airspeed is the cosine of the drift angle multiplied by the true airspeed.

When flying with strong cross track winds that require large drift angles to maintain the required ground track, comparing groundspeed to true airspeed to estimate a wind component results in the underestimation of the actual tailwind and an overestimation of the actual headwind components. The amount of drift experienced due to the cross track wind depends on the speed of the aircraft.

The wind component provided in the SPFIB is a resolution of the wind velocity into headwind/tailwind and cross track wind vectors. That is, it does not incorporate any correction for the reduction in effective true airspeed due to strong cross track winds and the effect of drift.

For the outbound flight from Sydney to Norfolk Island on 17 November 2009, the drift angle was relatively small at FL 340 / FL 385 and there was no appreciable reduction to the effective true airspeed. For the flight from Norfolk Island to Apia on 17 November, the average effective true airspeed was reduced by about 5 kt at FL 340 / FL 385 due to the drift angle, reducing the apparent effect of the tailwind component by a similar amount.

For the inbound flight from Apia to Norfolk Island on 18 November 2009, the average effective true airspeed was reduced by about 5 kt at FL 385 due to the drift angle, increasing the apparent effect of the headwind component by a similar amount.

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368 Times passed to ATS with position reports were to the nearest minute. Allowing for the effect of rounding, this gave an effective headwind component of between 51 and 75 kt. That range would increase if the accuracy of the position report was outside that tolerance.

369 Allowing for the effect of rounding, this gave an effective headwind component of between 52 and 63 kt.

370 Allowing for the effect of rounding, this gave and effective headwind component of between 83 and 91 kt.

Appendix E – Aircraft fuel status during accident flight from Norfolk Island to Apia 18 November 2009

Estimation of the fuel burn off during previous flights

The fuel burn offs during the flight from Sydney to Norfolk Island on 17 November 2009 and from Norfolk Island to Apia on 17 November 2009 were estimated using performance tables from the aircraft manufacturer's *1124A-Westwind Operational Planning Manual* (OPM). This involved using climb performance tables, constant speed cruise tables and the normal descent summary table.

The OPM tables required the use of parameters such as aircraft weight, outside air temperature, flight level and (for cruise) Mach number. The Mach number was converted to true airspeed (TAS) when estimating the fuel burn off. Table E1 indicates how the ATSB obtained or estimated these parameters.

Table E1: Source of relevant parameters for estimating fuel burn during flights on 17–18 November 2009

Data	Comment
Aircraft weight	The zero fuel weight (ZFW) for the 17 November 2009 flights from Sydney to Apia was estimated to be 6,440 kg (14,197 lb) comprising aircraft empty weight 5,944 kg (13,104 lb), flight crew and medical personnel 306 kg (675 lb), medical equipment 95 kg (209 lb), baggage 50 kg (110 lb) and life rafts and emergency equipment 45 kg (99 lb). The ZFW for the 18 November 2009 flight from Apia to Norfolk Island was estimated to be 6,640 kg (14,640 lb), which included the patient, passenger and their baggage. The estimation of the fuel on board is described below.
Flight level (FL) and altitude (ALT)	Obtained from the data on the FDR (see appendix B).
Indicated airspeed (IAS)	Obtained from the FDR. The FDR manufacturer specified a typical tolerance of ±3 kt at 200 kt.
Mach number and true airspeed (TAS)	The aircraft's Mach number was derived using the following data: • indicated airspeed from the FDR • altitude from the FDR • 1124A Westwind OPM airspeed and Mach calibration tables The Mach number was converted to TAS using outside air temperatures from the CSFR data (see appendix D).TAS values were checked by calculating the aircraft's groundspeed and position based on the TAS and CSFR wind data, and comparing these results with aircraft position reports provided by the flight crew to air traffic services and the Norfolk Island Unicom operator. The two sets of groundspeeds and position reports closely matched.

The flights were divided into a number of segments, and the fuel burn for each segment was estimated. When using the OPM tables, values often had to be interpolated. These interpolations were done in multiple ways and the results were cross-checked to minimise errors.

Fuel burns during climbs and approaches were cross-checked with aircraft speed to ensure the values were reasonable. Fuel burns during cruise were also checked by examining the estimated TAS and reported wind speed and checking the derived groundspeed to ensure the values matched the times the crew advised ATS they passed the various waypoints (reporting points).

For the flight from Sydney to Norfolk Island:

- The fuel on board prior to engine start was estimated to be 8,729 lb, which was full fuel at an estimated specific gravity (SG) of 0.790.[371]
- Using the OPM the total fuel burn off prior to engine shutdown at Norfolk Island was estimated to be 3,637 lb.
- At Norfolk Island, the added fuel was 1,294 L (2,268 lb at an estimated SG of 0.795[372]) to fill the main tanks. If the fuel already on board was at an estimated SG of 0.795 (an increase due to in-flight cold soaking), then the fuel burn off from Sydney to Norfolk Island was probably about 3,713 lb, a discrepancy of 76 lb with the estimated figure of 3,637 lb.
- Therefore, the figures based on using the OPM underestimated the total fuel burn off by about 2.1 per cent.

For the flight from Norfolk Island to Apia:

- The fuel on board prior to engine start was estimated to be 7,284 lb (full main tanks with fuel added at an estimated SG of 0.795 and fuel already on board at an estimated SG of 0.795).
- Using the OPM the total fuel burn off prior to engine shutdown at Apia was estimated to be 4,749 lb.
- At Apia, the added fuel was 2,780 L (4,811 lb at estimated SG of 0.785)[373] to fill the main tanks. If the fuel already on board was at an SG of 0.785 (a decrease in SG due to heat soaking as the aircraft was parked on the apron for the entire day), then the fuel burn off from Norfolk Island to Apia was probably about 4,902 lb, a discrepancy of 153 lb with the estimated figure of 4,749 lb.
- Therefore, the figures based on using the OPM underestimated the total fuel burn off by about 3.2 per cent.

In summary, using the OPM figures, the average underestimate of the total fuel burn for the two flights was 2.7 per cent. This underestimation could be due to a range of factors, such as airframe aging, engine aging, or minor errors in the recorded indicated airspeed on the FDR.

No other flights of a suitable flight time were able to be analysed in the same manner, as the FDR was replaced on 3 November 2009. Although some recorded data for some previous flights was obtained, the use of different recorders meant that these flights could not be compared with the 17–18 November 2009 flights.

Estimation of fuel on board during the accident flight

The fuel on board the aircraft after refuelling and prior to engine start was derived from the following data:

- The aircraft was refuelled at Apia with 2,780 L of Jet A1 aviation turbine fuel with an estimated SG of 0.785. Therefore, this volume equated to about 4,811 lb.
- The captain reported the aircraft's main tanks were full after refuelling.

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371 A mobile jet fueller was used to load fuel to VH-NGA at Sydney Airport. The SG of the fuel most recently loaded to the jet fueller was 0.7903 at standard temperature. At that time, there may have been a quantity of fuel already in the fueller and possibly from another batch. There were no records of the actual SG of the fuel loaded to VH-NGA. An SG of 0.790 was considered to be a reasonable estimate of the fuel loaded at Sydney (rounded to the nearest 0.005).

372 Due to a change in fuel agent at Norfolk Island Airport, records of the fuel SG used to refuel VH-NGA at Norfolk Island Airport were no longer available to the reopened investigation. However, the fuel batch used to refuel VH-NGA was independently tested before being released for use at the airport. A copy of that test report indicated the fuel's SG was 0.7958 at standard temperature. An SG of 0.795 was considered to be a reasonable estimate of the fuel loaded at Norfolk Island at ambient temperature (rounded to the nearest 0.005).

373 The SG of this fuel was calculated from diarised records of the daily checks of temperature-corrected fuel density and fuel temperature. Adjusting the temperature-corrected density for estimated fuel temperature at delivery, the SG of the fuel used to refuel VH-NGA was 0.7846. An SG of 0.785 was considered to be a reasonable estimate of the fuel loaded at Apia (rounded to the nearest 0.005).

- As the usable fuel capacity of the main tanks was 4,156 L, this meant that there was about 1,376 L of fuel already on board prior to refuelling. Using an SG of 0.785 due to the fuel on the aircraft being 'heat soaked', the fuel on board prior to refuelling (1,376 L) was about 2,381 lb.
- Using an SG of 0.785, the total usable fuel on board (4,156 L) prior to engine start was about 7,192 lb (rounded to 7,190 lb).

The fuel on board the aircraft during the flight from Apia to Norfolk Island was estimated using the OPM and the same method as per the two previous flights. The resulting data is shown in Table E2. The table also shows the estimated fuel remaining based on adding 2.1, 2,7 and 3.2 per cent correction factors.

As noted above, using the OPM resulted in an average underestimate of the fuel burned of about 2.7 per cent for recent flights. Given this was based on only two flights, the average was not necessarily the best correction factor to use. In order to determine the most appropriate correction factor, other available information was considered. This information included:

- On the CVR recording at 0909:12, the captain stated the fuel quantity gauges were indicating 'just south' of 2,000 lb. The best estimate of the fuel quantity gauge indication at that time was about 1,800 lb (see next section). The ATSB estimated that the fuel quantity gauges were underreading on average by about 260 lb since the last calibration. Therefore, the actual amount of fuel remaining at 0909:12 was probably close to 2,060 lb. The estimated figure in Table E2 is 2,040 lb.
- On the CVR recording at 0924:49, the captain indicated the fuel quantity gauges were reading 1,400 lb. The best estimate of the fuel quantity gauge indication at that time was about 1,450 lb (see next section). Therefore, the actual amount of fuel remaining at 0924:49 was probably close to 1,710 lb (that is, 1,450 plus 260 lb). The estimated figure in Table E2 is 1,700 lb.
- The captain recalled that, at the start of the first missed approach, the fuel quantity gauges indicated in the order of 1,200–1,400 lb. However, this recollection was provided several months after the accident. It is significantly inconsistent with the CVR information and other crew information and was considered to be unreliable. The estimated figure in Table E2 is 1,040 lb.
- The captain recalled soon after the accident that, after the second approach, the fuel quantity gauges were indicating about 300 lb each side (600 lb total). If the fuel quantity gauges were underreading by 260 lb, then the actual fuel on board should be close to 860 lb (±100 lb). The estimated figure in Table E2 is 820 lb.
- The captain recalled soon after the accident that, at the end of the second approach or during the missed approach, the FUEL LEVEL LOW warning light illuminated on the annunciator panel. The fuel system is designed to illuminate this light when the fuel quantity in either tank reduces to about 415 lb (±25 lb). This is based on the operation of a float switch in the tanks, not the fuel quantity gauge indication. There was no indication the flight crew opened the interconnect valve, so it is likely the fuel quantity on one tank was higher than the other tank when the light was activated. Therefore the fuel remaining was very likely to be more than 780 lb and probably about 830 lb at this time. The estimated figure in Table E2 is 820 lb.
- The first officer recalled soon after the accident that, at the start of the fourth approach, the gauges indicated there was about 200 lb of fuel remaining (total). If the fuel quantity gauges were underreading by 260 lb, then the actual fuel on board should be close to 460 lb (±100 lb). The estimated figure in Table E2 is 520 lb.
- The captain recalled soon after the accident that, just prior to the ditching, there was between 0 and 100 lb indicated on each fuel quantity gauge. If the fuel quantity gauges were indicating 100 lb total and the fuel quantity gauges were underreading by 260 lb, then the actual fuel on board should be close to 360 lb (±100 lb). The estimated figure in Table E2 is 440 lb.

Table E2: Aircraft's estimated fuel status during the accident flight

Time (UTC)	Position	Event	OPM	OPM + 2.1%	OPM + 2.7%	OPM + 3.2%
0515	Faleolo Airport, Apia	After refuelling	7,190	7,190	7,190	7,190
0545	Faleolo Airport, Apia	Start of the take-off roll on runway 08.	7,060	7,060	7,060	7,060
0636	KILAN waypoint	---	5,460	5,430	5,420	5,410
0644	57 NM after KILAN waypoint	Top of climb at FL 390.	5,250	5,210	5,200	5,190
0709	APASI waypoint	---	4,720	4,670	4,660	4,650
0736	DUNAK waypoint	---	4,150	4,090	4,080	4,060
0803	154 NM after DUNAK waypoint	Nadi ATS provided the crew with the 0800 Norfolk Island SPECI.	3,570	3,500	3,480	3,460
0839	DOLSI waypoint	---	2,810	2,720	2,690	2,670
0907	152 NM after DOLSI waypoint	Auckland ATS completed providing the crew with the 0902 Norfolk Island SPECI.	2,220	2,120	2,090	2,060
0909:12	165 NM after DOLSI waypoint 270 NM before Norfolk Island Airport	Captain stated "we're just north of two thousand rather than just south of two thousand".	2,170	2,070	2,040	2,010
0924:49	185 NM before Norfolk Island Airport	Captain stated "fourteen hundred pounds [gauge reading], we're actually a bit more than that, we got seventeen hundred"	1,840	1,730	1,700	1,670
0929	162 NM before Norfolk Island Airport	Captain requests an appreciation of the weather from the Norfolk Island Unicom operator.	1,750	1,640	1,610	1,580
0940	90 NM before Norfolk Island Airport	Top of descent.	1,510	1,390	1,360	1,330
0956:37		Start of first approach via 10 DME arc.	1,330	1,210	1,180	1,150
1003:43		Start of first missed approach	1,190	1,070	1,040	1,010
1011:45		Start of second missed approach	980	850	820	790
1017:19		Start of third missed approach	810	680	640	610
1021:23		Start of fourth approach	690	560	520	490
1025:58		Initial impact	610	470	440	400

In summary, applying a correction factor of 2.7 per cent to the estimated fuel burn estimated using the OPM provided a good fit with the available information. This resulting estimates provided a very good match for the expected values based on the two comments on the CVR recording (after considering the estimated amount of fuel quantity gauge underreading). It also provided a reasonable, although slightly low, figure for the fuel remaining at the reported time that the low level warning light illuminated. In addition, it provided a reasonable approximation of the flight crew's recollections.

Although the figures derived using the OPM and adding a 2.7 per cent correction factor are a good fit, they are still only an estimate. There are a significant number of assumptions involved in such an analysis, and many factors that could influence the results. Overall, the analysis provides the best estimate of the amount of fuel remaining at a particular time. However, the actual amount of fuel on board at any particular time could have been slightly different.

The captain reported he set the thrust at the start of the cruise at FL 390 based on an engine inter-turbine temperature (ITT) of about 820°C and this thrust setting was not changed for the remainder of the cruise. Using a correction factor of 2.7 per cent, the average fuel burn off during the cruise at FL 390, after the thrust had been set, was estimated to be 1,310 lb/hour (or 1,276 lb/hour multiplied by 1.027).

Estimation of the fuel quantity gauge indications during the accident flight

As noted in appendix F, the aircraft's fuel quantity gauges were probably underreading by about 260 lb (on average) after the last calibration (14 October 2009). Therefore actual fuel on board was not the same as the indicated fuel on board.

The best indications of the indicated fuel on board were two statements by the captain recorded on the CVR:

- At 0909:12 UTC, the captain stated the fuel quantity gauges were indicating 'just south of' 2,000 lb and he thought that they had 300 lb more than indicated, or 'just north of' 2,000 lb. This statement suggests the gauges were probably indicating 1,800–1,900 lb and he thought there was 2,100–2,200 lb of fuel on board.
- At 0924:49 UTC, the captain stated the fuel quantity gauges were indicating 1,400 lb. This could mean that the two gauges were indicating a total of 1,350–1,450 lb.

The ATSB estimated that the aircraft's fuel burn during the cruise at FL 390, after the thrust was set, was about 1,310 lb/hour. Therefore, over the 15.60 minutes between the two statements, the aircraft burned about 340 lb of fuel.

There was no evidence to suggest that the fuel quantity gauges were indicating erratically during the flight. Therefore, assuming that the gauge indications were steadily decreasing in a consistent manner over this relatively-short period, they should have provided an indication at 0924:49 that was about 340 lb less than the indication at 0909:12.

The best fit of the two statements on the CVR recording is if the gauges were indicating about 1,450 lb at 0924:49. In which case, they would have been indicating about 1,790 lb at 0909:12. If the gauges were actually indicating 1,400 lb at 0924:49, they would have been indicating about 1,740 lb at 0909:12. This would seem inconsistent with the statement made at that time.

Based on these indications and the estimated fuel burn, the fuel quantity gauge indications during the cruise can be estimated as indicated in Table E3. As noted in *Review of flight records to evaluate the accuracy of the fuel quantity gauges*, the captain reported he was aware that the fuel quantity gauges were underreading by about 300 lb. The last column in Table E3 also shows the likely fuel quantity gauge indication plus 300 lb, which corresponds to an estimate of the captain's likely understanding of the fuel on board at the selected times.

Table E3: Estimated fuel quantity gauge indications during cruise

Time (UTC)	Estimated gauge indication	Estimated gauge indication + 300 lb
0803:00	3,230 lb	3,530 lb
0839:00	2,450 lb	2,750 lb
0847:00	2,270 lb	2,570 lb
0855:00	2,100 lb	2,400 lb
0902:00	1,950 lb	2,250 lb
0907:00	1,840 lb	2,140 lb
0909:12	1,790 lb	2,090 lb
0924:49	1,450 lb	1,750 lb
0929:00	1,360 lb	1,680 lb
0940:00	1,120 lb	1,420 lb

It should be noted that reading values from the fuel quantity gauges would only have been accurate to the nearest 100 lb. However, the fuel status indicator should have provided a digital readout to the nearest 10 lb.

Appendix F – Accuracy of the aircraft's fuel quantity gauges and fuel flow indicators

Information about fuel quantity gauge indications before refuelling

For the accident flight:

- On the cockpit voice recorder (CVR) recording, at 0909 UTC, the flight crew stated the fuel quantity gauges indicated a total fuel on board of about 2,000 lb prior to refuelling at Apia.
- The captain refuelled the aircraft to full main tanks. He reported that, as was his normal practice, he asked the refueller to 'keep going' or 'go again' after the browser automatically clicked off. He did this a couple of times to ensure there was no air pockets left in the tanks. A witness recalled hearing the captain provide these instructions to the refueller.
- To get full main tanks, the refueller added 2,780 L. The estimated specific gravity (SG) of the added fuel was 0.785 kg/L (or 1.731 lb/L). Therefore, 4,811 lb (or about 4,810 lb) was added during refuelling.
- The fuel on board after refuelling was estimated to be about 7,190 lb (see appendix E). This was based on applying an SG of 0.785 kg/L to the known volume of the aircraft's main tanks, given that the aircraft had been parked all day at the airport.
- The fuel on board prior to refuelling was estimated to be 2,380 lb (that is, 7,190 - 4,810 lb).
- Therefore, the difference between the indicated fuel on board prior to refuelling (2,000 lb) and the estimated fuel on board prior to refuelling (2,380 lb) was -380 lb, suggesting the fuel quantity gauges were underreading by about 380 lb.

The captain also recalled that the fuel quantity gauges were indicating about 6,800–6,900 lb after the aircraft was refuelled to full main tanks at Apia, which suggested the gauges were underreading by about 300–400 lb when the main tanks were full.

In addition, the captain reported that, on the outbound flights on 17 November 2009, he reviewed the aircraft's flight record sheets for recent flights for which the aircraft had been refuelled to full main tanks. He found the fuel quantity gauges appeared to be underreading on those flights by about 300 lb.

Review of previous flights fuel quantity gauge indications before refuelling

The ATSB reviewed the aircraft's flight records for the period from April 2008 up until the 17–18 November 2009 trip. For each flight, the data on the operator's flight record included:

- fuel added (in L)
- fuel on board (prior to engine start in lb)
- fuel burn (or fuel consumed from engine start to engine shut down in lb)
- fuel remaining (after engine shutdown in lb).

The Westwind standards manager reported a flight crew's recorded fuel remaining on a flight record was usually based on reading the fuel remaining figure on the fuel status indicator, as the digital figure was easier to read than the fuel quantity gauges. A crew would also cross-check this figure with the gauges. As noted in *Fuel status indicating system*, for VH-NGA and other 1124/1124A aircraft with serial numbers of 309 or later, the fuel remaining figure on the fuel status display was always close to the combined sum of the two fuel gauges.

The ATSB's review of the flight records found the recorded fuel burn almost always equalled the difference between the recorded fuel on board at the start of the flight and the fuel remaining. The standards manager reported pilots would not usually record the fuel consumed figure from the fuel status indicator as that often had errors associated with it. Accordingly, the fuel consumed figure appeared to be derived from subtracting the indicated fuel remaining (after engine shutdown) from the recorded fuel on board prior to engine start.

The ATSB reviewed VH-NGA's flight records to compare:

- the recorded fuel on board prior to refuelling
- the estimated fuel on board based on the known capacity of the fuel tanks and the amount of fuel added during refuelling.

For these comparisons:

- An SG of 0.790 kg/L (or 1.742 lb/L) was used for all conversions of the fuel added in L to lb. As the same SG was used for both the fuel added (the majority of the estimated fuel on board) and the actual fuel on board, the value of the SG had limited influence on the comparisons.
- The review only considered flights where it appeared a crew had refuelled to a known quantity, either full main tanks (nominally 7,238 lb at an SG of 0.790) or full fuel (nominally 8,729 lb at an SG of 0.790). Full main tanks was considered to be a recorded fuel on board after refuelling of 7,100–7,400 lb (usually 7,200 lb), and full fuel was considered to be a recorded fuel on board after refuelling of 8,500–8,900 lb (usually 8,700 lb).[374] For most of these flights, it is likely the recorded fuel on board was usually based on the known quantity of fuel on board rather than the fuel quantity indication.

Figure F1 shows the difference between the recorded and estimated fuel on board prior to refuelling for the period from 1 April 2008 to 18 November 2009, after a small number of outliers were removed. The data is presented in six periods, depending on the date of maintenance activities (see Table 17). Table F1 provides summary statistics for the six periods.

Figure F1: Difference between recorded and estimated fuel on board VH-NGA

Note: A negative value indicates the recorded fuel on board was less than the estimated fuel on board. In other words, the gauges were underreading. Although written flight records were not available for the 17–18 November 2009, data was included for the Sydney to Norfolk Island flight on 17 November and the flight from Apia to Norfolk Island on 18 November 2009.

Source: ATSB, based on data provided by the Pel-Air Aviation

374 There were only a small number of recorded values of 7,400 lb, 8,500 lb or 8,900 lb, and none after October 2008.

Table F1: Sample size, mean and standard deviation of the difference between recorded and estimated fuel remaining

Date	Activity	Sample size	Mean (lb)	Standard deviation (lb)
1 Apr 2008	Start of selected sample	35	-147	114
11 Sep 2008	Fuel gauges adjusted	25	-251	88
3 Dec 2008	Dry calibration	46	157	135
3 Aug 2009	Tanks replaced, dry calibration	3	-117	75
18 Sep 2009	Probe replaced, wet calibration	8	-330	95
14 Oct 2009	Indicator test	10	-256	73

As is evident in the figure and the table, there is some variation in the data, due to factors such as rounding errors,[375] different pilot practices, aircraft nose angle, occasional recording errors and SG variations (of the fuel remaining and/or the fuel added). Nevertheless, there were observable step changes corresponding to the date of some maintenance activities.

For the period since the last maintenance activity (14 October 2009) and prior to the accident flight, there were nine relevant flights that could be used for comparisons. The mean difference was -242 lb (underreading), with the values ranging from -125 lb to -311 lb. With the addition of the accident flight, where the amount of underreading was estimated to be -380 lb, the mean difference was -256 lb. The median value of the difference was -261 lb.[376]

The data for the accident flight appeared to indicate a larger amount of underreading than was evident for previous flights since the last maintenance activity. There was no known change in the aircraft's fuel system that would suggest that the amount of underreading should have increased. Overall, it was concluded that the best estimate of the underreading since the last maintenance activity was about -260 lb.

The amount of underreading in the period 18 September to 7 October 2009 was 330 lb. Although the amount of underreading after 7 October 2009 appeared to be slightly lower, the difference between the two periods was not statistically significant.

Additional review of the data for each period found:

- For the period 1 April 2008 to 5 September 2008, there was an overall pattern of underreading, and the difference was significantly different to 0 lb. There was no indication the difference varied depending on the amount of fuel on board prior to refuelling.
- For the period 11 September 2008 to 1 December 2009, there was an overall pattern of underreading, and the difference was significantly different to 0 lb. There was no indication the difference varied depending on the amount of fuel on board prior to refuelling.
- For the period from 3 December 2008 to 27 April 2009, there was an overall pattern of overreading, and the difference was significantly different to 0 lb. There was also a significant correlation between the amount of overreading and the amount of fuel on board. More specifically, the difference decreased as the amount of fuel on board decreased. For example, when the amount of fuel on board was about 2,000 lb or less, the amount of overreading was about 100 lb. When the amount of fuel on board was 4,000 lb or more, the amount of overreading was about 200 lb. This result was consistent with the last maintenance activity being a dry calibration, and the 0 lb gauge indication being set to the capacitance value of empty tanks.

375 In almost all cases flight crews recorded the fuel on board, fuel burn off and fuel remaining to the nearest 100 lb.

376 In addition to the 10 flights, there was one flight where the flight crew had recorded the fuel on board as 6,900 lb. It was considered likely that the aircraft was refuelled to full main tanks rather than 6,900 lb, and the recorded fuel on board on this occasion was based on the fuel quantity gauges rather than the known quantity of the tanks. Assuming the aircraft was refuelled to full main tanks, the amount of underreading on this flight was -262 lb, consistent with the other values.

- For the period from 3 August 2009, there was insufficient data to conduct analyses. However, the average difference appeared to be closer to 0 lb compared to subsequent periods.
- For the period from 18 September to 9 October 2009, there was an overall pattern of underreading, and the difference was significantly different to 0 lb. There was also no indication the difference varied depending on the amount of fuel on board prior to refuelling.
- From the period from 14 October to 18 November 2009, there was an overall pattern of underreading, and the difference was significantly different to 0 lb. There was also a significant correlation between the amount of underreading and the amount of fuel on board. More specifically, the difference increased as the amount of fuel on board decreased. This result was considered spurious, associated with the relatively low number of data points. More importantly, the pattern was not consistent with the last maintenance activity (recorded as an 'indicator test') being a dry calibration.

Overall, the pattern of results indicated the fuel quantity gauges on VH-NGA were significantly underreading since 11 September 2009, and this level of underreading did not decrease as the amount of fuel remaining decreased. The results also indicated that, when a dry calibration was known to be performed, subsequent fuel gauge readings were more accurate, particularly as the amount of fuel remaining approached 0 lb.

The ATSB also reviewed records for six of the operator's other Westwind aircraft. In all cases there were no apparent step changes similar to those found for VH-NGA. In addition, the average difference between the recorded fuel quantity and the estimated fuel quantity was closer to 0 lb and/or not significantly different to 0 lb.

The ATSB requested fuel quantity indicating system maintenance records for two of the operator's other Westwind aircraft that were generally maintained at the same base as VH-NGA during 2008–2009. Across the two aircraft, there were four maintenance activities where some form of calibration would have been conducted, although two of these activities were outsourced to external maintenance providers. The four cases included:

- Two cases where maintenance records stated a dry calibration was conducted. A review of flight records indicated that following one of these calibrations (conducted externally), the fuel gauges were effectively calibrated. Following the other calibration (conducted internally), there was insufficient data points between the calibration and a subsequent maintenance activity to determine whether the gauges were effectively calibrated.
- Two cases where maintenance records did not indicate the nature of the calibration method that was used. Following one of these activities (conducted internally), the gauges appeared to be effectively calibrated. In the other case, the aircraft appeared to be undergoing extensive maintenance work (conducted externally) prior to being released for initial line operations for the operator, and it was considered likely that a dry calibration was conducted. However, there was insufficient information to determine whether the gauges were effectively calibrated.

Review of flight records to evaluate the accuracy of fuel flow indicators

Both flight crew recalled that the fuel flow indications after the aircraft was established in cruise at FL 390 was 550 lb/hour for each engine (or 1,100 lb/hour total). The ATSB fuel analysis estimated that the fuel flow was probably about 1,310 lb/hour (appendix E). Therefore, the crew's recalled fuel flow figure was probably about 16 per cent less than the estimated fuel flow.

On each daily flight record sheet, which could contain up to four flights, the flight crew would record one set of engine trend monitoring data.[377] The trend monitoring data included the following parameters:

[377] Flight crews used the same flight record sheet to record details for each flight conducted on the same day for the same task. Because multiple flights were usually recorded on the same flight record sheet, the flight on which the trend

- flight level
- Mach and indicated airspeed (IAS)
- outside air temperature (OAT)
- N1 for each engine
- Inter-turbine temperature (ITT) for each engine
- N2 for each engine
- fuel flow for each engine.

Based on the recorded flight level, Mach, OAT and N1, the fuel flow could be estimated using the manufacturer's Operational Planning Manual (OPM).

The ATSB reviewed the trend monitoring data for VH-NGA from mid-September to November 2009. There were 10 usable sets of data, with the last recorded on 30 October 2009. For this data:

- The N2 values were the same for each engine.
- The N1 values were higher on the left engine (average of 1.3% higher).
- The ITT values were higher on the left engine (average of 16°C higher).
- The fuel flows were usually higher on the left engine (7 cases, ranging from 20 to 80 lb/hour higher). However sometimes they were the same (3 cases).

Estimating the fuel flow based on the OPM involved some variability due to the recorded figures being rounded and a significant amount of interpolation was usually required. Nevertheless, the estimated fuel flows based on the average N1 were consistently higher than the recorded fuel flows, with an average value of 10 per cent (with a range of 3–18 per cent). If the 2.7 per cent correction was applied to the OPM figures consistent with the accident flight analysis (appendix E), the estimated fuel flows were 12 per cent higher (with a range of 5–20 per cent).

It is possible the differences could be due to problems associated with the recorded value of one of the other parameters rather than fuel flow. However:

- Even when using the lowest N1 value (right engine) instead of the average N1, there was still a consistent pattern of underreading, albeit by a slightly smaller amount.
- In some cases the recorded fuel flow was lower than the fuel flow for the lowest possible weight of the aircraft in cruise in the recorded conditions.

A similar pattern existed for flight records from January to April 2009, with no data recorded during the period from May to August.

One flight record sheet contained data for a flight at FL 390 in similar conditions to the accident flight. It was on 29 September 2009, and the data may have been recorded either on a flight from Sydney to Norfolk Island or a flight from Norfolk Island to Apia. The captain of the accident flight was the captain of 29 September flight. The recorded data included:

- OAT -53°C
- Mach 0.74
- N1 98.3% left, 97.7% right (average 98.0%)
- ITT 836°C, 827°C (average 832°C)
- fuel flow 600 lb/hour left, 600 lb/hour right.

The OAT was consistent with the forecast and actual conditions for both flights. The estimated fuel flow using the OPM was about 1,300 lb/hour, 100 lb/hour higher than the recorded fuel flow. The recorded fuel flow was also higher than the fuel flow for the lowest possible weight of the aircraft during the cruise for either flight.

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monitoring data was recorded was usually not known. The data was recorded when the aircraft was established in cruise.

The recorded ITT on 29 September 2009 (832°C) was slightly higher than the figure the captain recalled using for the accident flight (820°C). A sample of data from the FDR during the accident flight was selected with a speed of .72 Mach true (0.74 Mach indicated), which occurred at about 0803 UTC. The estimated fuel flow at this time based on using the OPM was 1,271 lb/hour and the estimated N1 was 97.0%, which was lower than the recorded N1 on 29 September 2009 (98.0%). Overall, the recorded fuel flow of 1,200 lb/hour on 29 September 2009 with a higher N1 at FL 390 was consistent with there being a lower indicated fuel flow than 1,200 lb/hour on the accident flight at FL 390.

Aircraft can vary in their performance characteristics, and it is not unusual for an aircraft to perform slightly worse or better than the figures published by a manufacturer. However, it was considered very unlikely that VH-NGA’s engines were able to achieve the same performance as the manufacturer’s published figures using 10 per cent or more less fuel.

In summary, it appears that VH-NGA’s fuel flow indicators were underreading. Although the exact amount of underreading was difficult to estimate, the apparent amount of underreading on the accident flight (16 per cent) was within the range of values estimated for previous flights.

A pilot reported a specific case of the left fuel flow indicator displaying a very low value for a brief period on 11 September 2009. A subsequent check found no fault. That event appeared to be different to a general pattern of underreading by a lesser amount indicated on flights both before and after 11 September 2009.

The ATSB also reviewed samples of trend monitoring data for the operator’s other aircraft. In most cases the recorded fuel flow was closer to the estimated fuel flow. For one aircraft there appeared to be a pattern of underreading (to a lesser extent than in the case of VH-NGA) and in another case there was a pattern of slight overreading. For all the aircraft there were a number of outlier values, indicating that at least one parameter was recorded incorrectly.

Appendix G – Transcript of communications between the captain and the Nadi international flight services officer from 0756–0803

Time UTC	From	To	Transmission
0756:34	VH-NGA	Nadi	Nadi radio, victor hotel november golf alpha [VH-NGA], request.
0756:46	Nadi	VH-NGA	victor november golf alpha [VNGA], Nadi.
0756:48	VH-NGA	Nadi	is it possible to obtain a METAR for yankee sierra november foxtrot [YSNF, Norfolk Island] please?
0757:01	Nadi	VH-NGA	victor november golf alpha, Nadi standby.
0801:15	Nadi	VH-NGA	victor hotel november golf alpha, Nadi. [Note: the Nadi international flight information service officer is now a different officer.]
0801:20	VH-NGA	Nadi	Nadi go ahead, victor golf alpha.
0801:24	Nadi	VH-NGA	roger, ready to copy METAR Norfolk?
0801:27	VH-NGA	Nadi	go ahead, victor golf alpha.
0801:31	Nadi	VH-NGA	METAR Norfolk at zero six three zero zulu [0630 UTC]. Wind three zero zero, zero nine knots [300/09 kt], niner niner niner niner [9999 m], few six thousand [6,000 ft], broken two thousand four hundred [2,400 ft], temperature two one [21°C], dewpoint one niner [19°C], QNH Norfolk one zero one one [1011 hPa]. Remarks closed till one niner three zero UTC [1930 UTC], go ahead.
0802:08	VH-NGA	Nadi	ah copy, eh just say again the issue time for the METAR.
0802:14	Nadi	VH-NGA	issue time for the METAR, this is the latest, zero six three zero zulu [0630 UTC].
0802:22	VH-NGA	Nadi	victor golf alpha, thank you.
0802:26	Nadi	VH-NGA	victor november golf alpha, Nadi.
0802:29	VH-NGA	Nadi	go ahead Nadi, victor golf alpha.
0802:32	Nadi	VH-NGA	roger this the latest weather for Norfolk. SPECI, I say again, special weather Norfolk, at zero eight zero zero zulu [0800 UTC]. auto, I say again auto, alpha uniform tango oscar [AUTO], wind two niner zero, zero eight knots [290/08 kt], niner niner niner November Delta Victor [999 m NDV], overcast one thousand one hundred [1,100 ft], temperature two one [21°C], dewpoint one niner [19°C], QNH Norfolk one zero one two [1012 hPa]. Remarks... romeo foxtrot zero zero decimal zero oblique zero zero zero decimal zero [RF 00.0/000.0], go ahead.
0803:21	VH-NGA	Nadi	thank you Nadi, much appreciated, november golf alpha.
0803:24	Nadi	VH-NGA	november golf alpha roger, DOLSI contact Auckland, thank you.
0803:24	VH-NGA	Nadi	Auckland at DOLSI, victor golf alpha.

Appendix H – Meteorological data for Australian remote islands

The data in this appendix was derived from products provided by the Bureau of Meteorology on its web site. These products provide averaged data since 1995 on various weather phenomenon, included significant cloud (broken or overcast) below specific heights and visibility below specific distances.

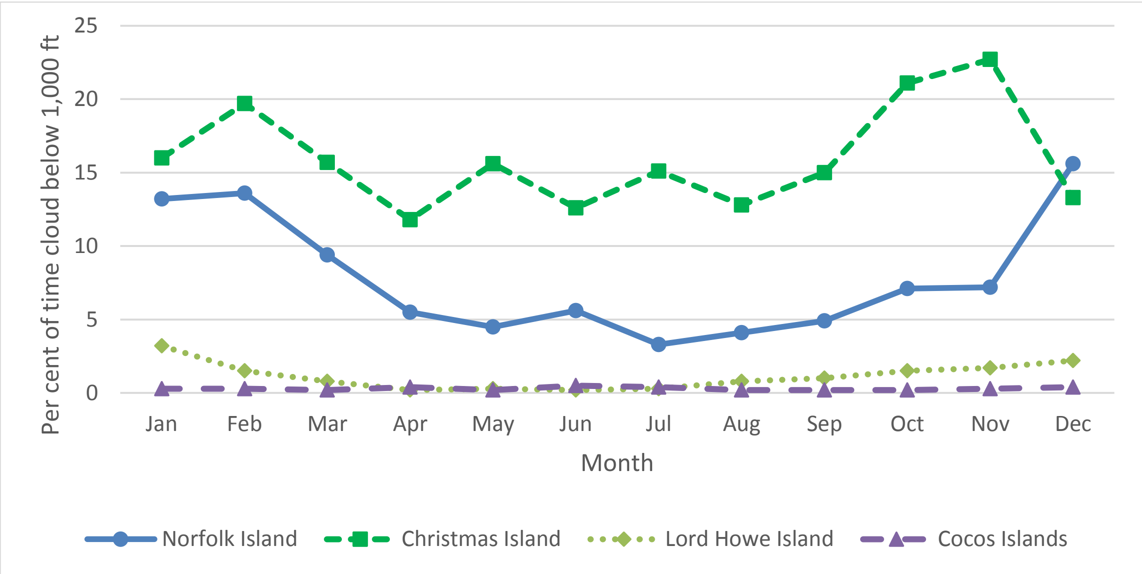
The ATSB reviewed the weather products for the four Australian remote islands with airports:

- Norfolk Island
- Christmas Island
- Cocos Island
- Lord Howe Island.

Figure H1 shows the average percentage of the time each month that the lowest significant cloud was below 1,000 ft above the aerodrome. Figure H2 shows the same type of data for when the lowest level of significant cloud was below 500 ft. In broad terms, 1,000 ft is just less than the alternate minima for instrument approaches and 500 ft is close to the landing minima.

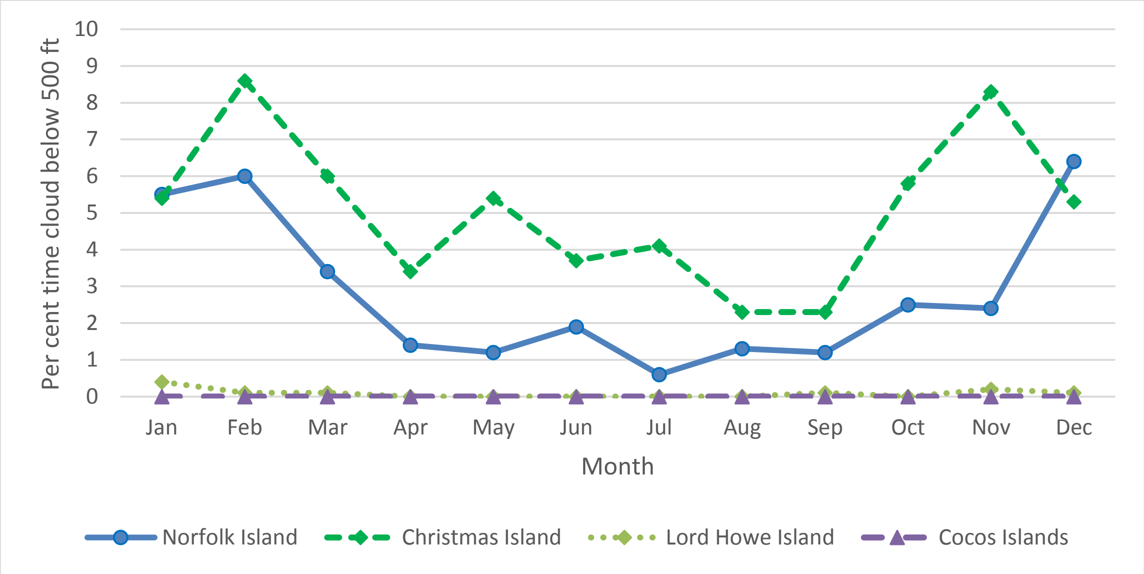
As can be seen in both figures, Norfolk Island and Christmas Island have a significantly higher number of days where low cloud is below these specified heights, particularly during the summer months.

Figure H1: Average percentage of time broken / overcast cloud base is below 1,000 ft



Source: ATSB, derived from climatological data provided on the Bureau of Meteorology website.

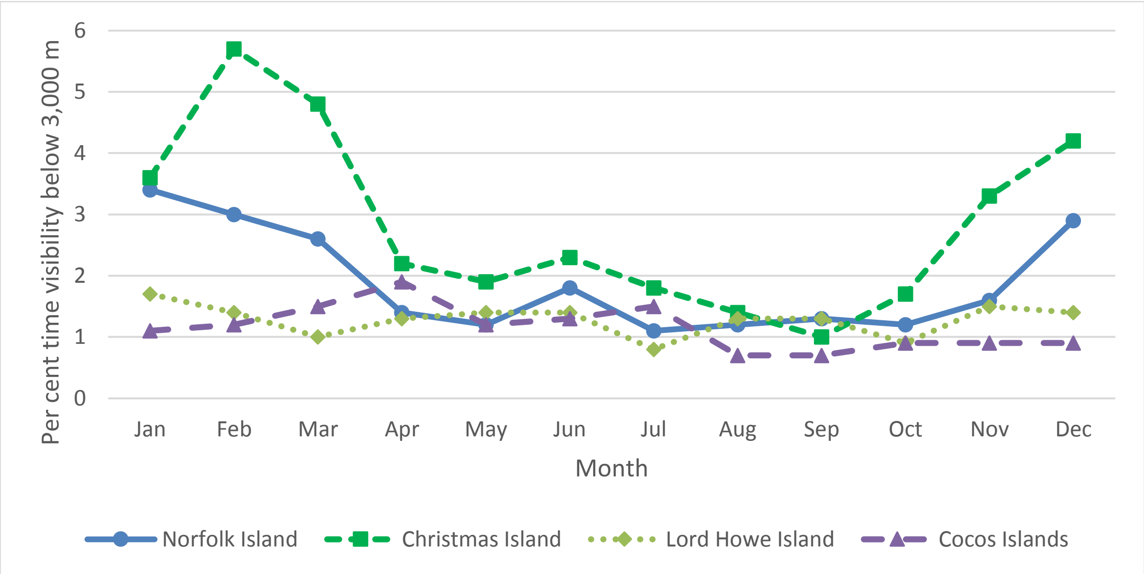
Figure H2: Average percentage of time broken / overcast cloud base is below 500 ft



Source: ATSB, derived from climatological data provided on the Bureau of Meteorology website.

Figure H3 shows the average percentage of the time each month that the recorded visibility was below 3,000 m. This distance broadly is just less than the landing minima for instrument approaches. The data shows a similar pattern of results as those for low cloud.

Figure H3: Average percentage of time visibility is below 3,000 m



Source: ATSB, derived from climatological data provided on the Bureau of Meteorology website.

Appendix I – Fuel-management occurrences at Australian remote islands 1991–2009

Occurrence criteria

The investigation reviewed the ATSB occurrence database for occurrences during 1991–2009 that met the following criteria:

- The aircraft was on a flight to Norfolk Island, Christmas Island, Lord Howe Island or the Cocos Islands.
- The aircraft arrived at the island without sufficient fuel to divert to an alternate aerodrome.
- The flight crew could not land without proceeding below the landing minima or waiting for a significant period to time.

Three occurrences were identified that met these criteria. In all three cases:

- the flight was a regular public transport (RPT) flight to Norfolk Island
- the crews received an aerodrome forecast (TAF) prior to the flight that indicated conditions did not require fuel to be carried for an alternate airport, but the conditions changed during flight.

Details of these occurrences are based on the original Bureau of Air Safety (BASI)[378] or ATSB Investigation reports, with additional details added based on reviewing the investigation files.

Occurrence 199801482 (26 April 1998)

A British Aerospace 146 (BAe146) air transport aircraft was conducting an RPT flight from Sydney to Norfolk Island, arriving at night. The TAF for Norfolk Island indicated there would be 3 oktas (scattered) cloud at 2,000 ft and visibility at least 10,000 m. These conditions were above the alternate minima. Given the forecast conditions, the flight crew did not upload fuel to divert to an alternate aerodrome.

At about 1.25 hours after take-off, the crew obtained a METAR that indicated there was 2 oktas (few) cloud at 2,000 ft.

Approaching Norfolk Island, the crew found that the area was completely overcast. The crew conducted a VOR/DME approach to runway 11. The captain subsequently reported they became visual at 950 ft above mean sea level and landed. The captain also reported there was 6–7 oktas (broken) cloud at about 600 ft above the aerodrome. These conditions were below the alternate minima and just above the landing minima.

The TAF was amended after the aircraft landed to indicate the lower cloud.

Occurrence 199802796 (28 April 1998)

A Piper Navajo Chieftain was conducting an RPT flight from Lord Howe Island to Norfolk Island during the day. The TAF for Norfolk Island current when the flight was planned indicated there would be 3 oktas (scattered) cloud at 2,000 ft and the visibility at least 10,000 m. These conditions were above the alternate minima.

An amended TAF issued at the time of departure stated the cloud would be scattered at 700 ft, visibility at least 10,000 m and there was a requirement for 30 minutes holding. An amended TAF issued 1 hour later was similar, but required 60 minutes holding.

[378] The Bureau of Air Safety Investigation (BASI) became part of the newly formed multi-modal Australian Transport Safety Bureau (ATSB) on 1 July 1999.

The pilot later advised he became aware of the deteriorating weather at his destination via METARs only after he had passed the planned point of no return (PNR). However, the aircraft was carrying sufficient fuel to allow it to hold at Norfolk Island for 60 minutes.

When the aircraft arrived in the Norfolk Island circuit area, the pilot assessed the conditions as unsuitable to land due to low cloud and rain showers. After approximately 45 minutes of holding, the weather conditions improved sufficiently for the pilot to make a visual approach and landing.

Occurrence 199900604 (15 February 1999)

A Piper Navajo Chieftain was conducting an RPT flight from Lord Howe Island to Norfolk Island during the day. While flight planning, the pilot noted the TAF required the carriage of fuel sufficient for a diversion to an alternate aerodrome. As the aircraft was unable to carry sufficient fuel for the flight to Norfolk Island and then divert to an alternate aerodrome, the flight was postponed. Later in the day, the forecast was amended to require the carriage of 60 minutes of holding fuel and the flight departed carrying the additional fuel. The TAF stated there would be scattered cloud at 500 ft, broken cloud at 2,500 ft and visibility 8,000 m.

Events prior to reaching Norfolk Island included:

- 0255 UTC: the aircraft departed Lord Howe Island.
- 0311: Brisbane air traffic services (ATS) provided the pilot with the 0300 SPECI, which stated there was broken cloud at 500 ft, broken cloud at 2,500 ft and visibility 5,000 m. These conditions were below the alternate minima. A similar SPECI was issued at 0330.
- 0314: An amended TAF was issued that stated there would be broken cloud at 500 ft and visibility 8,000 m. These conditions were below the alternate minima. The pilot did not request or receive this amended forecast.
- 0354: A SPECI was issued stating there was broken cloud at 500 ft, overcast cloud at 1,500 ft and visibility 5,000 m.
- 0413: The aircraft transferred to Auckland ATS. No SPECIs were provided. The Auckland A/G operator later advised they were aware that Brisbane ATS had provided the pilot with the 0300 SPECI and not the 0354 SPECI. They also noted the 0354 SPECI was similar to the 0300 SPECI.
- 0426: A SPECI was issued stating there was broken cloud at 400 ft, broken cloud at 1,000 ft and visibility 4,000 m. Another SPECI at 0437 indicated similar cloud conditions, with the visibility reduced to 3,000 m. Auckland A/G did not pass these SPECIs to the pilot. However, the pilot received the 0426 SPECI from another source and continued the flight.
- 0445: The aircraft passed the PNR.
- 0500: A SPECI was issued stating there was broken cloud at 400 ft and visibility 2,000 m. The Auckland A/G operator did not provide this SPECI to the pilot. However, the pilot received it from another source.

The pilot's initial attempt to land on runway 11 was unsuccessful and, in conditions of deteriorating visibility, the pilot descended visually over the sea to a height of about 500 ft and used the inbound track of the runway 04 VOR instrument approach to track towards the runway. The next two approaches to runway 04 were also unsuccessful. For the third approach to runway 04, the pilot requested aerodrome personnel position themselves at the runway threshold to provide information about the location of the aircraft relative to the runway centreline. The aircraft was sighted passing overhead and to the right of the runway centreline. On the fourth approach, the pilot sighted the lights associated with the precision approach path indicator and landed on the runway.

Subsequent investigation determined that the actual conditions at Norfolk Island were continuously below the alternate minima for the period from 2.5 hours before the aircraft departed from Lord Howe Island until 6 hours after the aircraft landed.

The operator's procedures included guidance regarding the nature of weather conditions at Norfolk Island. They also required that pilots calculate a PNR as soon as they reached cruise altitude, and then obtain an updated TAF and latest METAR prior to reaching the PNR. The procedures also noted the importance of obtaining a number of METARs to indicate a trend as 'sea fog' conditions at Norfolk Island were not always predicted in forecasts.

The New Zealand Civil Aviation Authority conducted a safety investigation into the provision of the flight information service by the Auckland A/G operator. The investigation concluded that the operator had not passed on the 0354 and 0500 SPECI as required. According to the report, Airways New Zealand issued an operations bulletin to all air/ground staff reminding them of the importance of passing SPECI and SIGMET information to all relevant flights.

Other occurrences

In addition to the three occurrences above, there were also the following reported occurrences involving flights to Norfolk Island:

- Six occurrences where the aircraft reached the island, conducted one or more approaches and diverted to an alternate aerodrome. For one occurrence (in 1998), the adverse weather conditions (wind gusts) had not been included in the TAF used prior to departure, although the forecast included a requirement for 60 minutes holding due to thunderstorms and the forecast was amended 30 minutes after the aircraft's departure.[379] For 3 other occurrences (1999, 2007 and 2009) the adverse weather conditions had been forecast. There was no indication in the other 2 notifications that the adverse conditions were unforecast (2002 and 2003). All 6 occurrences involved high-capacity RPT flights.
- Thirteen occurrences where the crew diverted to an alternate aerodrome before reaching the island due to reports of adverse weather. Five occurred during 1991–1999, 7 occurred during 2000–2003 and 1 occurred in 2005. There was no indication in 12 notifications that the adverse conditions were unforecast. The other notification (1998) indicated the TAF obtained prior to departure had indicated acceptable weather conditions, but METARs obtained during the flight indicated deteriorating conditions. All 12 occurrences involved high-capacity RPT flights.

There were also the following reported occurrences involving flights to other Australian remote islands:

- One occurrences on a flight to Christmas Island where the aircraft reached the island, conducted an approach and diverted to an alternate aerodrome (1991). The flight crew's notification indicated the conditions had not been forecast, but this was not verified at the time.
- One occurrence on a flight to Christmas Island where the crew diverted to an alternate aerodrome before reaching the island due to reports of adverse weather (1994). There was no indication in the notification that the adverse conditions were unforecast.
- One occurrences on a flight to Lord Howe Island where the aircraft reached the island, conducted an approach and diverted to an alternate aerodrome (2008). There was no indication in the notification that the adverse conditions were unforecast.
- One occurrence on a flight to Lord Howe Island where the crew diverted to an alternate aerodrome before reaching the island due to reports of adverse weather (1992). There was no indication in the notification that the adverse conditions were unforecast.
- All of these occurrences involved high-capacity RPT flights, except the 1992 occurrence which occurred on a low-capacity RPT flight.

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[379] Following this occurrence, BoM advised that the forecasters at the time were more concerned with rain and thunderstorms than the wind and did not update the forecast to reflect the increasing wind strength and gustiness.

Information about reporting requirements

Prior to 2003, the requirements for reporting occurrences in Australia were relatively general in nature. There were no specific requirements for reporting fuel or weather-related occurrences.

The reporting requirements changed with the introduction of the *Transport Safety Investigation Act* in 2003. The associated regulations included specific types of incidents that had to be reported. These include, for all types of operations:

- fuel exhaustion
- the aircraft's supply of usable fuel becoming so low that the pilot declares an emergency in flight
- fuel starvation (air transport operations only)
- loading of an incorrect quantity of fuel (air transport operations only)
- use of any procedure to overcome an emergency
- flight below a minimum altitude (air transport operations only)
- a weather phenomenon affecting control of the aircraft
- any other weather phenomenon (air transport operations only).

The diversion to another aerodrome in the absence of another event, for any reason, was not a reportable matter.

In the ATSB's experience, types of occurrences other than those specified in the regulations are often reported. However, a change in the frequency of notifications regarding a specific type of event on flights to a specific location may be associated with a change in the operator conducting those flights.

Appendix J – Norfolk Island weather analysis, 2009–2014

Background

The ATSB compared reported weather observations (METARs and SPECIs) to aerodrome forecasts (TAFs) at Norfolk Island Airport between 2009 and 2014. This analysis used the ATSB's predictive weather analysis algorithm, as described in ATSB report AR-2013-200.[380]

The primary objective of this analysis was to calculate the probability of a pilot retrieving a TAF predicting conditions above the alternate minima and subsequently arriving during unsuitable landing conditions.

Two assumptions were applied regarding the operational effect of TAFs and reported observations:

- TAFs forecasting conditions below the alternate minima were assumed to warn a flight crew that a contingency plan was required.
- Reported observations below the landing minima were assumed to be unsuitable for landing.

Alternate and landing minima were obtained from the Airservices Australia Instrument Approach Procedures. These were obtained for a Category C aircraft so that they applied to the operator's Westwind 1124 and 1124A aircraft (the accident aircraft type), allowing systemic analysis of how this aircraft configuration was affected by weather conditions and TAF forecasting. As the operator did not conduct RNAV approaches in its Westwind aircraft, such procedures were excluded from the analysis of all airports. The resulting specifications used in this analysis are summarised in Table J1.

Table J1: Aircraft specifications used in simulation

Aircraft manufacturer and model	Aircraft category	Crosswind limit	Tailwind limit	Approaches allowed
Israel Aircraft Industries 1124A "Westwind"	C	23 kt	10 kt	ILS (up to cat. II), LOC, LOC/DME, NDB, VOR, VOR/DME, NDB/DME

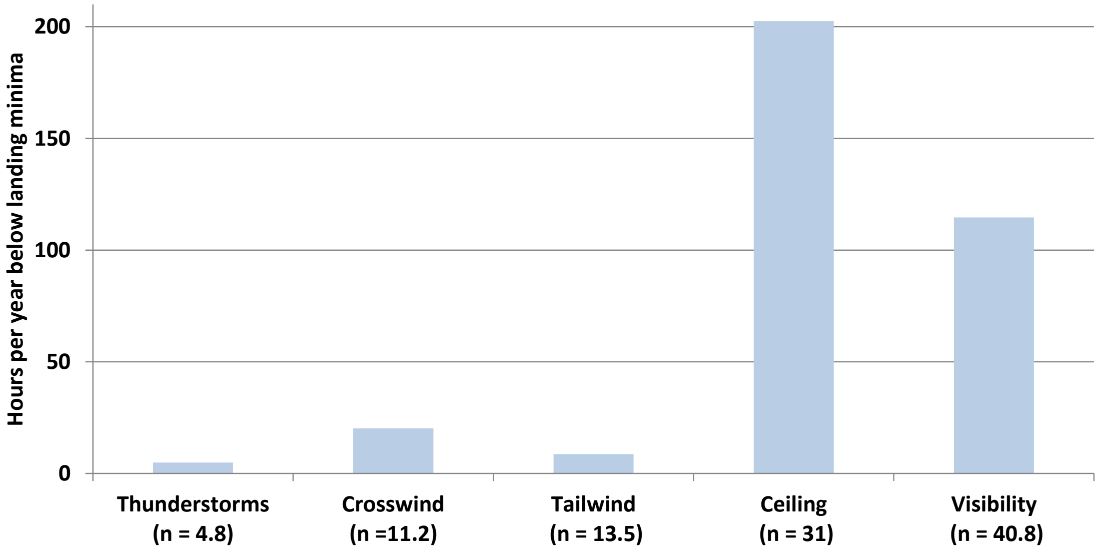
Observed conditions below the landing minima at Norfolk Island

During 2009–2014 at Norfolk Island, there was an average of about 288 hours per year where the observed conditions were below the landing minima for the specified aircraft type. This equated to about 3.3 per cent of the time.

More than 200 hours of cloud (ceiling) below the landing minima were reported each year at Norfolk Island during 2009–2014, as shown in Figure J1. Low visibility was also notable, occurring more often, but for shorter durations than low cloud. These two factors made up the vast majority of weather below the landing minima.

[380] ATSB Aviation research investigation AR-2013-200, The effect of Australian aviation weather forecasts on aircraft operations: Adelaide and Mildura airports, Australia. Available from www.atsb.gov.au.

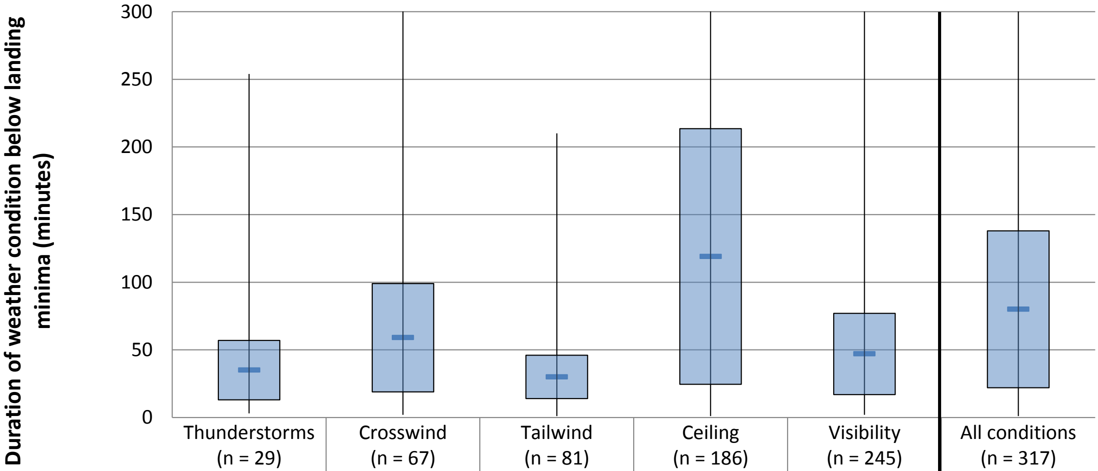
Figure J1: Observations below landing minima (hours per year) by landing minima parameters (number of episodes per year shown in brackets) for Westwind 1124/1124A without RNAV, Norfolk Island Airport 2009–2014



Source: ATSB, derived from data provided by BoM.

Figure J2 shows the median duration that landing minima parameters were observed below the accident aircraft type landing minima at Norfolk Island during 2009–2014. Ceiling below the landing minima had considerably longer reported durations and larger variability than the other parameters, with a median duration of almost 2 hours per episode. Variability is represented by the blue box around the median based on ± 1 median absolute deviation (MAD).[381]

Figure J2: Duration of observations below landing minima (hours per year) by landing minima parameters (number of episodes per year shown in brackets) for Westwind 1124/1124A without RNAV, Norfolk Island Airport 2009–2014



	Thunderstorms (n = 29)	Crosswind (n = 67)	Tailwind (n = 81)	Ceiling (n = 186)	Visibility (n = 245)	All conditions (n = 317)
Median	35	59	30	119	47	80
Median - 1 MAD	13	19	14	24.5	17	22
Maximum	254	426	210	3864	1730	4068
Minimum	3	2	1	1	2	1
Median +1 MAD	57	99	46	213.5	77	138

Source: ATSB, derived from data provided by BoM.

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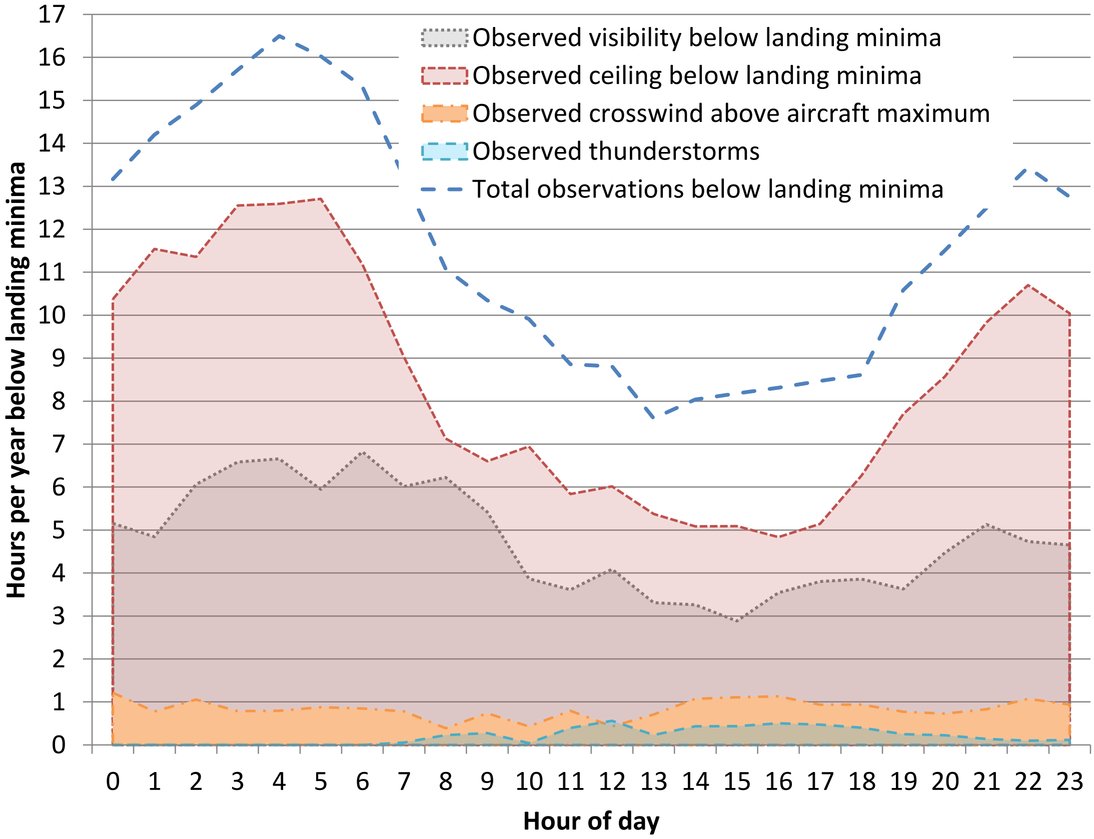
381 The *median absolute deviation* (MAD) is a non-parametric measure of the variability of a sample of data, roughly equivalent to 1.5 standard deviations in a normally distributed large population.

Figure J3 shows the reported duration per year of conditions below the accident aircraft type landing minima by time of day (local time) for each of the landing minima parameters. Each landing minima parameter displayed is not cumulative, with the blue dashed line showing the combined reported observations below the landing minima, taking into account parameters occurring at the same time. For example, low ceiling and low visibility were often observed together.

Low ceiling was the most prevalent landing minima parameter below the landing minima in all hours of the day, ranging between 58 and 81 per cent of all reported time below the landing minima in each hour of day. Low ceiling was most prevalent at night. The peak time period for observations below the landing minima was between 0300–0700 local time,[382] and was largely driven by low ceiling.

The time the aircraft arrived at Norfolk Island on 18 November 2009 (about 2130 local time) was also associated with a relatively high level of observations below the landing minima (about 13 hours per year and most often due to low ceiling).

Figure J3: Time of day of individual observed weather phenomena when conditions were below the landing minima at Norfolk Island Airport, 2009–2014 for Westwind 1124/1124A without RNAV (dashed blue line shows total time any observation was below the landing minima)

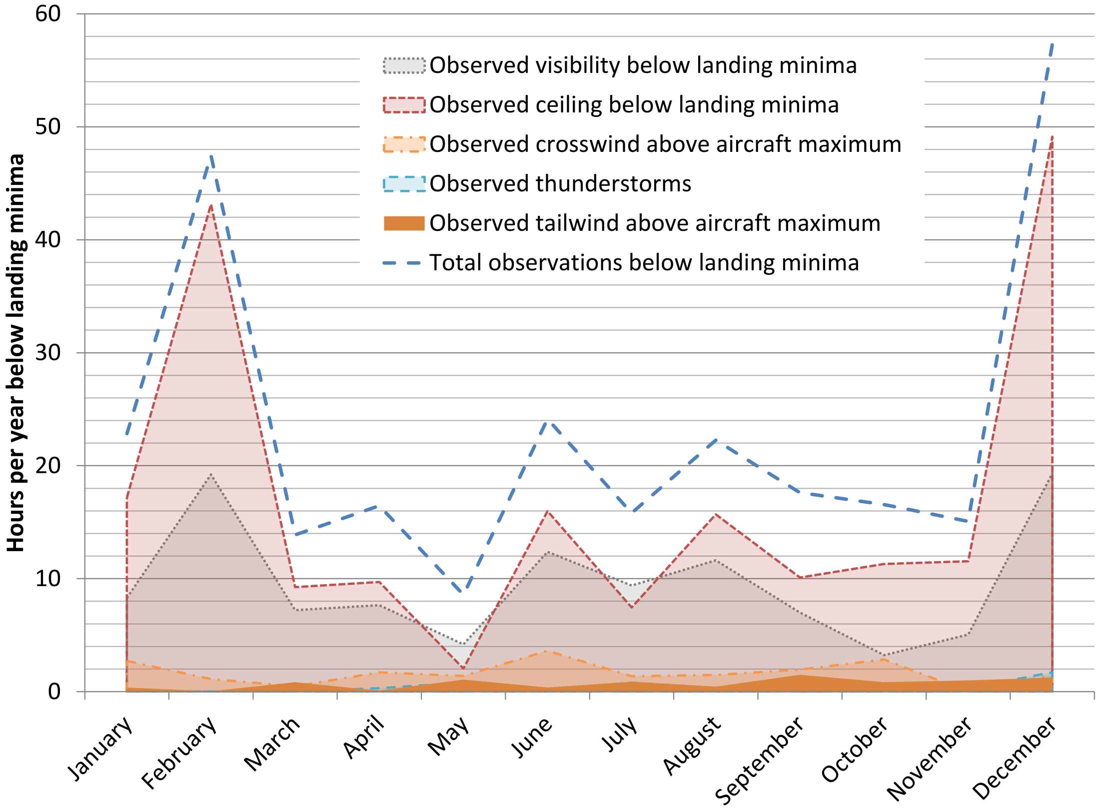


Source: ATSB, derived from data provided by BoM.

Figure J4 shows the same data as for Figure J3 by each month for individual landing minima parameters. With the exception of May and July, low ceiling was the most prevalent in all months. Summer (December to February) was the peak season for observations below the landing minima, again driven by low ceiling, which was observed between 75 per cent and 91 per cent of conditions below the landing minima during these months.

[382] Local time at Norfolk Island was UTC + 11.5 hours up to 4 October 2015.

Figure J4: Month of individual observed weather phenomena when conditions were below the landing minima at Norfolk Island Airport, 2009–2014 for Westwind 1124/1124A without RNAV (dashed blue line shows total time any observation was below landing minima)



Source: ATSB, derived from data provided by BoM.

Overall TAF reliability at Norfolk Island Airport, 2009 to 2014

This section contains results of comparisons between observed weather conditions (from METARs and SPECIs) compared with TAF predictions. Comparisons were averaged over nine simulations for forecast retrieval between 1 and 3 hours prior to arrival (in 15 minute intervals).[383]

Figure J5 shows the overall results of a comparison between forecast and actual observed conditions (at the time the aircraft would arrive at the destination). It includes the overall likelihood of arriving at a time of unforecast observations below the landing minima.[384]

Unforecast observations below the landing minima (when conditions were forecast to be above the alternate minima, shown in yellow as a 'miss' in Figure J5) were rare during the study period, occurring an average of 5 hours 31 minutes per year or 0.06 per cent of the time during 2009–2014. Furthermore, when conditions were observed below the landing minima (about 3.17 per cent of the time), only 1 in every 50 minutes of active TAFs[385] predicted conditions above the alternate minima.

False alarms (when conditions were forecast to be below the alternate minima but were observed to be above the alternate minima, shown in purple in Figure J5) occurred 36.7 per cent of the total

[383] Averaging between 1 and 3 hours prior to arrival was chosen to indicate times where a flight crew may retrieve a TAF prior to the point of no return (PNR). However, there is further analysis of individual forecast retrieval time later in this appendix.

[384] Observation of weather conditions below the landing minima preceded by a weather TAF for conditions above the alternate minima.

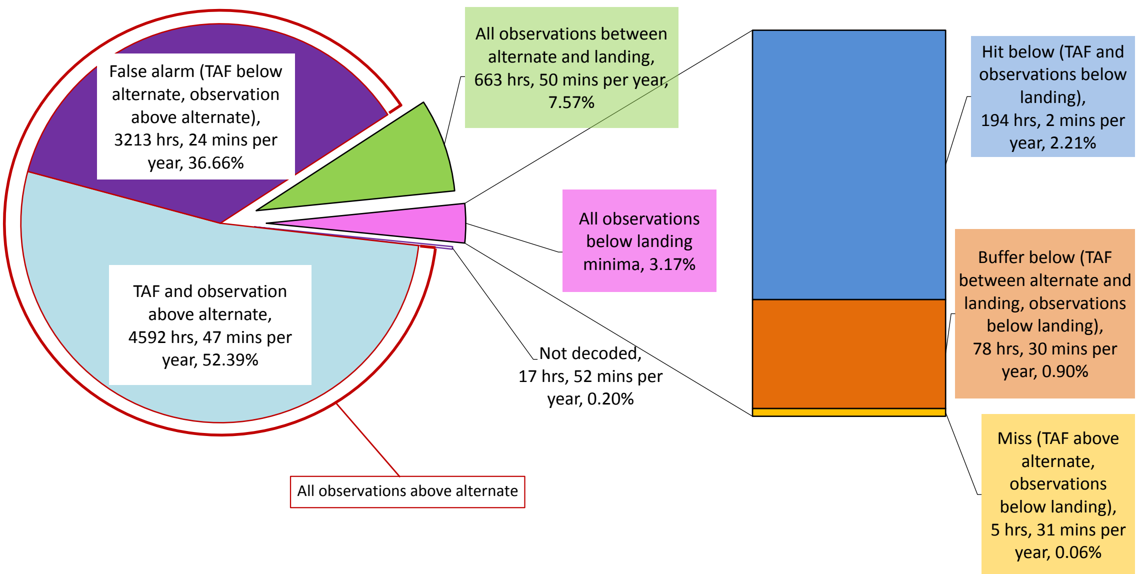
[385] Active forecasts include only those forecasts publically available and valid at a given time.

time during 2009–2014. These false alarms were significantly more likely than conditions observed below the alternate minima. This result indicates the overall forecasting system at Norfolk Island during 2009–2014 was conservative in regard to the prediction of unsuitable weather for landing. Note that the false alarm time shown in Figure J5 includes periods occurring shortly after or prior to conditions below the alternate minima, which can therefore be considered over-represented at these times.

The orange box labelled 'Buffer below' indicates scenarios where the TAF predicted conditions between the alternate and landing minima, and conditions were reported below the landing minima on arrival. This shows the importance of using the alternate minima for operational decision-making. In the hypothetical scenario where the landing minima rather than the alternate minima was used as an operational decision threshold, the likelihood of arriving during unforecast conditions were 16 times greater at Norfolk Island for retrieval of a TAF 1–3 hours earlier.

A very small percentage of the time for forecasts/observations pairs (0.20%) were not decoded completely and excluded from the analysis. These appeared to be evenly distributed across all comparison states and were not expected to affect the analysis.

Figure J5: Percentage of total time and total time per year for TAF comparisons with observations – averaged for simulated forecast retrieval 1–3 hours prior to arrival at Norfolk Island 2009–2014 for Westwind 1124/1124A without RNAV



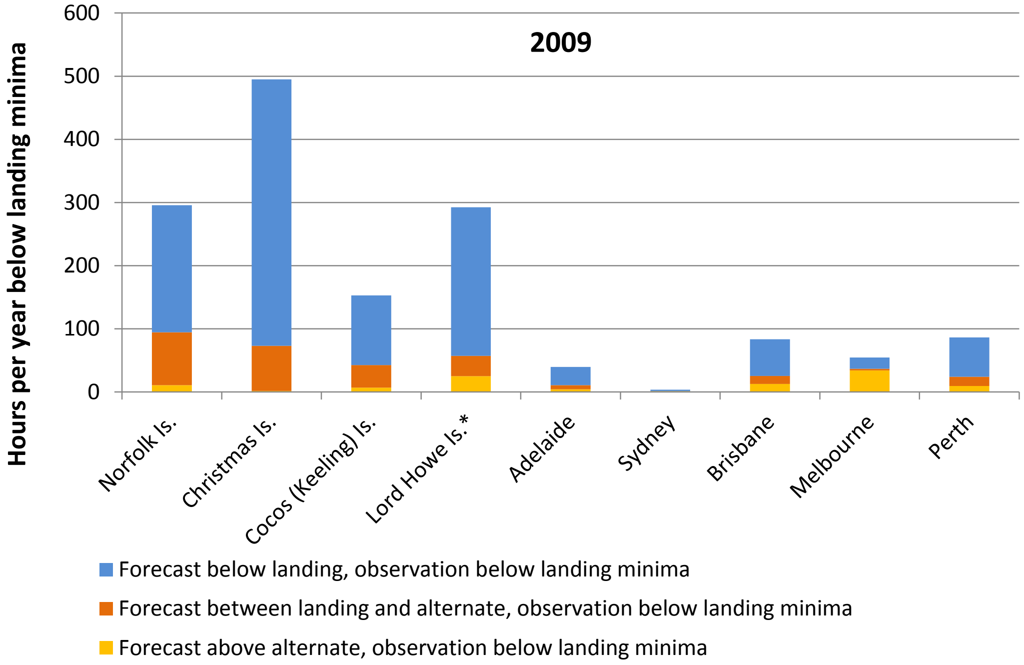
Source: ATSB, derived from data provided by BoM.

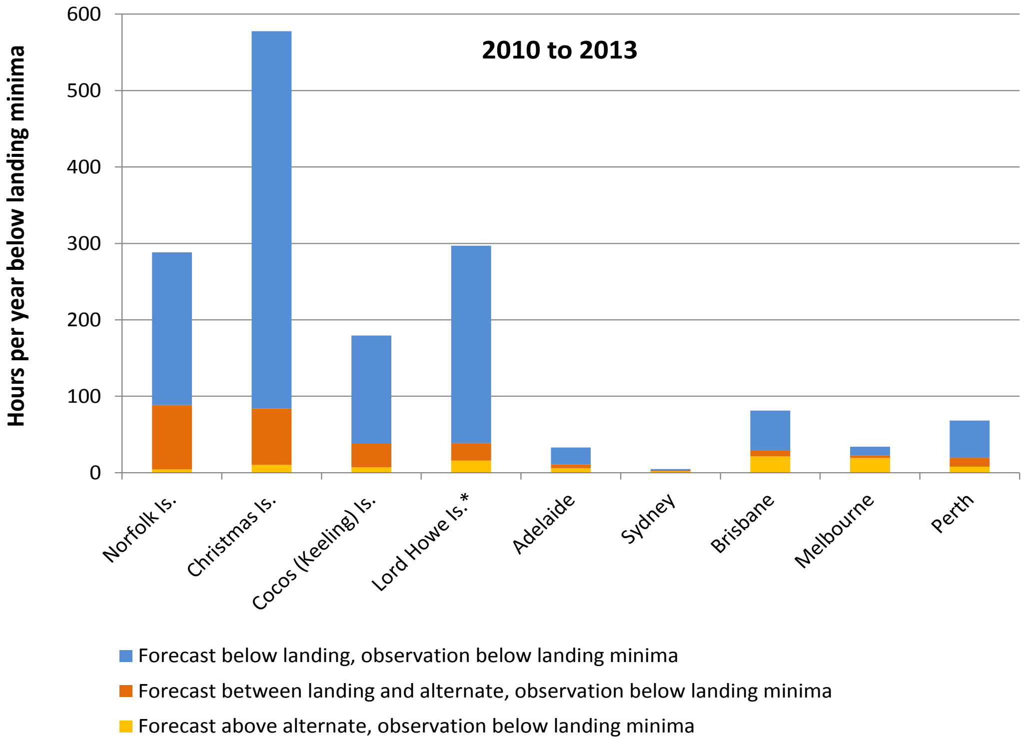
Comparison of TAF effectiveness and weather of Norfolk Island Airport with selected airports (conditions below landing minima)

To evaluate the relative likelihood of TAF effectiveness, TAFs for Norfolk Island were compared with TAFs for the other Australian remote islands and the top five Australian capital city airports by aircraft movements. The same type of simulations were conducted as for Norfolk Island using the accident aircraft type specifications (Westwind 1124/1124A without RNAV approaches, see Table J1).

Figure J6 shows observations below the landing minima in hours per year for each airport. This is divided for when the TAF predicted conditions above the alternate minima (yellow), between the alternate and landing minima (orange) and below the landing minima (blue). All upper graphs in each figure of this section show the accident year 2009, with the average of all years 2010 to 2013 shown in the lower section. These year ranges were selected due to common data availability across all the airports.

Figure J6: Observations below landing minima (hours per year) by TAF above alternate minima, between alternate and landing minima and below landing minima averaged for simulated TAF retrieval 1–3 hours prior to arrival for Westwind 1124/1124A without RNAV at selected airports, 2009–2013[386]





Source: ATSB, derived from data provided by BoM.

386 Approximately 28 per cent of Lord Howe Island data was not decoded - numbers are expected to be larger than presented.

As indicated in Figure J6:

- Remote islands generally had more observed weather below the landing minima compared to the five busiest capital city airports. This was likely due a combination of factors such as more accurate instrument approaches available to the accident aircraft type at the capital cities, and more adverse weather conditions at the remote islands.
- Compared to the other remote islands, the Cocos Islands had the least weather below the landing minima (about 180 hours per year) and Christmas Island[387] had the most weather below the landing minima (about 580 hours per year). Norfolk and Lord Howe Island had about the same amount of weather below the landing minima (just under 300 hours per year). However, Norfolk and Christmas Island had a similar amount of weather below the landing minima where the TAF was above the landing minima (orange and yellow combined).[388]

Figure J7 shows an expansion of the unforecast observations (or misses) below the landing minima depicted by yellow bars in Figure J6. This data indicates the likelihood (displayed in hours per year) of retrieving a TAF between 1–3 hours prior to arrival that predicts conditions above the alternate minima, and arriving during conditions below landing minima in the accident aircraft type.

As indicated in Figure J7:

- There was significant variability across the airports in the amount of time when there was unforecast observations below the landing minima.
- Overall, remote island airports had a similar amount of time with unforecast conditions below the landing minima in 2009 (about 10.9 hours per airport) as capital city airports (about 12.3 hours). Similarly, in 2010–2013, remote islands airports had an average of about 9.4 hours of unforecast weather below the landing minima and capital city airports had an average of about 11.3 hours.
- In 2009, Norfolk Island had more unforecast weather below the landing minima (about 10.5 hours) than in subsequent years (about 4.5 hours per year). However, Christmas Island had considerably less unforecast weather below the landing minima in 2009 (about 1.5 hours) than for subsequent years (about 10.5 hours per year).
- Lord Howe Island had the largest amount of unforecast weather below the landing minima compared to the other remote islands (about 24.8 hours in 2009 and an average of 15.9 hours per year in subsequent years).
- In terms of the conditions associated with weather below the alternate minima, Christmas Island was similar to Norfolk Island (that is, mainly driven by low cloud and then visibility). However, Lord Howe Island had similar amounts of unforecast crosswind above the applied 23-kt limit on the Westwind 1124/1124A and unforecast low cloud below the landing minima.

Although remote islands had a similar amount of unforecast weather below the landing minima as the capital city airports, it should be noted the potential consequences are more serious, given the locations of the airports.

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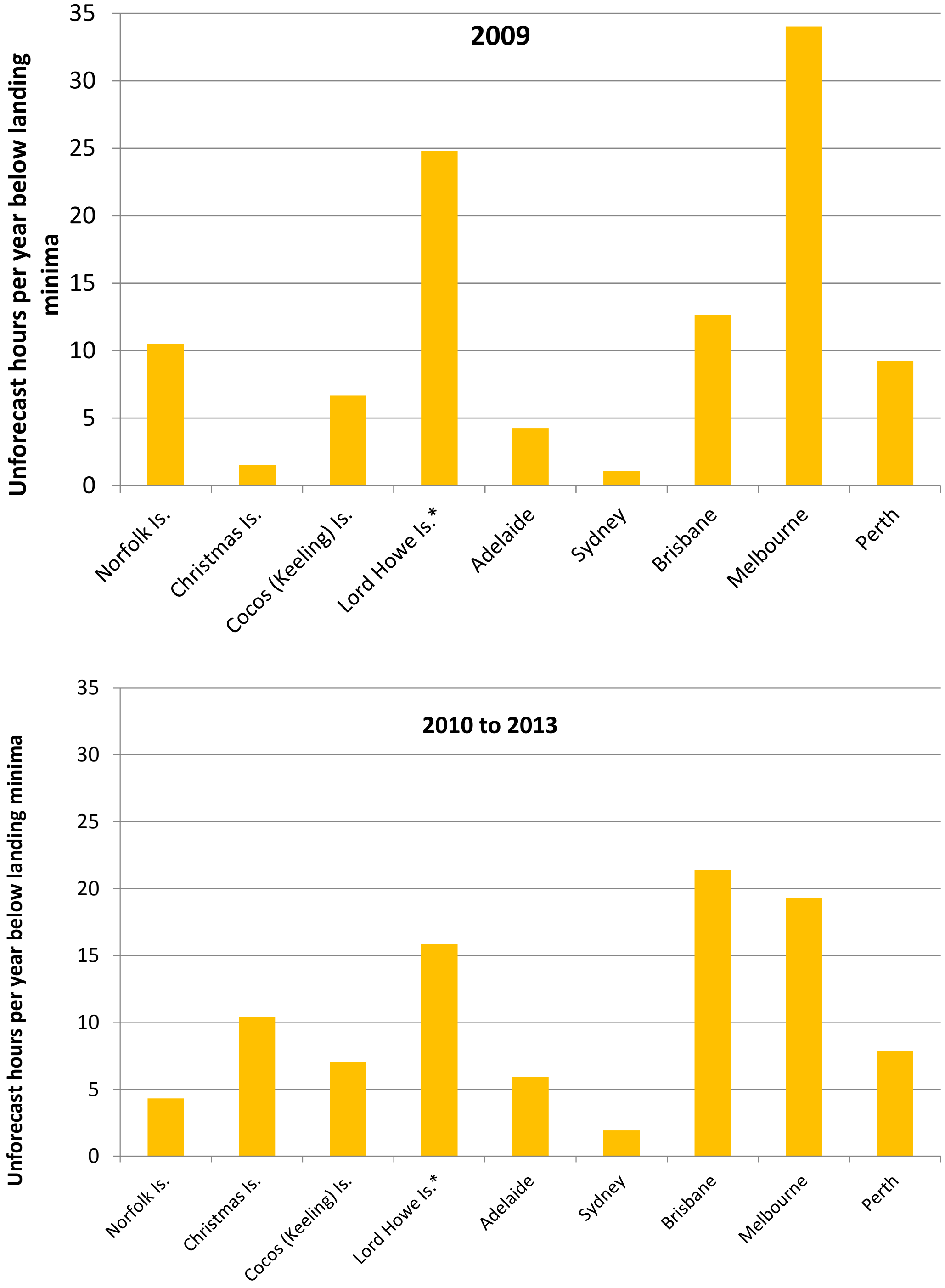
387 Observations below the landing minima at Christmas Island had a similar median release frequency to Norfolk Island Airport (about 23 minutes), despite routine observations (METARs) at Christmas Island being released every hour (instead of every 30 minutes). Based on this it was assumed that the SPECI trigger mechanisms at Norfolk and Christmas Islands were similar, reducing the risk of over counting time below the landing minima at Christmas Island.

388 Although TAFs at Christmas Island were quoted in ERSA as being released twice daily, the vast majority of TAFs (98 per cent) were released within every 7 hours of one another. This was very similar to Norfolk Island TAF and amended TAF release frequency.

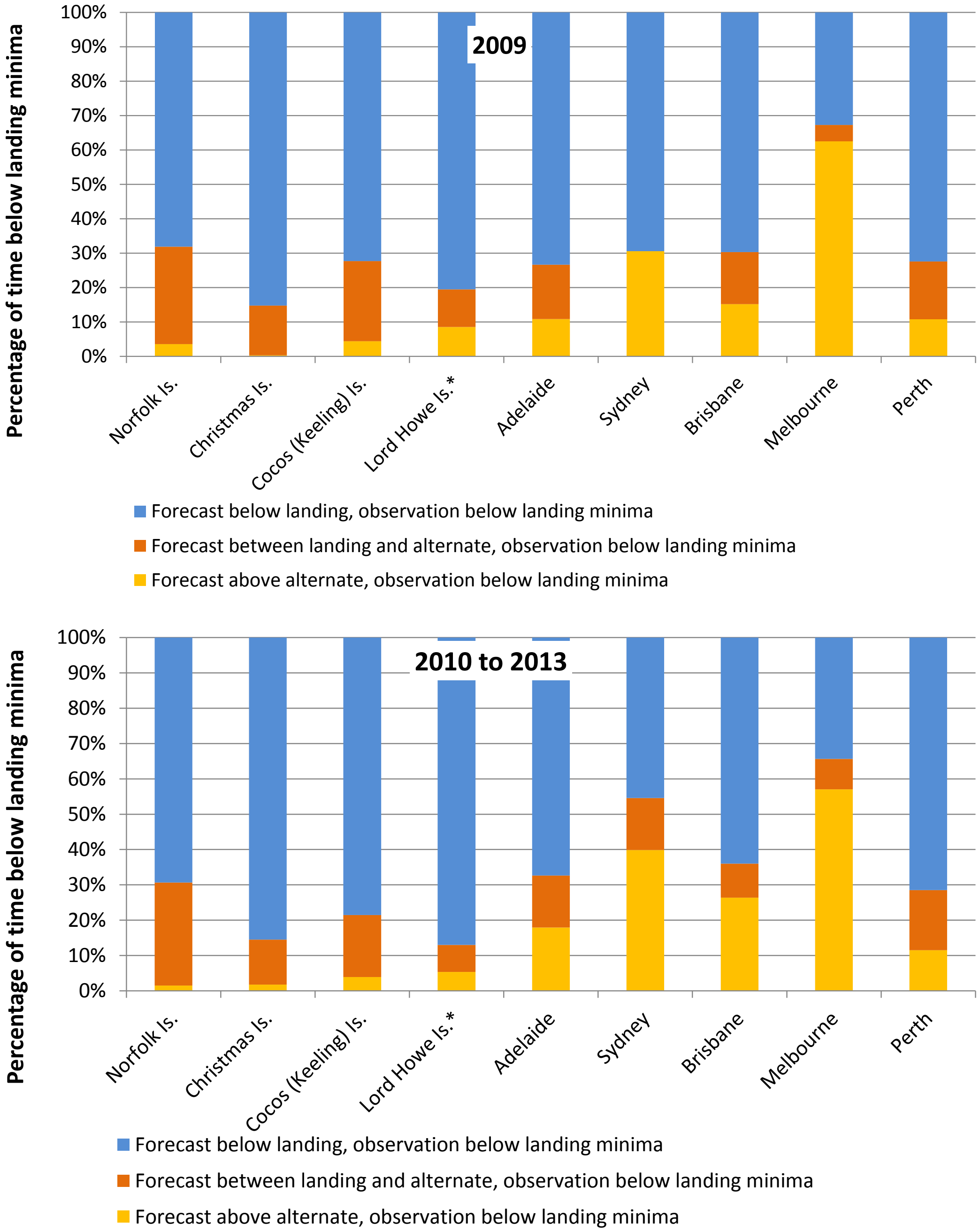
Figure J7: Unforecast observations below landing minima (hours per year) averaged for simulated TAF retrieval 1–3 hours prior to arrival for Westwind 1124/1124A without RNAV at selected airports, 2009–2013[386]



Source: ATSB, derived from data provided by BoM.

Figure J6 provided data on the total time below the landing minima that was forecast and not forecast. To provide an indication of the relative accuracy of predictions between the airports, Figure J8 shows the same data as for Figure J6 calculated as a percentage of the total conditions below the landing minima at each airport for the accident aircraft type.

Figure J8: Percentage of time below landing minima by TAF above alternate minima, between alternate and landing minima and below landing minima averaged for simulated TAF retrievals 1–3 hours prior to arrival for Westwind 1124/1124A without RNAV at selected airports, 2009–2013



Source: ATSB, derived from data provided by BoM.

As indicated in Figure J8:

- Remote islands had lower proportions of conditions below the landing minima that were unforecast (in yellow) compared to the selected capital city airports, with all the islands being less than half of the proportion of any selected capital city airport.
- Norfolk and Christmas Islands had the lowest proportions of conditions below the landing minima of the four remote islands.
- In 2009, 3.55 per cent of the time at Norfolk Island when observations were below the landing minima there was a TAF predicting conditions above the alternate minima, which was lower than all locations except Christmas Island. From 2010 onwards, only 1.65 per cent of the time at

Norfolk Island when observations were below the landing minima there was a TAF predicting conditions above the alternate minima.

Although the total time for each particular condition provides the best indication of operational risk, the ATSB also examined the number of episodes of each type of event, which better enabled statistical tests to be conducted. Table J2 shows data for the number of discrete weather episodes for observed conditions below the landing minima in 2009 for Norfolk Island,[389] the total of all other remote islands and the total of selected capital cities as shown in Figure J6. The total episodes below the landing minima are also shown for 2010–2013.

Table J2: Episodes below the landing minima by worst TAF operational state,[390] averaged for simulated TAF retrieval 1–3 hours prior to arrival for Westwind 1124/1124A without RNAV at selected airports, for 2009 and 2010–2013

Episode category	2009			2010–2013		
	Norfolk Island	Other remote islands	Capital cities	Norfolk Island	Other remote islands	Capital cities
TAF below landing minima	9	90	51	38	445	173
TAF between landing and alternate minima	28	50	27	156	238	112
TAF above alternate minima	15	46	65	30	183	252
Total episodes below landing minima	52	186	143	224	866	537

Episode categories are the same as shown in Figure J6, with the episode category TAF above alternate minima in Table J2 (in yellow) corresponding to the number of episodes in 2009 for the total unforecast time below the landing minima as shown in Figure J7.

Based on the episode data:

- The total number of episodes below the landing minima at Norfolk Island in 2009 (52) was about the same as during 2010–2013 (56 per year). This was consistent with the data in Figure J6 that showed the total number of hours each year with conditions below the landing minima (just under 300 hours per year).
- In 2009, the proportion of episodes below the landing minima at Norfolk Island that were unforecast (29 per cent) was significantly higher than in subsequent years (15 per cent).[391]

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389 For the period including the accident flight on 18 November 2009, the ATSB algorithm identified one episode of unforecast conditions below the landing minima. The total duration below the landing minima was 121 minutes (0830-0856 UTC and 0925-1100 UTC), which was similar to the median duration of periods below the landing minima (119 minutes). The duration of unforecast weather below the landing minima calculated by the ATSB algorithm was 66 minutes, which was longer than the median duration of 30 minutes per unforecast episode in 2009.

390 Episodes presented are mutually exclusive. Episodes below the landing minima were categorised in the following hierarchy - any coincident TAF predictions above the alternate minima, followed by any predictions between the landing and alternate minima, with the remaining episodes being completely forecast below the landing minima.

391 X^2, $P < 0.05$, 1df. Norfolk Island 2009 vs 2010–2013, TAF above alternate minima during conditions below the landing minima as a proportion of all conditions below the landing minima.

- In 2009, the proportion of episodes below the landing minima that were unforecast was not significantly different at Norfolk Island (29 per cent) compared to the other islands (25 per cent).[392] However, the proportion of episodes below the landing minima that were unforecast was significantly lower at Norfolk Island (29 per cent) compared to the selected capital city airports (45 per cent).[393]
- During 2010–2013, the proportion of episodes below the landing minima that were unforecast at Norfolk Island (13 per cent)[394] was significantly lower than the proportion for the other remote islands (21 per cent) and the proportion for the selected capital city airports (47 per cent).[395,396]

For the accident aircraft type, it was considerably less likely to retrieve an unforecast TAF 1–3 hours prior to arrival at Norfolk Island airport when compared with most other capital city airports between 2009 and 2013. In the accident year of 2009, there were significantly less[397] episodes with unforecast TAFs at Norfolk Island compared with all capital cities combined. Norfolk Island had a comparable amount of unforecast weather to Adelaide Airport following retrieval of a TAF.

Comparison of TAF effectiveness and weather of Norfolk Island Airport with selected airports (conditions above alternate minima)

The columns in Figure J9 represent the percentage of all time where reported conditions were above the alternate minima. The lower purple bars show the total percentage of time of false alarms each year (where forecast conditions were below the alternate minima, and conditions on arrival 1–3 hours after were observed above the alternate minima).

As indicated in the figure:

- During 2009–2013, conditions were above the alternate minima about 89 per cent of the time at Norfolk Island, and similarly at Lord Howe Island[398] 91 per cent of the time. In comparison, Christmas Island (57 per cent) had a lower percentage of the time reported above the alternate minima. The Cocos Islands airport was comparable to the mainland airports (about 96 per cent of the time).
- False alarms occurred 37 per cent of the total time at Norfolk Island during 2009–2013. In comparison, false alarms occurred more frequently at the Cocos Islands, slightly more frequently at Christmas Islands, and slightly less frequently at Lord Howe Island. Overall, false alarms occurred more frequently at remote islands than at the capital city airports.

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392 X^2, $P > 0.10$, 1df. Norfolk Island 2009 vs Other remote islands 2009, TAF above alternate minima during conditions below the landing minima as a proportion of all conditions below the landing minima.

393 X^2, $P < 0.05$, 1df. Norfolk Island 2009 vs Capital cities 2009, TAF above alternate minima during conditions below the landing minima as a proportion of all conditions below the landing minima.

394 The ATSB also had data for Norfolk Island for 2014, during which there were 43 episodes and 21 per cent were unforecast. Adding this data to the 2010-2013 data resulted in an overall percentage of 15 per cent. This proportion was still significantly lower than the 2009 proportion.

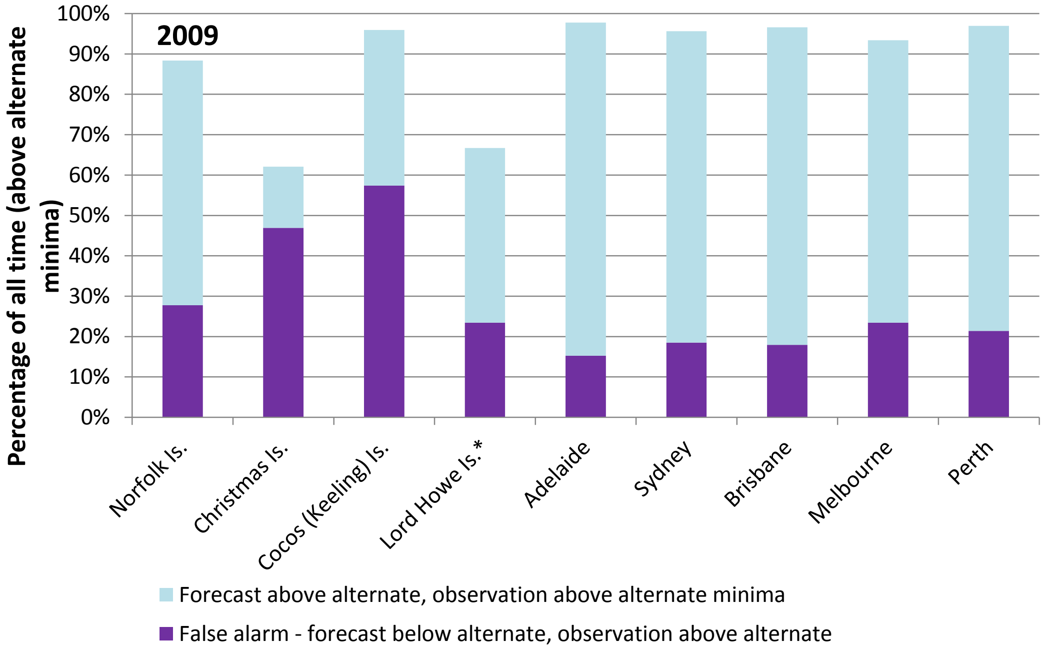
395 X^2, $P < 0.01$, 1df. Norfolk Island 2010-2013 vs Other remote islands 2010-2013. TAF above alternate minima during conditions below the landing minima as a proportion of all conditions below the landing minima.

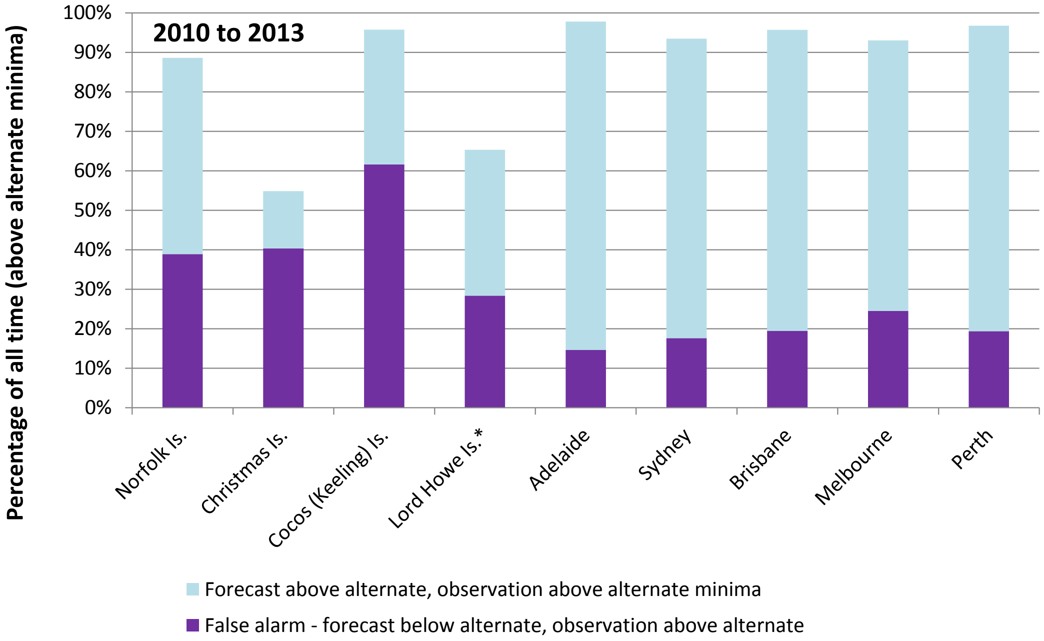
396 X^2, $P < 0.001$, 1df. Norfolk Island 2010-2013 vs Capital cities 2010-2013, TAF above alternate minima during conditions below the landing minima as a proportion of all conditions below the landing minima.

397 X^2, $P < 0.05$, 1df. Norfolk Island 2009 vs Capital cities 2009, TAF above alternate minima during conditions below the landing minima as a proportion of all conditions below the landing minima.

398 Due to Lord Howe Island having a large proportion of data not decoded, calculations were based on the percentage of decoded time.

Figure J9: Total percentage of time above alternate minima by TAF above alternate minima, between alternate and landing minima and below landing minima averaged for simulated TAF retrievals 1–3 hours prior to arrival for Westwind 1124/1124A without RNAV at selected airports, 2009–2013[386]





Source: ATSB, derived from data provided by BoM.

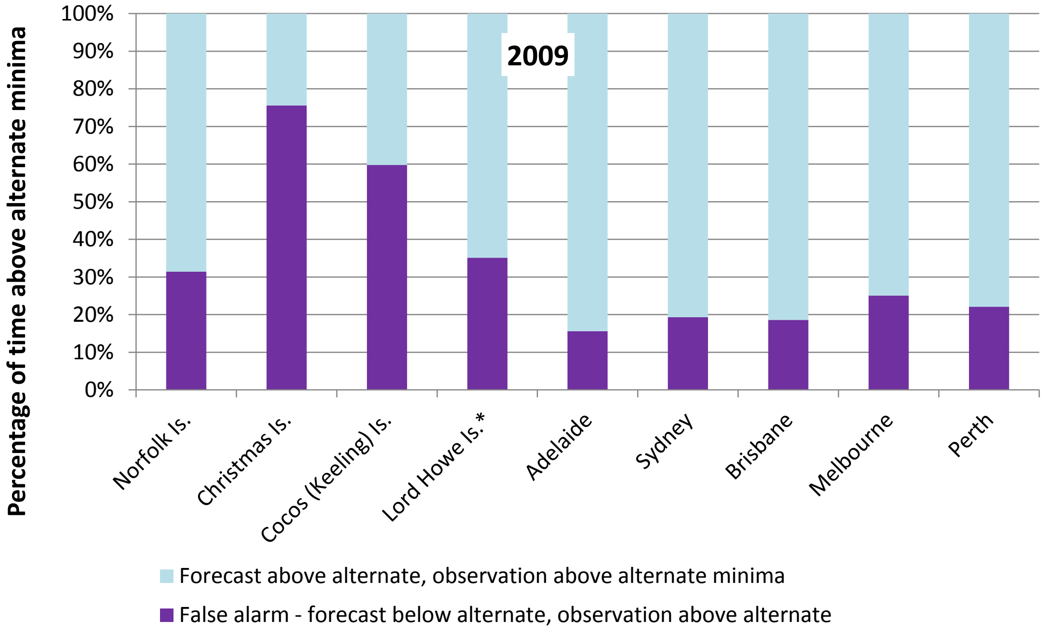
Figure J10 shows the same data as for Figure J9 calculated as a percentage of the total conditions above the alternate minima at each airport for the accident aircraft type.

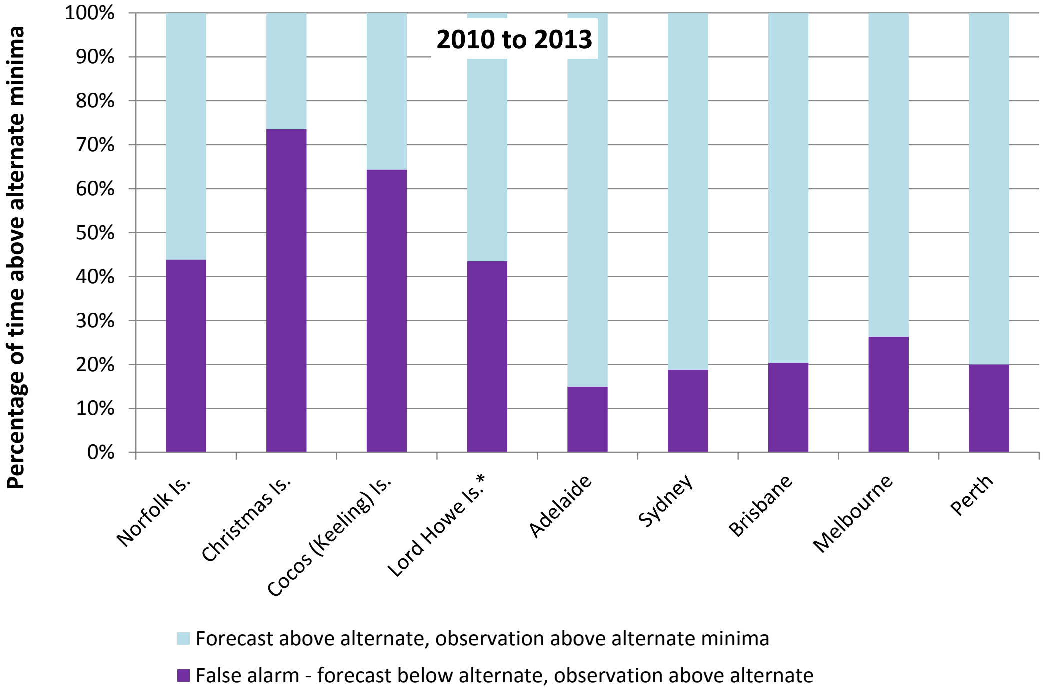
As indicated in Figure J10, when conditions were above the alternate minima:

- The false alarm percentage at Norfolk Island was 31 per cent in 2009 and 44 per cent during 2010–2013. The false alarm percentages at Lord Howe Island were similar.
- In comparison, the false alarm percentage during 2009–2013 was about 74 per cent at Christmas Island and 63 per cent at the Cocos Islands.

- The false alarm percentages for the capital city airports averaged about 20 per cent during 2009–2013.

Figure J10: Percentage of time above alternate minima by TAF above alternate minima, between alternate and landing minima and below landing minima for averaged for simulated TAF retrievals 1–3 hours prior to arrival for Westwind 1124/1124A without RNAV at selected airports, 2009–2013





Source: ATSB, derived from data provided by BoM.

Due to the wide variation in the length of time of periods above the alternate minima, it was not appropriate to conduct comparisons of episode data (as was conducted for the observations below the landing minima). However, the ATSB compared the proportion of days when conditions remained above the alternate minima that included a forecast below the alternate versus days that did not include a forecast below the alternate minima. Using this type of data, Norfolk Island had a higher proportion of days above the alternate minima that had false alarms during 2010–2014 than it did in 2009.[399]

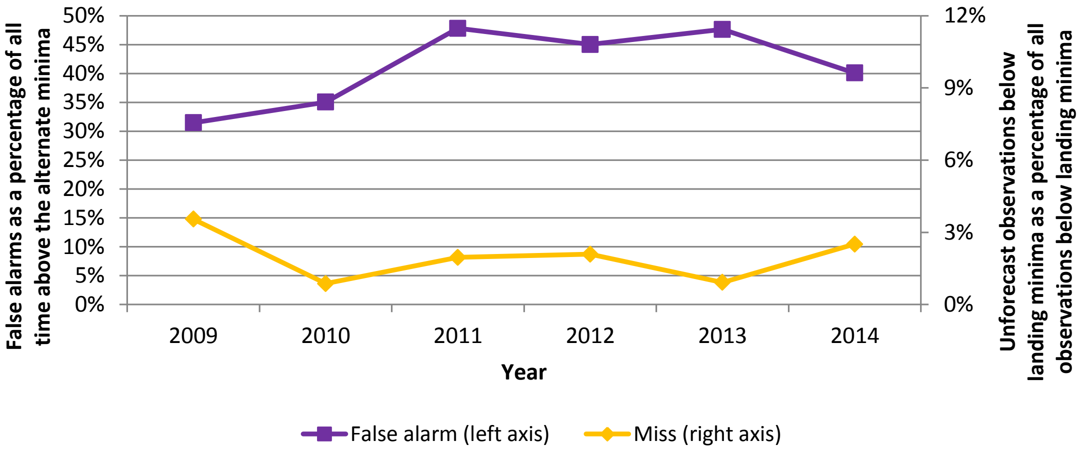
Changes to TAF prediction characteristics at Norfolk Island Airport from 2009 to 2014

As discussed in the previous sections, the amount of weather below the landing minima at Norfolk Island was the same in 2009 as it was during 2010–2013. However, the proportion of episodes below the landing minima that were unforecast was higher in 2009 than it was in subsequent years. Similarly, there was an apparent increase in false alarms from 2009 to 2010–2014.

Figure J11 provides a more detailed comparison of the unforecast weather below the landing minima (misses) and unforecast weather above the alternate minima (false alarms) during 2009–2014. The yellow line is indicating the proportion of just under 300 hours per year below the landing minima that was unforecast, whereas the purple line is indicating the proportion of about 7,770 hours per year observed above the alternate minima that was forecast below the alternate minima.

As indicated in the figure, the proportion of time associated with misses decreased after 2009 and the proportion of time associated with false alarms increased after 2009, particularly from 2011–2014. Overall, this data suggests weather forecasting at Norfolk Island was more conservative after 2009. However, the relative extent to which the apparent improvement in the forecasting of weather below the landing minima was due to improved forecasting models and practices and/or a more conservative approach could not be determined.

Figure J11: False alarms as a percentage of all time above the alternate minima and unforecast observations below landing minima as a percentage of all time below the landing minima for averaged simulated TAF retrieval times 1–3 hours prior to arrival by year, Norfolk Island Airport, Westwind 1124/1124A without RNAV (note that the two sets of data use different vertical scales)



Source: ATSB, derived from data provided by BoM.

399 X^2, $P < 0.001$, 1df. Norfolk Island 2009 vs Norfolk Island 2010-2014, Days with TAF below alternate minima during days with all conditions above the alternate minima as a proportion of all days with all conditions above the alternate minima. (Total days above alternate – 2009: 197, 2010–2014: 925 | Days with TAF below alternate and observations above alternate – 2009: 60, 2010–2014: 498).

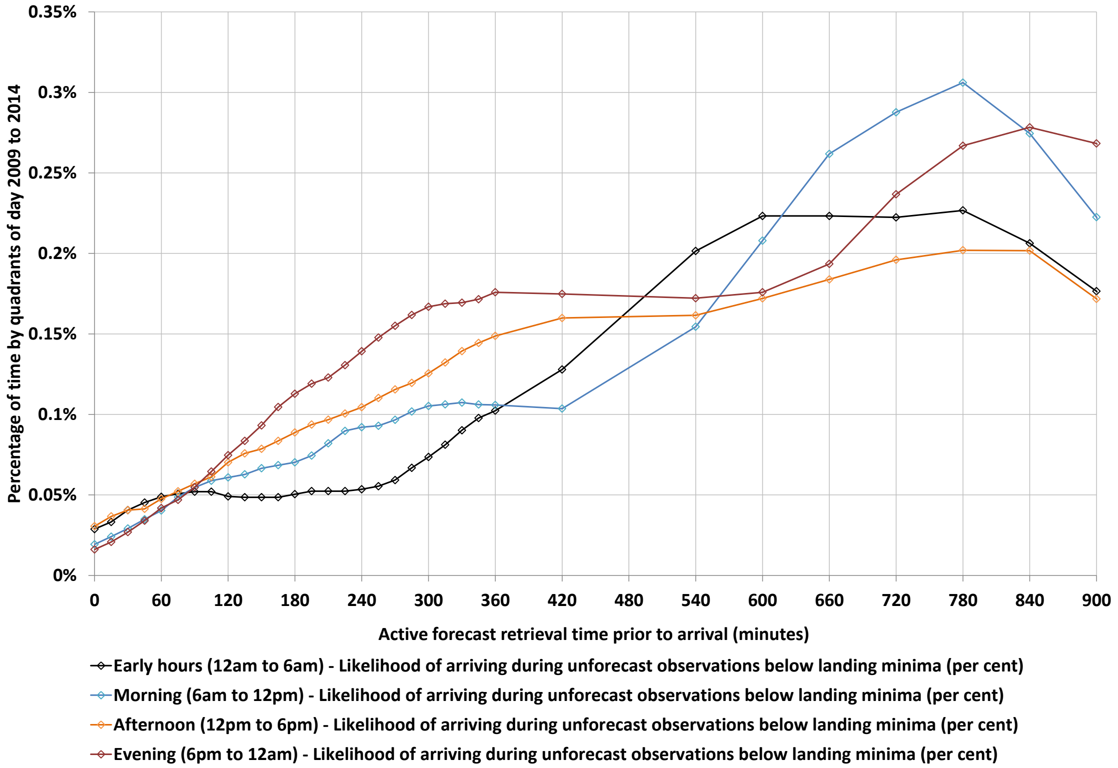
The effect of time of retrieval prior to arrival on TAF reliability at Norfolk Island Airport, 2009–2014

Figure J12 shows the time of unforecast observations below the landing minima per year as a percentage of all time (any type of observed weather) for each quadrant of the day (starting from 0000 local time), for simulated retrieval of TAFs up to 900 minutes (15 hours) prior to arrival.

This figure shows that likelihood of arriving during unforecast observations below the landing minima increased as the duration between TAF retrieval and arrival increased. This was particularly important for arrival in the evening (between 1800 and 0000 local time, or 0630 and 1230 UTC) at Norfolk Island. For example, if a TAF was retrieved 6 hours prior to arrival, the chances of arrival during unforecast conditions below the landing minima are more than two times greater than if a TAF was retrieved 2 hours prior to arrival.

From the perspective of operational decision-making, this shows that forecasts retrieved at the latest possible time (before the point of no return) provided a better warning of potential conditions below the landing minima at Norfolk Island Airport during 2009–2014.

Figure J12: Likelihood of arriving during unforecast observations below the landing minima by quadrant of day for simulated TAF retrieval times 0–900 minutes prior to arrival, Norfolk Island Airport, 2009–2014 for Westwind 1124/1124A without RNAV



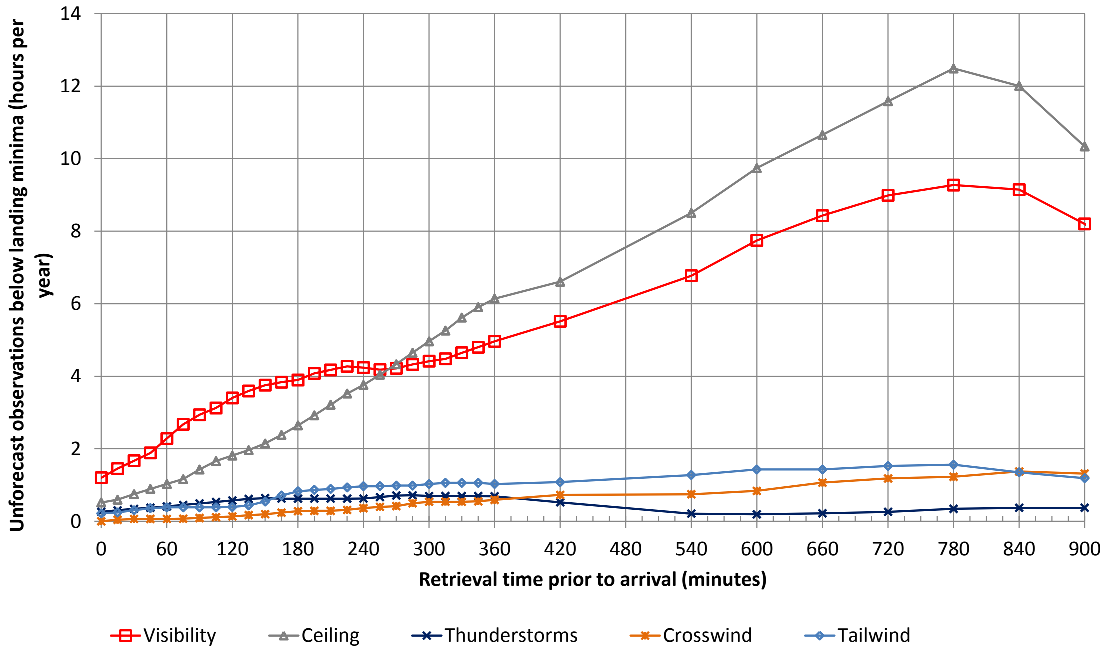
Source: ATSB, derived from data provided by BoM.

Figure J13 shows the hours each year of unforecast observations below the landing minima for each of the minima criteria for TAF retrievals up to 15 hours prior to arrival. Increasing the TAF retrieval time prior to arrival had the greatest effect for reported visibility and ceiling below the landing minima.

Although low ceiling was more prevalent overall (Figure J2), it was more common to arrive during unforecast visibility below the landing minima for TAF retrievals up to 4.5 hours prior to arrival.

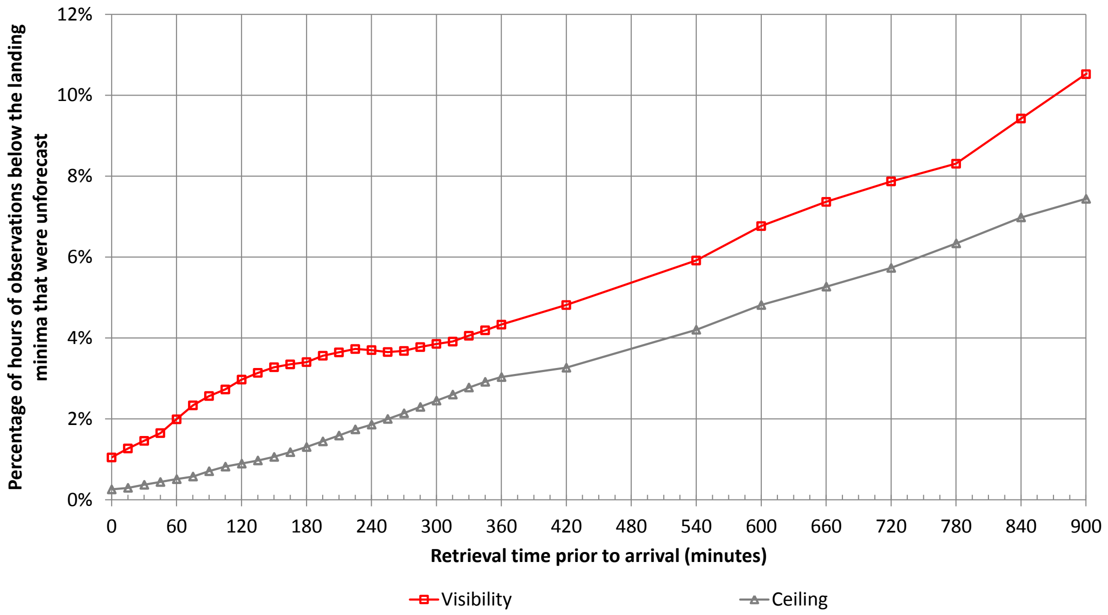
The prediction of low visibility and low ceiling degraded at a similar rate as the percentage of all observations below the landing minima that were not forecast for simulated TAF retrievals up to 15 hours prior to arrival (Figure J14).

Figure J13: Likelihood of arriving during unforecast observations below the landing minima by landing minima parameter for simulated TAF retrieval times 0–900 minutes prior to arrival, Norfolk Island Airport, 2009–2014 for Westwind 1124/1124A without RNAV



Source: ATSB, derived from data provided by BoM.

Figure J14: Unforecast visibility and ceiling below the landing minima as a percentage of observations below the visibility and ceiling landing minima for simulated TAF retrieval times 0–900 minutes prior to arrival, Norfolk Island Airport, 2009–2014 for Westwind 1124/1124A without RNAV



Source: ATSB, derived from data provided by BoM.

Summary of analysis

The ATSB's analysis of weather forecasting was conducted using a Category C aircraft without the capacity to conduct RNAV approaches in order to reflect the most relevant for considering operations in a Westwind 1124/1124A as used by the operator. Different results would be expected if a different category aircraft or other assumptions were made regarding the types of approaches that were available.

Key results from the ATSB's analysis regarding weather below the landing minima included:

- Overall, there was about 288 hours per year from 2009–2014 at Norfolk Island where the observed conditions were below the landing minima, with the amount in 2009 (296 hours) being similar to the later years.
- Low cloud was the most common type of weather below the landing minima at Norfolk Island (about 200 hours per year), although low visibility was also notable. Low cloud was also observed for the longest durations, with a median duration of 119 minutes. In addition, low cloud was most prevalent at night, and it was most prevalent during summer months.
- Compared to other Australian remote islands during 2009–2013, Norfolk Island had a similar amount of weather below the landing minima as Lord Howe Island (just under 300 hours per year), which was lower than the amount for Christmas Island (about 580 hours per year) and higher than the Cocos Islands (about 180 hours per year). These amounts were substantially higher than those for the five busiest capital city airports in Australia.

Key results from the ATSB's analysis regarding the reliability of forecasting included:

- Unforecast observations below the landing minima (when a TAF forecast conditions above the alternate minima and was retrieved 1–3 hours prior to arrival) were rare at Norfolk Island during 2009–2014, occurring about 5.5 hours per year (or 0.06 per cent of the total time). In 2009 the amount was 10.5 hours (0.12 per cent of the total time).
- Overall, remote islands had a similar amount of unforecast weather below the landing minima as capital city airports. The overall average was about 11.5 hours per year per airport (about 0.13 per cent of the total time), but there was significant variability between airports and across years.
- The number of weather episodes below the landing minima at Norfolk Island was about the same in 2009 (52) as it was during 2010–2013 (56 per year). However the proportion of these episodes that were unforecast was significantly higher in 2009 (29 per cent) compared with 2010–2013 (13 per cent).
- During 2009, the proportion of episodes below the landing minima that were unforecast was similar at Norfolk Island compared to the other remote islands (25 per cent), and significantly lower than the capital city airports (45 per cent).
- False alarms (where conditions were above the alternate minima but were forecast below the alternate minima) occurred about 37 per cent of the total time at Norfolk Island during 2009–2014. This rate appeared to increase from 2009 (31 per cent) to subsequent years (43 per cent).
- Overall, false alarms were more prevalent at remote islands than at capital city airports, particularly at Christmas Island and the Cocos Islands. This, combined with the lower proportion of unforecast observations below the landing minima, suggests that forecasting for remote islands was more conservative than forecasting for capital city airports.
- The relative extent to which the apparent improvement in the forecasting of weather conditions below the landing minima at Norfolk Island was due to improved forecasting models and practices and/or a more conservative approach (as shown by false alarms) could not be determined.
- From the perspective of operational decision-making, forecasts retrieved at the latest possible time (before the point of no return) provided a better warning of potential conditions below the landing minima at Norfolk Island during 2009–2014. In other words, as the time between retrieving a TAF and arriving at the airport increased, the likelihood of encountering unforecast weather increased. This was particularly applicable for aircraft arrivals in the evening between 1800 and 0000 local time (0630 and 1230 UTC) for a TAF retrieved up to 6 hours prior to arrival.

Appendix K – Requirements for alternate aerodromes and isolated aerodromes in other countries

Overview

The ATSB reviewed the regulatory requirements of other countries that applied in 2009 regarding:

- when an alternate aerodrome was required for an IFR flight (and therefore alternate fuel was required)
- requirements for flights to isolated aerodromes.

The focus was on commercial operations, particularly those that applied to fixed-wing air ambulance operations. The review did not consider the requirements for extended diversion time operations.

The countries (or groups of countries) selected were:

- New Zealand
- United States
- Canada
- Europe.

Each country has its own set of regulatory requirements, and focussing on specific aspects may not give a full picture of the relative standards that apply in each country.

New Zealand

The New Zealand Civil Aviation Regulation (NZ CAR) 91.405(a) applied to all IFR flights. It stated:

> A pilot-in-command of an aircraft operating under IFR must list at least one alternate aerodrome in the flight plan unless—
>
> (1) the aerodrome of intended landing has a standard instrument approach procedure published in the applicable AIP; and
>
> (2) at the time of submitting the flight plan, the meteorological forecasts indicate, for at least 1 hour before and 1 hour after the estimated time of arrival at the aerodrome of intended landing, that—
>
> (i) the ceiling at the aerodrome will be at least 1000 feet above the minima published in the applicable AIP for the instrument procedure likely to be used; and
>
> (ii) visibility will be at least 5 km, or 2 km more than the minima published in the applicable AIP, whichever is the greater.

There were no specific requirements for isolated aerodromes.

However, NZ CAR 121.157(b), which applied to air transport flights in large aircraft (more than 30 passenger seats), stated.

> A pilot-in-command of an aeroplane must not commence an air operation under IFR unless at least one alternate aerodrome is available… if—
>
> (1) the departure or destination aerodrome for the operation is outside New Zealand; and
>
> (2) the destination aerodrome has less than two separate runways suitable for use by the aeroplane being used.

United States

Part 135 of the US Federal Aviation Regulations (FARs) applied to most charter and air ambulance operations. FAR 135.223 stated:

> 135.223 IFR: Alternate airport requirements.

(a) Except as provided in paragraph (b) of this section, no person may operate an aircraft in IFR conditions unless it carries enough fuel (considering weather reports or forecasts or any combination of them) to—

(1) Complete the flight to the first airport of intended landing;

(2) Fly from that airport to the alternate airport; and

(3) Fly after that for 45 minutes at normal cruising speed or, for helicopters, fly after that for 30 minutes at normal cruising speed.

(b) Paragraph (a)(2) of this section does not apply if part 97 of this chapter prescribes a standard instrument approach procedure for the first airport of intended landing and, for at least one hour before and after the estimated time of arrival, the appropriate weather reports or forecasts, or any combination of them, indicate that—

(1) The ceiling will be at least 1,500 feet above the lowest circling approach MDA; or

(2) If a circling instrument approach is not authorized for the airport, the ceiling will be at least 1,500 feet above the lowest published minimum or 2,000 feet above the airport elevation, whichever is higher; and

(3) Visibility for that airport is forecast to be at least three miles, or two miles more than the lowest applicable visibility minimums, whichever is the greater, for the instrument approach procedure to be used at the destination airport.

Slightly different weather-related requirements applied to general aviation operations.[400] Part 121 specified requirements for scheduled air transport operations and charter operations in larger aircraft. It stated flights could not be dispatched under the IFR without an alternate aerodrome if similar types of weather conditions as specified for Part 135 or Part 91 operations existed.[401]

There was no specific requirements for isolated aerodromes for Part 135 operations. However, there were additional isolated aerodrome requirements for some Part 121 operations. For Part 121 operations in turbine-engine aircraft where either the departure aerodrome and/or the destination aerodrome was outside the continental USA, the flight required either alternate fuel (if an alternate aerodrome was required) or sufficient fuel to fly to destination aerodrome and then fly for 2 hours at normal cruise consumption.

Canada

In Canada, commercial operations with passengers could be conducted as air taxi, commuter or airline operations. Air ambulance operations could be classified as air taxi or commuter, depending on the type of aircraft involved. Operations in a turbo-jet powered aircraft (such as a Westwind) with a passenger capacity of 19 or less were classified as commuter operations, as were operations in other multi-engine aeroplanes with a passenger capacity of 10–19.

Under the Canadian Aviation Regulations, all IFR flights were required to include an alternate aerodrome in the flight plan unless the operator had an authorisation not to do so. For commuter (aeroplane) and airline operations, an operator would only be provided with such an approval if it complied with the relevant published Commercial Air Service Standard (CASS). For commuter (aeroplane) operations, the standard stated:

724.27 No Alternate Aerodrome - IFR Flight

For an air operator of aeroplanes to qualify to conduct a flight under IFR without naming an alternate aerodrome on the flight plan the following standard shall be met:

400 FAR 91.167 stated weather-related requirements for aeroplanes were a ceiling of 2,000 ft above the aerodrome elevation and a visibility of 3 miles.

401 Part 121 applied the Part 91 weather-related requirements to all scheduled domestic IFR operations, and applied the Part 135 weather-related requirements to all scheduled international (flag) IFR operations. Part 121 international operations without an alternate aerodrome were also restricted to flights of not more than 6 hours.

> (1) Area of Operations
>
> (a) take-off aerodrome shall be: (i) situated within the North American continent, the Caribbean islands and Bermuda; and
>
> (ii) not more than the hours of flight time (Scheduled) from the aerodrome of intended landing;
>
> (b) aerodrome of intended landing authorized for no alternate IFR shall meet the requirements of subsection (3) below; and
>
> (c) provided the requirements of subsections (2), (3), (4), (5) and (6) are met, the pilot-in-command may refile "No Alternate IFR" on flights to a destination aerodrome in Canada, regardless of the location of the departure aerodrome, when within six hours of the scheduled destination aerodrome.
>
> (2) Weather Requirements
>
> For at least one (1) hour before and until one (1) hour after the estimated time of arrival at the aerodrome of intended landing, there shall be, in respect to that aerodrome:
>
> (a) no fog or other restrictions to visibility, including precipitation, whether forecast or reported, below 3 miles;
>
> (b) no thunderstorms, whether isolated or otherwise forecast or reported;
>
> (c) a forecast ceiling of at least 1,000 feet above FAF altitude and a visibility of at least 3 miles or a ceiling of at least 1,500 feet above the MDA and a visibility of at least 6 miles; and
>
> (d) no freezing precipitation whether forecast or reported;
>
> (3) Aerodrome of Intended Landing - Requirements
>
> (a) the aerodrome of intended landing shall be:
>
> (i) equipped with at least two (2) separate runways each of which shall be operational and suitable for a safe landing for the aeroplane type, taking into consideration the approved operational limitations; and
>
> (ii) equipped with emergency or standby electrical power supply in support of the main electrical power supply used to operate all equipment and facilities that are essential to the safe landing of the aeroplane, whether such landing be by day or by night…

The standard for airline operations were similar. In addition, it included specific requirements for islands. These requirements included:

> In addition, where the flight is to a destination aerodrome located on an island, the following standards shall be met:
>
> (a) Minimum Fuel on Board Requirements
>
> The minimum fuel to be carried on board an aeroplane shall include:
>
> (i) taxi fuel,
>
> (ii) fuel to destination,
>
> (iii) contingency fuel, and
>
> (iv) additional contingency fuel or enroute fuel reserve or remote destination reserve fuel to hold for two hours at 10,000 feet at holding fuel consumption after arriving overhead the destination aerodrome, whichever is the greater…

There was no standard available for conducting air taxi (aeroplane) operations under the IFR without an alternate aerodrome (although there was a standard available for air taxi helicopter operations). Transport Canada confirmed that air taxi operations in fixed-wing aircraft could not conduct IFR operations without an alternate aerodrome. The only exception would be if the operator had applied for an exemption, providing a full justification and adequate safety mitigation. In that case, the regulator would consider the request and might issue an exemption.

Europe

Regulations for commercial air transport operations in aeroplanes in countries within the European Union were specified in EU OPS 1. Prior to July 2008, similar requirements were specified in the Joint Aviation Requirements (JAR) OPS 1. The requirements applied to all passenger-carrying operations in the member states, including air ambulance operations.

An isolated aerodrome was defined as

> If acceptable to the Authority, the destination aerodrome can be considered as an isolated aerodrome, if the fuel required (diversion plus final) to the nearest adequate destination alternate aerodrome is more than… For aeroplanes with turbine engines, fuel to fly for two hours at normal cruise consumption above the destination aerodrome, including final reserve fuel.

OPS 1.295 stated an operator must select at least one destination alternate for each IFR flight unless:

> 1. both:
>
> (i) the duration of the planned flight from take-off to landing … does not exceed six hours, and
>
> (ii) two separate runways … are available and usable at the destination aerodrome and the appropriate weather reports or forecasts for the destination aerodrome, or any combination thereof, indicate that for the period from one hour before until one hour after the expected time of arrival at the destination aerodrome, the ceiling will be at least 2 000 ft or circling height + 500 ft, whichever is greater, and the visibility will be at least 5 km;
>
> or
>
> 2. the destination aerodrome is isolated.

The fuel requirements stated in appendix 1 to OPS 1.255 effectively required that, for a flight to an isolated aerodrome, there would be sufficient fuel to fly to the destination and then fly above the destination aerodrome for 2 hours at normal cruise consumption.

Application of different alternate minima to Norfolk Island

Table K1 outlines how the different countries' weather-related requirements for an alternate aerodrome would be applied to Norfolk Island. As can be seen in the table, the cloud base requirement in Australia was lower than that of New Zealand and ICAO Annex 6 Part II (by 300 ft), and significantly lower than that in other countries (by 700 ft or more). Similar to Australia, all of the cloud requirements (other than Annex 6 Part II) were stated as ceiling rather than cloud base. The visibility minima were broadly similar across the countries.

Although the ceiling for Norfolk Island was lower using the Australian rules compared to rules in the other countries, this will not always be the case. In particular, depending on the type of instrument approaches available, the alternate minimum for ceiling in New Zealand could be similar to or lower than that in Australia. However, in many of these cases in Australia special (lower) alternate minima could apply for suitably-equipped aircraft.[402]

[402] For further details of the rules for special alternate minima in Australia, see the Manual of Standards (MOS) for (Australian) Civil Aviation Safety Regulation Part 173 (Standards applicable to instrument approach procedure design).

Table K1: Application of each countries' weather-related requirements for an alternate aerodrome to Norfolk Island

Country / Source	Context	Ceiling (ft)	Visibility (m)
Australia	All IFR operations	1,269	6,000
New Zealand	All IFR operations	1,584	5,300
United States	Part 135 IFR (and international airline operations)	2,269	6,600
	Part 91 IFR (and domestic airline operations)	2,000	4,800
Canada	Commuter IFR operations (aeroplane) option 1	2,464	4,800
	Commuter IFR operations (aeroplane) option 2	2,084	9,600
	Air taxi IFR operations (aeroplane)	Not permitted	Not permitted
Europe	Other than isolated aerodrome	2,000	5,000
	Isolated aerodrome	Not applicable	Not applicable
ICAO Annex 6 Part I (international commercial air transport)	Other than isolated aerodrome	Not specified	Not specified
	Isolated aerodrome	Not applicable	Not applicable
ICAO Annex 6 Part II (international general aviation)	All IFR	1,584 (cloud base)	7,300

Summary

Each of the countries had different requirements for isolated aerodromes and when an alternate aerodrome was required. In general terms:

- Europe effectively applied the ICAO Annex 6 Part I requirements for isolated aerodromes to all commercial air transport operations (that is, no weather-related criteria were specified, but all operations needed sufficient fuel for at least 2 hours holding, including the fixed reserve).
- The US and Canada required airline operations to some isolated aerodromes have sufficient fuel to arrive at the destination aerodrome and then fly for 2 hours. This requirement only applied if an alternate aerodrome was not required due to weather-related requirements.
- For operations to non-isolated aerodromes in Europe, and all aerodromes in the other countries, weather-related requirements were specified for when an alternate aerodrome was required. These weather-related requirements generally included a more conservative ceiling than specified in Australia.
- For operations in Canada, operations to non-isolated aerodromes in Europe and international airline operations to and from New Zealand, a flight could not be conducted without an alternate aerodrome unless the destination aerodrome had two separate runways.

Appendix L – History of Australian requirements for flights to remote islands or isolated aerodromes

Requirements before August 1999

As of 1988, Civil Aviation Regulation (CAR) 234 (Fuel requirements) stated:

> An aircraft shall not commence a flight within Australian territory or to or from Australian territory if the quantity of fuel and oil on board is less than the quantity which the Authority, having regard to the circumstances of the proposed flight and the safety of the aircraft, considers necessary and directs.

The Aeronautical Information Publication (AIP) RAC/OPS 1-42 contained the Authority's directions in relation to the fuel requirements. In broad terms, these requirements were similar to those subsequently included in the Civil Aviation Advisory Publication (CAAP) 234 (Guidelines for Aircraft Fuel Requirements).

The requirements for carrying fuel for an alternate aerodrome or holding fuel were outlined in AIP RAC/OPS-1-38 (Operational Requirements). In terms of weather and aerodrome lighting, these requirements were similar to those discussed in *Alternate fuel*. There were no specific requirements stated in relation to remote islands. However, the AIP stated:

> These requirements do not apply to flights bound for Cocos Islands, for which destination there is no available alternate, provided that “island reserve” fuel, as specified in the approved operations manual, is carried.

In relation to remote or isolated aerodromes, paragraph 5.4.3 of RAC/OPS 1-42 (section 5 Fuel Requirements) stated:

> For a flight to a destination which requires an alternate, but no alternate is available within the distance covered by the aircraft at normal cruise speed for 2 hours, the fuel on board should be sufficient to fly to the destination aerodrome, approach and land, and then hold for a period of 2 hours calculated at the normal cruise consumption rate.

In other words, there was no specific requirement for the 2-hours holding fuel unless the weather or aerodrome lighting conditions were such that an alternate was required. This was in contrast to the requirements of the International Civil Aviation Organization (ICAO) Annex 6 Part I, which required (for commercial air transport flights) the 2-hours fuel for a remote aerodrome regardless of the weather or aerodrome lighting conditions.

In a 2011 regulatory change document,[403] CASA stated:

> Prior to 1991, the then Civil Aviation Authority (CAA) had specific fuel requirements for flights to remote island destinations. Flights to Lord Howe Island required enough fuel to return to the mainland, and for flights to Norfolk Island and Cocos (Keeling) Island an additional minimum of 2 hours holding fuel was required irrespective of the forecasted weather. This requirement was known as an ‘island reserve’. At this time Christmas Island was not designated as a remote island.
>
> In 1991, the Civil Aviation Regulations 1988 (CARs) were enacted and required the operator and pilot in command of an aircraft to ensure sufficient fuel is carried on an aircraft for a particular flight. However, no additional requirement was placed on flights to remote islands.

CASA subsequently advised the ATSB that the ‘island reserve’ was the colloquial name given to the requirements to operate to those islands, and not some specifically stated or defined term used in legislation or the AIP.

In 1991, CASA replaced CAR 234 (as stated above) with the wording as shown in *General requirements*. The specific requirements in the AIP were also removed, and replaced with

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[403] CASA, July 2010, *Notice of Proposed Rule Making: Carriage of fuel on flights to a remote island*, Document NPRM 1003OS.

advisory material in CAAP 234-1(0). The explanatory memorandum associated with the change stated:

> The Civil Aviation Authority considers that it is not necessary from a safety point of view for it to specify the only method that may be used to calculate the fuel requirements that need to be carried on aircraft. It considers that the calculation of fuel should be a matter for the pilot in command and the operator of an aircraft to determine in each particular case. The Authority will provide advisory guidelines for the use of pilots and operators which will set out one possible method that may be used to calculate fuel requirements. However, there may be other methods of calculating fuel requirements that a pilot and operator may wish to use instead of the method suggested by the Authority. Operators and pilots will be free to use whichever method they wish so long as they comply with the statutory requirement in the new regulation 234 that sufficient fuel is carried to enable a flight to be undertaken in safety.

Changes in August 1999

In August 1999, CASA amended Civil Aviation Order 82.0 (Air operator's certificates – Applications for certificates and general requirements) to introduce fuel-related requirements for passenger-carrying charter operations to remote islands. The Explanatory Note for the change stated:

> Lord Howe Island, Norfolk Island and Christmas Island have been identified by the Bureau of Meteorology as locations where the difficulty in accurately forecasting the onset and cessation of weather significant to aviation operations is significantly greater than for corresponding mainland locations. In such circumstances, it is important from a safety perspective that aircraft flying to and from these Islands carry sufficient fuel to divert to an alternate aerodrome.
>
> A number of recent incidents have highlighted these issues. For example, BASI records indicate that there have been 2 recent incidents where a PA 31-350 aircraft arrived at Norfolk Island, when weather conditions precluded a safe landing, without sufficient fuel to divert to an alternate aerodrome.
>
> Additionally, questions have been raised as to the suitability of certain types of aircraft to operate safely between the Australian mainland and Lord Howe and Norfolk Island. Technical data, supported by anecdotal evidence, indicates that some of the aircraft types that are flown to these Islands are incapable of carrying sufficient fuel to reach a suitable alternate aerodrome in the event of an engine failure during certain phases of flight between Lord Howe Island and Norfolk Island…

The August 1999 version of the CAO defined a remote island as Christmas Island, Lord Howe Island, Norfolk Island and the Cocos (Keeling) Islands. It terms of 'minimum safe fuel', it stated:

> 2.3 The minimum safe fuel for an aircraft undertaking a flight over a particular route segment is:
>
> (a) the amount of fuel that will, whatever the weather conditions, enable the aircraft to fly, with all its engines operating, to its destination and then from its destination to the aerodrome that is, for that flight, the alternate aerodrome for the aircraft together with any reserve fuel requirements for the aircraft; or
>
> (b) the amount of fuel that the aircraft should carry at the start of the flight to ensure that, if at any time during the flight the aircraft's critical engine were to become inoperative, the aircraft would be able to reach either its destination or an aerodrome that meets the requirements for the operation of the aircraft with its critical engine inoperative;
>
> whichever is the greater.
>
> 2.4 The amount of fuel mentioned in subparagraph 2.3 (a) or (b) is to be worked out by using:
>
> (a) the fuel consumption data for the aircraft's engines provided by the manufacturer of the engines; and
>
> (b) the performance data for the aircraft provided by the manufacturer of the aircraft's airframe.

The requirement only applied to passenger-carrying charter operations. More specifically.

> 3.1 Each certificate authorising charter operations is subject to the condition that its holder must ensure that an aircraft operated under the certificate does not carry passengers on a flight over a route segment to or from a remote island unless:

(a) CASA has approved in writing the aircraft for the carriage of passengers on flights over the route segment; and

(b) the total amount of fuel carried by the aircraft at the start of the flight is not less than the minimum safe fuel for the aircraft for that flight; and

(c) the alternate aerodrome for the aircraft for that flight is a nominated aerodrome for the purposes of paragraph 3.2.

3.2 CASA must, on the application of the operator of an aircraft, approve the aircraft for the carriage of passengers on flights over a particular route segment to and from a remote island if, and only if:

(a) the aircraft has more than one engine; and

(b) the operator nominates in the application the aerodromes (the nominated aerodromes) out of which one may be chosen as the alternate aerodrome for the aircraft for a flight over that route segment; and

(c) on the information given to it by the operator, CASA is satisfied that the total fuel capacity of the aircraft is not less than the amount of fuel that would be the minimum safe fuel for that aircraft if:

(i) it were undertaking a flight over that route segment; and

(ii) the alternate aerodrome for the aircraft for that flight were the nominated aerodrome that is the furthest away from the aircraft's destination.

3.3 The operator of an aircraft must not nominate in an application under paragraph 3.2 an aerodrome that:

(a) is located on a remote island; or

(b) does not meet the requirements for the operation of the aircraft with its critical engine inoperative.

Changes in December 2000

In December 2000, CASA introduced changes to the remote island requirements for passenger-carrying charter operations. In its Explanatory Statement, CASA stated:

> These [August 1999] measures were prompted by safety considerations based on the following premises:
>
> - the lack of accuracy in weather forecasting on those islands;
> - the inadequacy of the fuel reserves being carried by a number of operators on those flights, given the necessity, because of the inaccurate weather forecasts, of having very often to divert to the alternate airport for the flight.
>
> CASA is now satisfied, on the basis of recent representations made to it, that, having regard to the quality of the weather forecast emanating from Cocos (Keeling) Islands and from the mainland destinations of flights from remote islands, the measures imposed were not required in the case of flights to or from Cocos (Keeling) Islands and flights from remote islands back to the Australian mainland. Furthermore, while the adopted measures took into account the failure of an aircraft's critical engine as a criterion for the calculation of the minimum safe fuel to be carried by an aircraft on a flight, notwithstanding the fact that the critical engine has little effect on an aircraft's performance other than during take-off, they failed to include as a criterion for fuel planning a more demanding emergency situation, namely, loss of pressurisation.
>
> … In addition, the definition of ***minimum safe fuel*** has been amended (paragraphs 2.3 to 2.4.1) so that, in the case of an operator who has made provision for a remote island fuel policy in its operations manual, the minimum amount of fuel to be carried by that operator's charter aircraft on a flight to a remote island is to be calculated in accordance with that policy (paragraph 2.3). Calculation of the minimum safe fuel in accordance with an operations manual is subject to the manual being revised, if CASA so directs in order to ensure that an adequate amount of fuel is carried.
>
> In other cases, operators are required to comply with requirements set out in paragraphs 2.4 and 2.4.1 as to the minimum amount of fuel they have to carry…

Accordingly, minimum safe fuel was now defined as:

> 2.3 The minimum safe fuel for an aeroplane undertaking a flight to a remote island is:
>
> (a) the minimum amount of fuel that the aeroplane should carry on that flight, according to the operations manual of the aeroplane's operator, revised (if applicable) as directed by CASA to ensure that an adequate amount of fuel is carried on such flights; or
>
> (b) if the operations manual does not make provision for the calculation of that amount or has not been revised as directed by CASA — whichever of the amounts of fuel mentioned in paragraph 2.4 is the greater.
>
> 2.4 For the purposes of subparagraph 2.3 (b), the amounts of fuel are:
>
> (a) the minimum amount of fuel that will, whatever the weather conditions, enable the aeroplane to fly, with all its engines operating, to the remote island and then from the remote island to the aerodrome that is, for that flight, the alternate aerodrome for the aircraft, together with any reserve fuel requirements for the aircraft; and
>
> (b) the minimum amount of fuel that would, if the failure of an engine or a loss of pressurisation were to occur during the flight, enable the aeroplane:
>
> (i) to fly to its destination aerodrome or to its alternate aerodrome for the flight; and
>
> (ii) to fly for 15 minutes at holding speed at 1,500 feet above that aerodrome under standard temperature conditions; and
>
> (iii) to land at that aerodrome.
>
> 2.4.1 An amount of fuel mentioned in paragraph 2.4 is to be worked out by using:
>
> (a) if the aeroplane is a transport category aircraft — the performance data, and the fuel consumption data, for the aeroplane contained in the aeroplane's flight manual; or
>
> (b) in any other case:
>
> (i) the performance data for the aeroplane provided by the manufacturer of the aircraft's airframe or contained in the aeroplane's flight manual, the operations manual of the aeroplane's operator or the pilot's operating handbook for the aeroplane; and
>
> (ii) the fuel consumption data for the aeroplane obtained from one of the sources mentioned in sub-subparagraph (i) or provided by the manufacturer of the aeroplane's engines;
>
> or, if any of those data need to be amended because of the issue of a supplemental type certificate for the aeroplane, those data as so amended; or
>
> (c) in all cases — the performance data, and the fuel consumption data, for the aeroplane obtained in the course of a flight test of the aeroplane carried out in an approved manner.

In addition, section 3A was also simplified:

> 3A.1 Each certificate authorising charter operations for the carriage of passengers is subject to the condition that an aeroplane operated under the certificate is to carry passengers on a flight to a remote island only if:
>
> (a) the aeroplane has more than 1 engine; and
>
> (b) the total amount of fuel carried by the aeroplane at the start of the flight is not less than the minimum safe fuel for the aeroplane for that flight; and
>
> (c) the alternate aerodrome for the aeroplane for that flight is not an aerodrome located on a remote island.

The CAO 82 requirements for remote islands did not change again until December 2014 (see *Safety issues and actions*).

Appendix M – Review of the operator's long-distance air ambulance flights

Background

The operator's Westwind pilots reported they generally took significantly more fuel than the minimum amount required. They said they usually departed with full fuel (full main and full tip tanks) for long-distance flights. Occasionally, if they had specific limitations, such as aircraft weight, they refuelled to a more specific amount. Such weight limitations were often associated with freight flights, and rarely associated with long-distance air ambulance flights.

In order to verify these statements, the investigation reviewed flight records for the operator's long-distance Westwind flights.

Overview of the dataset

The ATSB obtained copies of the following data:

- Flight records for VH-NGA from April 2008 to November 2009.
- Database entries of the flight records for six other Westwind aircraft from mid-May 2008 to November 2009. Together with VH-NGA, these six aircraft were used for all of the operator's Westwind air ambulance and passenger charter tasks during this period.
- Database entries of the flight records for all the operator's Westwind aircraft from January 2002 to mid-May 2008. These records prior to mid-May 2008 were contained in a different database to subsequent records.

The primary fields used from the dataset were:

- departure aerodrome
- destination aerodrome
- flight time
- fuel on board (prior to engine start)
- fuel burn off
- fuel remaining (after engine shutdown).

Other fields were derived from this data, such as flight distance and groundspeed.

Overall there were records for more than 18,000 flights from 1 January 2002 to 17 November 2009 (the day prior to the accident flight). Based on the available information, the flights were able to be classified as:

- air ambulance
- freight
- other.

The 'other' flights primarily included passenger charter and freight charter flights. They also included some aerial work and private flights (that is, flights where the listed client was the operator). In most cases there was insufficient information available to determine the nature of the flight. Where sufficient information was available or obtained to conclude a flight only carried freight, it was classified as a freight flight.

A small number of the flights were excluded because of missing or unreliable data. The most common problem occurred when the fuel on board minus the fuel burn did not equal the fuel remaining. For some flights the errors could be corrected with confidence based on other available data. Flights where the difference was more than 200 lb were excluded. Similarly, flights where the groundspeed or fuel burn per hour produced extreme values were reviewed and, if the data could not be corrected with confidence, the records were excluded. Almost all of the unreliable data was for flights before May 2008.

Most of the 18,000 plus flights were domestic freight flights, primarily between Darwin, Alice Springs and Melbourne. However, for the 1,428 flights with a flight time of 3.25 hours or more, 49 per cent were air ambulance flights and only 13 per cent were known freight flights.

The ATSB analysis focussed on air ambulance flights. This was because:

- Many of the operator's freight flights had operational limitations, such as the maximum take-off weight or maximum landing weight. For such flights the amount of fuel that could be carried was often limited to less than full fuel.
- The nature of many of the 'other' flights could not be easily determined. Many of these flights may have been freight flights and therefore had operational limitations. In addition, the operator advised some of the passenger charter flights probably had weight limitations that could have restricted the fuel load. However, the number of passengers and therefore the potential for weight limitations was not readily available.
- Air ambulance flights provided a more relevant comparison to the accident flight from Apia, Samoa to Norfolk Island on 18 November 2009.

Fuel on board air ambulance flights

VH-NGA had a slightly larger fuel tank capacity than the 1124 and the other 1124A in the operator's Westwind fleet (see *Fuel storage*). Pilots appeared to usually record a figure of 7100–7,200 lb as meaning full main tanks for both aircraft types, with indications that 7,300 lb or slightly higher was used more frequently for VH-NGA. Pilots appeared to usually record 8,700–8,900 lb to mean full fuel for VH-NGA and 8,700 lb to mean full fuel for the other aircraft.

Accordingly, for the purpose of the investigation the ATSB defined:

- 'full fuel' as 8,500 lb or more for all Westwind aircraft
- 'full main tanks' as 7,100–7,400 lb for VH-NGA and 6,900–7,200 lb for the other aircraft.

The ATSB examined the amount of fuel on board for different flight times. However, the analysis focussed on flights with a flight time of 3.25–4.24 hours. This was because, for the accident flight:

- The captain's submitted flight plan included an estimated flight time of 3.50 hours. This time could be compared to flights with a flight time in the range 3.25–3.74 hours.
- The captain's normal fuel planning method resulted in an estimated flight time of 3.92 hours, which would typically be rounded up to 4.00 hours. This time could be compared to flights with a flight time in the range 3.75–4.24 hours.

Table M1 shows the fuel on board and flight time for the 1,380 air ambulance flights with a flight time of at least 1.75 hours and a flight distance of at least 600 NM.

Table M1: Fuel on board and flight time for the operator's long-distance air ambulance flights (2002–2009)

Fuel on board (prior to engine start)	Flight time (hours)						Total
	1.75–2.24	2.25–2.74	2.75–3.24	3.25–3.74	3.75–4.24	4.25 +	
Full fuel	47	203	98	274	187	124	930
8,000–8,400 lb	6	9	16	50	8	2	90
7,300/7,500–7,900 lb	1	7	17	22	4		51
Full main tanks	23	67	105	31	3		227
< Full main tanks	21	37	17	1			75
Total	98	323	253	378	202	126	1,380

Note: Fuel on board amounts are explained in the text above.

Key results included:

- For air ambulance flights of 3.25–3.74 hours, 72 per cent departed with full fuel and 8 per cent departed with full main tanks or less.
- For flights of 3.75–4.24 hours, 93 per cent departed with full fuel and 1 per cent departed with full main tanks or less.
- All 119 flights with a flight time of 3.25–4.24 hours that departed with less than full fuel landed at an Australian mainland airport or an international airport with an ILS approach.[404] None of these flights landed at a remote aerodrome.
- All 35 flights with a flight time of 3.25–4.24 hours that departed with full main tanks or less landed at an Australian mainland airport or an international airport with an ILS approach.[405]

Only 3 flights over 3.75 hours departed with full main tanks. These flights included:

- a 3.95-hour flight from Adelaide to Darwin that landed during the day
- a 3.80 hour flight from Dili, Timor-Leste to Townsville that landed at night
- a 3.80-hour flight from Auckland to Sydney that landed at night.

The circumstances of these flights, and the extent to which they encountered unforeseen delays, is unknown.[406] However, each of these flights had alternate aerodromes available en route and/or relatively close to the destination airport.

Comparison of fuel on board with other types of flights

Figure M1 presents the percentage of air ambulance, freight and other flights that departed with full fuel for different flight times. Figure M2 shows the percentage of flights that departed with full main tanks or less for the same types of flights.

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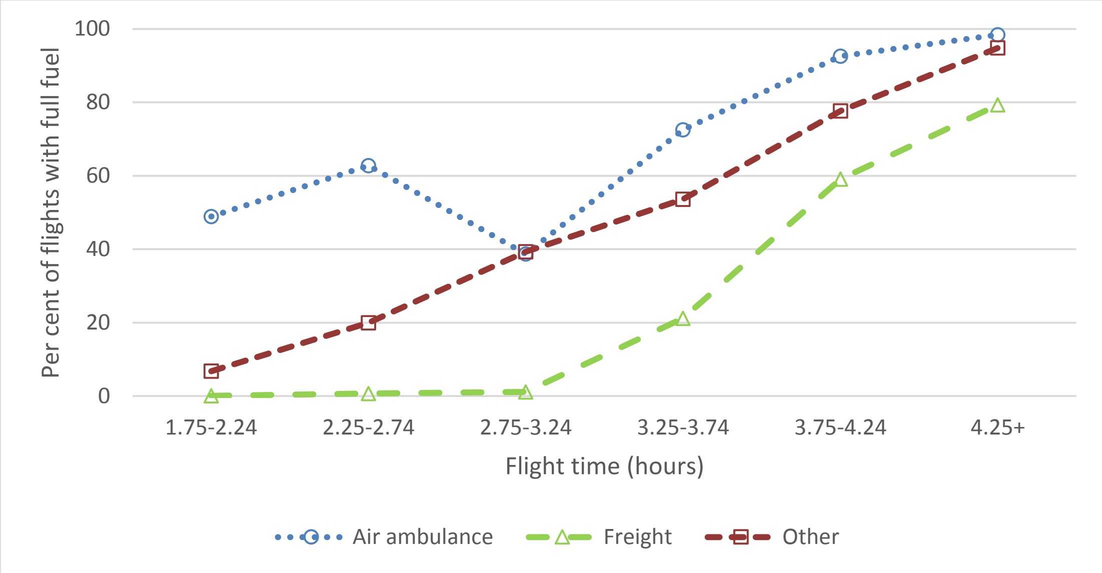
[404] The Australian airports included Sydney (41 flights), Darwin (29 flights), Adelaide (17 flights), Perth (15 flights), Brisbane (6 flights), Mebourne (3 flights), Alice Springs (1 flight), Nowra (1 flight) and Townsville (1 flight). The international airports included Bali (4 flights) and Apia (1 flight). For most if not all of these flights, an air traffic control service would have been provided at the airport.

[405] The Australian airports included Sydney (13 flights), Darwin (6 flights), Brisbane (5 flights), Adelaide (4 flights), Perth (3 flights), Nowra (1 flight) and Townsville (1 flight). The international airports included Bali (1 flight) and Apia (1 flight).

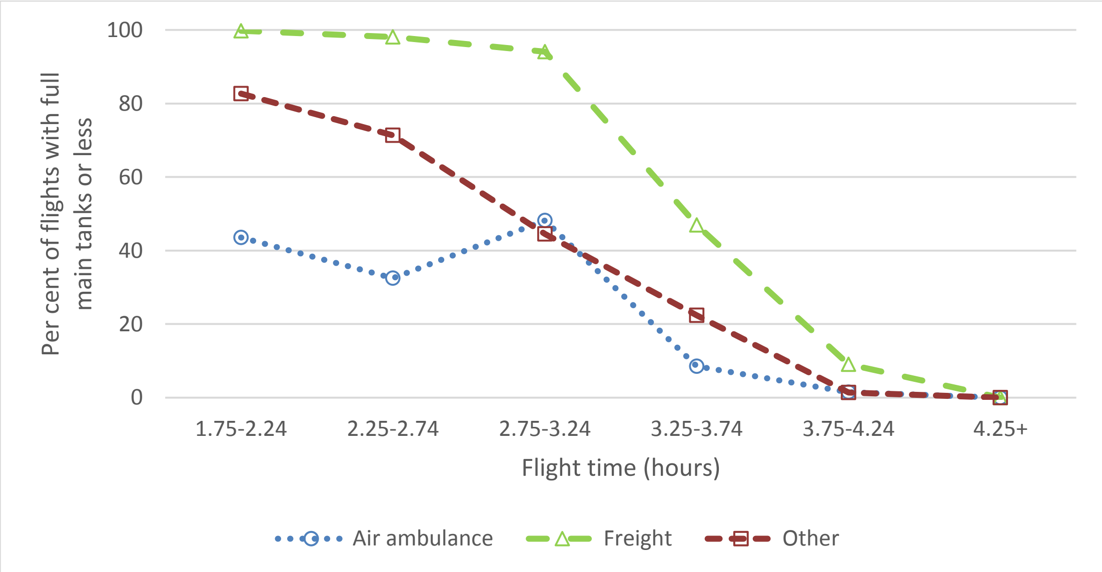
[406] For the flight to Darwin, the TAF indicated no requirements or concerns. During the flight, there was a SPECI and METARs issued that indicated reduced visibility due to smoke haze. The reduced visibility was still above the landing minima.

Figure M1: Percentage of the operator's Westwind flights that departed with full fuel (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

Figure M2: Percentage of the operator's Westwind flights that departed with full main tanks or less (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

Overall, air ambulance flights had a higher percentage of flights that departed with full fuel and a lower percentage of flights that departed with full main tanks or less. This is consistent with weight limitations being a factor for many of the freight flights and some of the other flights. In addition, a significantly higher percentage of air ambulance flights were conducted to remote or semi-remote aerodromes (see appendix N).

In general, as the flight time increased the use of full fuel increased and the use of full main tanks decreased. The only exception to this trend was for air ambulance flights, where flights of 2.25–2.74 hours had a higher percentage that departed with full fuel and a lower percentage that departed with full main tanks or less compared to flights of 2.75–3.24 hours. This appeared to be because a relatively high percentage of the air ambulance flights with a flight time of less than 2.75 hours were to remote or semi-remote aerodromes, whereas only a small percentage of air ambulance flights with a flight time of 2.75 hours or more were to remote or semi-remote aerodromes. As discussed in appendix P, flights to remote or semi-remote aerodromes generally departed with full fuel.

Across all types of flights there were 116 flights with a flight time of 3.25–4.24 hours that departed with full main tanks or less. For these flights:

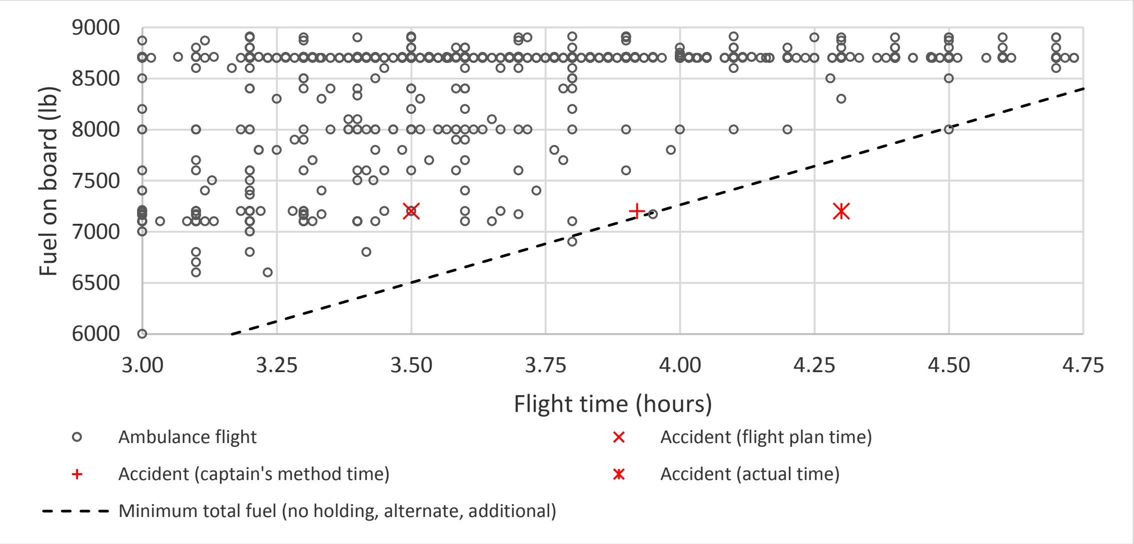
- Almost all (112) of the flights landed at Australian mainland airports and 4 landed at international airports. All of the destination airports had an ILS approach.
- None of the flights landed at a remote aerodrome, and 1 flight landed at a semi-remote aerodrome. This was a 3.40-hour freight flight to Noumea, New Caledonia that landed during the day.
- The longest flight with full main tanks was 4.10 hours, which occurred on a charter flight from Perth to Nowra.
- At least 35 of the 116 flights were freight flights, including 6 of the 12 flights with a flight time of 3.75–4.24 hours.

Potential discretionary fuel on air ambulance flights

For almost all of the flights, there was insufficient information available to determine the fuel planning requirements and therefore how much of the total fuel on board was discretionary fuel. Nevertheless, for indicative purposes, the ATSB estimated the minimum total fuel for a normal operation based on the recorded flight time. This estimate used the operator's 23 lb/minute method and included variable reserve, fixed reserve and taxi fuel, but did not include alternate, holding or additional fuel required for aircraft system failures.[407]

Figure M3 shows the fuel on board and flight time of the 828 air ambulance flights with a flight time of 3.00–4.75 hours. It also compares the fuel on board to the minimum total fuel for a normal operation, depicted by the dashed line. The distance above the line provides an indication of the potential amount of discretionary fuel (assuming no requirements for alternate, holding or additional fuel for aircraft system failures).

Figure M3: Fuel on board and flight time for the operator's long-distance air ambulance flights to all destinations compared to minimum total fuel (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation. Notes: The markers for many of the flights that departed with full fuel overlap on the graph and therefore the number of these flights cannot be clearly seen. This graph does not include 26 flights with a flight time over 4.75 hours, all of which departed with full fuel.

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[407] The estimate of the total fuel required included 23 lb/minute, 400 lb for climb, 10 per cent variable reserve, 600 lb fixed reserve and 150 lb for taxi. The operator's 23 lb/minute method provided slightly higher estimates of the total fuel required, and lower estimates of the excess fuel, than the operator's hour-by-hour method.

Figure M3 also compares the 828 air ambulance flights to the accident flight. As can be seen in the figure, for a flight of 3.50 hours (the captain's submitted flight plan time), a fuel load of full main tanks (7,200 lb) had about 700 lb more fuel than the minimum total fuel required for a normal operation. For a flight time of 4.00 hours (the flight plan time obtained using the captain's normal method), a fuel load of full main tanks had little if any excess fuel than for a normal operation. The captain indicated that he thought he had about 200–300 lb of excess fuel for the accident flight.

Most of the flights departed with substantially more fuel than the minimum total fuel for a normal operation. More specifically:

- For the 378 flights with a flight time of 3.25–3.74 hours, the average amount of excess fuel (compared to the minimum total fuel for a normal operation) was 1,926 lb. Almost all flights (98 per cent) had more than 600 lb of excess fuel, and most flights (92 per cent) had more than 1,000 lb of excess fuel.
- For the 202 flights with a flight time of 3.75–4.24 hours, the average amount of excess fuel (compared to the minimum total fuel for a normal operation) was 1,481 lb. Almost all flights (97 per cent) had more than 600 lb of excess fuel and most flights (96 per cent) had more than 1,000 lb of excess fuel.

Regarding the extent to which the excess fuel for the 828 air ambulance flights was discretionary fuel:

- In most cases there were probably no weather-related requirements to carry alternate or holding fuel.[408]
- For almost all the flights, there would have been no need for additional fuel to allow for aircraft system failures, or the additional fuel required would have been much less than the excess fuel.
- Flights to some major airports would have required holding for air traffic control purpose. For example, Sydney, Melbourne, Brisbane and Perth generally required some holding to be planned due to traffic delays. This was usually in the order of 15 minutes (or about 300 lb for a Westwind 1124/1124A).
- The actual flight time may have been more than the planned flight time for many reasons, such as holding, missed approach, diversion or other unexpected delay encountered during flight.

Overall, for most flights, most of the fuel in excess of the minimum total fuel for a normal operation would have been discretionary fuel. However, for some flights, at least some of this excess fuel would have been a required component of the total fuel required.

Fuel remaining after engine shutdown

The ATSB reviewed the recorded amount of fuel remaining after engine shutdown for the air ambulance flights. The captain of the accident flight initially reported that, based on his fuel planning calculations, he expected to have 1,700–1,800 lb of fuel remaining after arriving at Norfolk Island (assuming none of the fuel reserves were used). He subsequently reported he expected to have 1,400 lb of fuel remaining. The ATSB's analysis of the fuel remaining during the accident flight indicated there would have been about 1,000 lb remaining after engine shutdown if the first approach was successful (appendix E).

For comparison purposes:

- Using the operator's 23 lb/minute method for a 3.50-hour flight results in an expected fuel remaining of 1,820 lb if the aircraft departs with 7,200 lb (and no variable reserve is used).
- Using the operator's 23 lb/minute method for a 4.00-hour flight results in an expected fuel remaining of 1,130 lb if the aircraft departs with 7,200 lb (and no variable reserve is used).

[408] The ATSB examined the weather forecasts for a sample of the flights, particularly for flights to remote aerodromes. Most of the forecasts indicated no weather-related requirement for alternate or holding fuel.

Key results included:

- For the 378 air ambulance flights of 3.25–3.74 hours, 95 per cent of flights had more than 1,800 lb of fuel remaining, 4 per cent had 1,700–1,800 lb remaining and 1 per cent had less than 1,700 lb remaining.
- For the 202 air ambulance flights of 3.75–4.24 hours, 89 per cent had more than 1,800 lb of fuel remaining, 6 per cent had 1,700–1,800 lb remaining, 3 per cent had 1,500–1,600 lb remaining and 2 per cent had less than 1,500 lb remaining.
- All 42 air ambulance flights with a flight time of 3.25–4.24 hours that had 1,800 lb or less remaining landed at an Australian mainland airport or an international airport with an ILS approach. None of these flights landed at a remote aerodrome.

Capacity for holding at the destination aerodrome

The ATSB also examined the capacity for holding after arriving at the destination aerodrome. For a Westwind 1124, the fuel burn when holding at 1,500 ft in ISA conditions at a normal landing weight (16,000 lb) is about 1,020 lb/hour and for a 1124A it is about 980 lb/hour. For the purposes of examining the fuel remaining after engine shutdown, the ATSB used the following figures:

- 600 lb equated to the fixed fuel reserve of 30 minutes
- 1,200 lb equated to at least 30 minutes holding plus the fixed fuel reserve
- 1,800 lb equated to at least 60 minutes holding plus the fixed fuel reserve
- 2,400 lb equated to at least 90 minutes holding plus the fixed fuel reserve.

If the holding was conducted at cruise levels rather than 1,500 ft, the capacity to hold would have been significantly increased.

Table M2 provides information about the fuel remaining for the 1,380 air ambulance flights with a flight time of 1.75 or more hours, classified by flight time.

Table M2: Fuel remaining for air ambulance flights with a flight time of 1.75 hours or more

Flight time	Number of flights with fuel amount remaining				Total flights	Average fuel remaining
	600–1,100 lb	1,200–1,700 lb	1,800–2,300 lb	2,400+ lb		
4.50+ hours	12	49	15	1	77	1,460 lb
4.25–4.49 hours	1	9	33	6	49	1,992 lb
3.75–4.24 hours	2	10	88	102	202	2,343 lb
3.25–3.74 hours	1	7	74	296	378	2,741 lb
2.75–3.24 hours		7	65	181	253	2,915 lb
2.25–2.74 hours		6	22	295	323	3,825 lb
1.75–2.24 hours		1	11	86	98	4,148 lb
Total	16	89	308	967	1,380	2,970 lb

As indicated in the table, most of the 580 flights with a flight time of 3.25–4.24 hours had a significant amount of fuel remaining, with the average amount being 2,602 lb, and 560 flights (97 per cent) having 1,800 lb or more remaining. More specifically:

- 398 flights (69 per cent) had 2,400 lb or more fuel remaining
- 162 flights (28 per cent) had 1,800–2,300 lb of fuel remaining (with half of these flights having 2,100 lb or more remaining)
- 17 flights (3 per cent) had 1,200–1,700 lb of fuel remaining (with 15 of these flights having 1,500 lb or more remaining)

- 3 flights (0.5 per cent) had less than 1,200 lb of fuel remaining.

For the 674 flights with a flight time of 1.75–3.24 hours, the average amount of fuel remaining was 3,536 lb. In addition:

- 562 flights (83 per cent) had 2,400 lb or more fuel remaining
- 98 flights (15 per cent) had 1,800–2,300 lb of fuel remaining
- 14 flights (2 per cent) had 1,200–1,700 lb of fuel remaining
- 0 flights had less than 1,200 lb of fuel remaining.

For the 49 flights with a flight time of 4.25–4.49 hours, the average amount of fuel remaining was 1,992 lb. Most flights (80 per cent) had 1,800 lb or more remaining.

For very long flights, there will generally be less fuel remaining, even if the flight departed with full fuel.[409] When reviewing these flights, it is worth noting:

- Almost all of these flights departed with full fuel (see Table M1).
- It is likely at least some of these flights had a recorded flight time that was longer than the planned flight for many reasons, such as holding, missed approach, diversion or other unexpected delay encountered during flight.
- It is likely at least some of these flights were conducted on the basis of in-flight replanning, and/or were planned or conducted using long-range cruise settings.

Overall, 105 of the 1,380 air ambulance flights with a flight time of 1.75 hours or more had less than 1,800 lb remaining. Almost all (103) of these flights landed at an Australian mainland airport or an international airport with an ILS approach. The two exceptions were a 4.57-hour flight from Apia to Norfolk Island that departed with full fuel and had 1,500 lb of fuel remaining (see *30 September 2009 flight from Apia to Norfolk Island*), and a 2.40-hour flight from Funafuti, Tuvalu to Port Vila, Vanuatu that departed with 5,000 lb and had 1,400 lb of fuel remaining.[410] The 4.57-hour flight to Norfolk Island was the only air ambulance flight to a remote aerodrome that had less than 1,800 lb of fuel remaining.

None of the air ambulance flights landed with less than the 600 lb fixed reserve, although one very long flight (5.60-hour) from Suva, Fiji to Brisbane had 600 lb remaining. The circumstances of this flight are unknown, although based on the subsequent flight record it is likely the actual flight time was shorter than 5.60 hours.

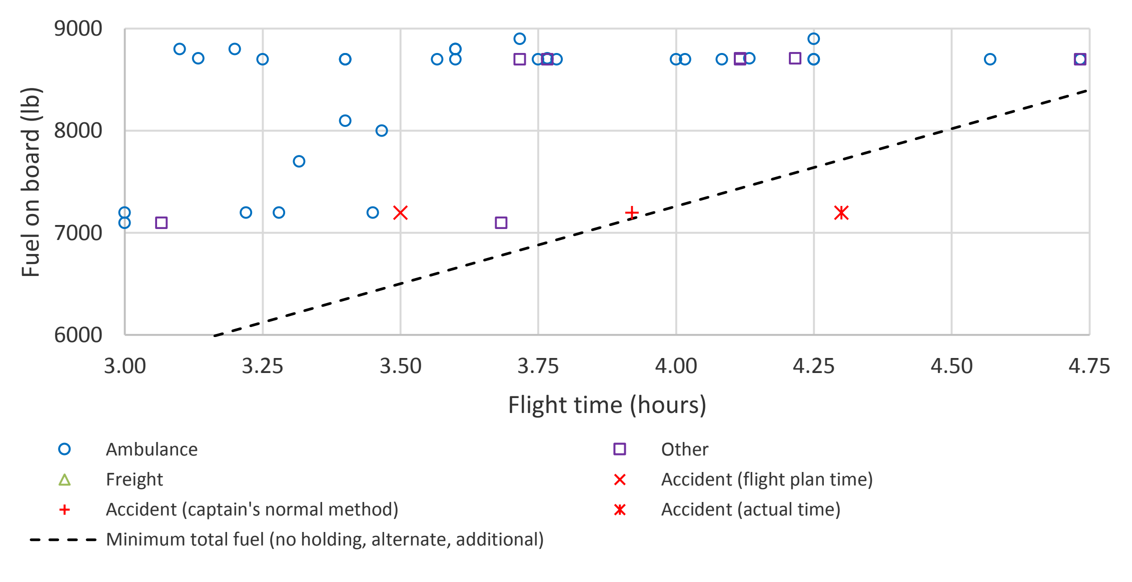
Flights involving the captain of the accident flight

Figure M4 shows the fuel on board and flight time of long-distance flights involving the captain of the accident flight, after he became a captain in November 2008.

409 For a 4.50-hour flight that departed with 8,700 lb, there would be about 1,940 lb of fuel remaining. This figure reduces as the flight time increases.

410 This flight was returning from an international remote island and no fuel may have been available at the time of departure.

Figure M4: Fuel on board and flight time of flights of 3.00–4.75 hours involving the captain of the accident flight



Source: ATSB, derived from data provided by Pel-Air Aviation. Note: This graph does not include 1 flight with a recorded flight time of 5.28 hours, which departed with full fuel.

The captain conducted 21 air ambulance flights with a flight time of 3.25–4.24 hours.[411] Details regarding these flights included:

- For the 13 air ambulance flights with a flight time of 3.25–3.74 hours, 8 flights (62 per cent) departed with full fuel and 2 flights (15 per cent) departed with full main tanks or less.
- For the 8 air ambulance flights with a flight time of 3.75–4.25, all departed with full fuel.

Overall, these flights appeared to be similar to those of other Westwind flight crew. The amount of excess fuel was also similar to other flight crew, with 20 of the 21 flights (95 per cent) with a flight time of 3.25–4.24 hours having more than 1,000 lb of excess fuel and none having less than 770 lb. In addition, the amount of fuel remaining was similar to other flight crew, with 20 of the 21 flights (95 per cent) having more than 1,800 lb remaining and the other flight having 1,800 lb remaining.

The captain also conducted 2 other (non-ambulance) flights with a flight time of 3.25–3.74 hours, with 1 flight departing with full fuel and 1 flight departing with full main tanks. Four other flights with a flight time of 3.75–4.24 hours all departed with full fuel.

The 3 flights of all types with a flight time of 3.25–3.74 hours that departed with full main tanks included:

- a 3.68-hour charter flight from Tindal to Williamtown
- a 3.45-hour air ambulance flight from Bali to Perth
- a 3.28-hour air ambulance flight from Norfolk Island to Apia on 17 November 2009.

All 3 flights landed during the day. The number of passengers on the 3.68-hour charter flight, and therefore the potential for weight limitations, could not be determined. The operator reported it was likely that the flight had some weight restrictions. There were also aerodromes available en route and relatively close to the destination aerodrome if required.

The captain reported that if he calculated the total fuel required for a flight to be more than 7,200 lb, he would almost always refuel to full fuel. He would rarely refuel to an amount between

[411] Before being cleared to line as a captain in November 2008, the captain conducted 18 flights (including 10 air ambulance flights) with a flight time of 3.25-4.24 hours. There was no apparent difference in the fuel on board for different flight times in the period before he was a captain versus after he was a captain.

full main tanks and full fuel, and would only do so if he had to get a specific amount for some reason. Of the 66 flights of all types he conducted after becoming a captain with a flight time of 2.25 hours or more:

- 43 departed with full fuel (2.25–5.28 hours)
- 4 departed with 7,700–8,100 lb (2.88–3.47 hours)
- 17 departed with full main tanks (2.38–3.68 hours)
- 2 departed with less than full main tanks (2.40–2.43 hours).

The 4 flights that departed with 7,700–8,100 lb included:

- a 3.47-hour air ambulance flight from Perth to Bali (departed with 8,000 lb)
- a 3.40-hour air ambulance flight from Noumea to Sydney (departed with 8,100 lb)
- a 2.88-hour freight flight returning with no freight from Noumea to Sydney (departed with 8,000 lb)
- a 3.32-hour air ambulance flight from Christmas Island to Perth (departed with 7,700 lb).

All 4 flights landed at night. Based on a consideration of the TAFs, en route winds and other available information, it is likely that 3 of the 4 flights departed with significantly more fuel (at least 800 lb) than the minimum total fuel required for the flight. The minimum total fuel required for the flight from Perth to Bali could not be reliably estimated.[412]

In terms of fuel remaining for the captain’s flights:

- For the 15 flights of all types with a flight time of 3.25–3.74 hours, 13 flights had more than 1,800 lb of fuel remaining. The 3.68-hour charter flight from Tindal to Williamtown (which departed with full main tanks) had 1,640 lb remaining and the 3.45-hour air ambulance flight from Bali to Perth (which departed with full main tanks) had 1,800 lb remaining.
- For the 12 flights of all types with a flight time of 3.75–4.24 hours, all had more than 1,800 lb of fuel remaining.

Flights involving the captain of the accident flight before he became a captain in November 2008 appeared to be similar in nature to the flights after he became a captain. For example, with regard to air ambulance flights:

- all 5 flights with a flight time of 3.75–4.24 hours departed with full fuel
- 3 of the 5 flights with a flight time of 3.25–3.74 hours departed with full fuel, with the other 2 flights departing with 8,000 lb (3.50-hour flight to Perth) and full main tanks (3.50-hour flight to Darwin).

Of the 8 flights of other types with a flight time of 3.25–4.24 hours, 5 departed with full fuel. The other 3 flights departed with 8,200 lb (4.00-hour flight to Williamtown), 8,100 lb (4.00-hour flight to Cairns) and 7,800 lb (3.30-hour flight to Perth).

Flights involving the first officer of the accident flight

The first officer conducted 28 air ambulance flights with a flight time of 3.25–4.24 hours. Details regarding these flights included:

- For the 16 air ambulance flights with a flight time of 3.25–3.74 hours, 11 flights (69 per cent) departed with full fuel and 1 flight (6 per cent) departed with full main tanks or less.
- The 12 air ambulance flights with a flight time of 3.75–4.25 hours all departed with full fuel.

Overall, these flights appeared to be similar to those of other Westwind flight crew.

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[412] A TAF issued about 1 hour prior to departure included a 1 hour holding requirement. It was unclear whether the captain conducted his flight planning before or after this amended TAF was issued.

The first officer also conducted 13 other (non-ambulance) flights with a flight time of 3.25–3.74 hours, with 6 flights departing with full fuel and 5 flights departing with full main tanks or less. Ten other flights with a flight time of 3.75–4.24 hours all departed with full fuel.

The 5 flights of all types with a flight time of 3.25–3.74 hours that departed with full main tanks included:

- 2 freight flights from Broken Hill to Darwin (3.73 hours and 3.25 hours)
- a 3.30-hour charter flight from Williamtown to Mount Isa
- a 3.30-hour charter flight from Edinburgh to Pearce
- the 3.28-hour air ambulance flight from Norfolk Island to Apia on 17 November 2009.

Summary

The use of full fuel was significantly more common than full main tanks for air ambulance flights of 3.25 hours or more, regardless of the destination aerodrome. More specifically, the use of only full main tanks:

- was relatively uncommon (7 per cent of the time) for air ambulance flights of 3.25–3.74 hours
- was rare (2 per cent of the time) for air ambulance flights of 3.75 to 3.99 hours
- had not occurred before for flights of 4.00 hours or more.

Overall, the operator’s pilots appeared to generally plan air ambulance flights with a substantial amount of fuel in excess of the minimum total fuel for a normal operation. For most of the flights, most of this excess fuel would probably have been discretionary fuel. Similarly, most air ambulance flights had a substantial amount of fuel remaining after engine shutdown.

Appendix N – Review of the operator's flights to remote aerodromes

Background

The operator's Westwind pilots reported that for long-distance flights to Australian remote islands, and similar aerodromes internationally, they always departed with as much fuel as possible. This was almost always full fuel, particularly for air ambulance flights.

Some pilots also reported that for flights to Norfolk Island and/or Christmas Island they always ensured they had sufficient fuel to arrive at the destination aerodrome, conduct a missed approach and then divert to an alternate aerodrome. Others stated they simply took as much fuel as they could, which usually provided enough fuel for an alternate aerodrome. However, they would only ensure there was sufficient fuel for an alternate if the forecast weather conditions or other circumstances indicated it was required.

In order to verify these statements, the investigation reviewed flight records for the operator's Westwind flights to remote aerodromes. This review used the same approach to examine fuel on board and supplementary fuel as the review of air ambulance flights (appendix M).

Overview of flights to remote aerodromes

For the purposes of this report, the ATSB defined a 'remote aerodrome' for Westwind 1124/1124A aircraft as a destination aerodrome where no suitable alternate aerodrome for a safe landing was available within 240 NM. The review considered a suitable aerodrome for a safe landing to be one that had:

- a sealed runway with a length suitable for a Westwind landing
- runway lighting available (if the landing was conducted at night).

The minimum distance of 240 NM was selected so that Christmas Island (266 NM to the nearest alternate aerodrome) was included.

The review also examined flights to 'semi-remote aerodromes', which are discussed towards the end of this appendix.

The selected dataset contained 184 flights from 1 January 2002 to 17 November 2009 that landed at a remote aerodrome with a flight time of at least 1.75 hours and a flight distance of at least 600 NM.[413] The investigation also identified one flight in early 2009 from Sydney to Norfolk Island where the crew conducted a missed approach at Norfolk Island and then diverted to Auckland, New Zealand.[414] This flight was also included in the selected sample, increasing the number of flights to remote aerodromes to 185.

Table N1 shows the number of flights of each type to different aerodromes. The ATSB was particularly interested in the flights to Norfolk Island and Christmas Island. These aerodromes have a significant number of days each month where cloud is below the alternate minima (see appendix H). As far as could be determined, the other remote aerodromes frequently used by the operator were not associated with the same type of meteorological challenges. In addition, Norfolk Island and Christmas Island were specified as remote islands for the purposes of fuel planning requirements in Civil Aviation Order (CAO) 82.0 (see *Australian requirements for remote islands*), along with Lord Howe Island. The operator did not conduct any Westwind flights to Lord Howe Island.

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[413] The minimum time limit (1.75 hours) was selected so that all flights to Norfolk Island were included.

[414] This air ambulance flight occurred prior to the temporary ban on Pel-Air aircraft operating flights to Noumea. The aircraft diverted to Auckland rather than Noumea because Auckland was closer to the final destination for the task.

Table N1: Operator's Westwind flights to remote aerodromes classified by location and type of operation (2002–2009)

Remote aerodrome	Air ambulance	Freight	Other	Total
Norfolk Island	61	8	7	76
Christmas Island	15	1	36	52
Cocos Islands	1	0	3	4
Non-Australian aerodromes	30	8	15	53
Total	107	17	51	185

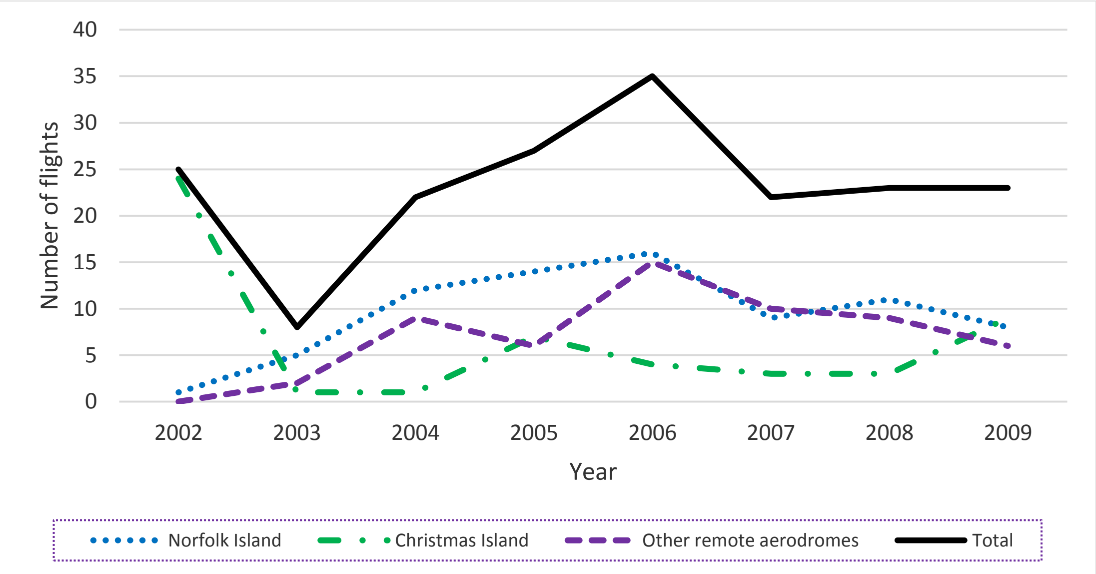
The most commonly used non-Australian remote aerodromes were:

- Honiara, Solomon Islands (26 flights)
- Nauru (5 flights)
- Niue (4 flights)
- Bonriki, Kiribati (4 flights)
- Hihifo, Territory of the Wallis and Futuna Islands (4 flights).

Most (107) of the 185 flights (58 per cent) were air ambulance flights, particularly to Norfolk Island (80 per cent).

Figure N1 shows the number of flights each year (up to 17 November 2009). The number of flights was fairly constant from 2004–2009, averaging about 25 flights per year. The number of flights to Norfolk Island was also fairly constant from 2004–2009, with about 12 flights a year. There was a relatively large number of flights to Christmas Island in 2002. Most (21) of these 24 flights were aerial work flights (with no passengers) for the same client.

Figure N1: Number of flights to remote aerodromes each year (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

Table N2 shows the distance to the nearest suitable alternate aerodrome for selected remote aerodromes. As indicated in the table, 85 flights (46 per cent) were conducted at night. Similarly, about half (51 per cent) of the flights to Norfolk Island were conducted at night.

Table N2: Remote aerodromes and their nearest alternate

Destination aerodrome	Alternate aerodrome	Distance to alternate	Day flights	Night flights	Total
Banana, Kiribati[415]	Hilo, Hawaii	1,068 NM	2	0	2
Cocos Islands	Jakarta, Indonesia	686 NM	2	2	4
Honiara, Solomon Islands	Luganville, Vanuatu	556 NM	0	26	26
Marshall Islands	Nauru	524 NM	0	1	1
Norfolk Island	Noumea, New Caledonia	431 NM	37	39	76
Various non-Australian	Various non-Australian	300–400 NM	14	3	17
Christmas Island	Jakarta, Indonesia	265 NM	42	10	52
Various non-Australian	Various non-Australian	240–250 NM	3	4	7
Total			100	85	185

In relation to the distances to the nearest suitable alternate aerodrome presented in Table N2:

- The nearest aerodrome to the Cocos Islands is Christmas Island (532 NM away). As Christmas Island was defined as a remote island in CAO 82.0, Jakarta, Indonesia was listed as the nearest suitable alternate aerodrome.
- The nearest suitable aerodrome to Honiara at night was Luganville, Vanuatu (556 NM away). There were 26 flights that landed at Honiara at night, which were therefore considered flights to a remote aerodrome. During the day other options were available, including Munda Airport, Solomon Islands (178 NM away). The operator conducted 27 flights to Honiara during the day, which were not considered flights to a remote aerodrome (see also *Semi-remote aerodromes*).

In terms of the departure aerodrome for the 76 flights to Norfolk Island, most (57) of the flights departed from Sydney and were relatively short (1.88–2.40 hours flight time). Norfolk Island was also regularly used as a refuelling stop for flights from Pacific Island countries back to Australia, including flights from Fiji (11 flights, 2.40–3.00 hours), Apia, Samoa (3 flights, 4.20–4.57 hours) Pago Pago, American Samoa (1 flight, 4.00 hours) and Tonga (1 flight, 3.00 hours). Other flights departed from Canberra and Adelaide.

In terms of the departure aerodrome for the 52 flights to Christmas Island:

- 24 departed from Broome (2.70–3.60 hours flight time)
- 13 departed from Darwin (3.60–4.03 hours)
- 8 departed from Perth (3.60–4.22 hours)
- 4 departed from Learmonth (2.20–2.42 hours).

Other flights departed from Albany, Karratha and Port Headland.

In addition to the 185 flights to a remote aerodrome in the selected sample:

- 6 flights to Christmas Island were excluded as they also departed from Christmas Island
- 3 flights to the Cocos Islands were excluded as they also departed from the Cocos Islands
- 11 flights were excluded as the flight time was less than 1.75 hours.

In addition to Westwind flights, the operator also conducted a small number of flights to remote aerodromes in other aircraft types. As far as could be determined, these were primarily ferry flights or transit flights for aerial work tasks, and they were not analysed further.

[415] These flights involved several long-distance legs. Such trips were generally crewed by the operator's most experienced pilots.

Fuel on board

Fuel on board flights to Norfolk Island

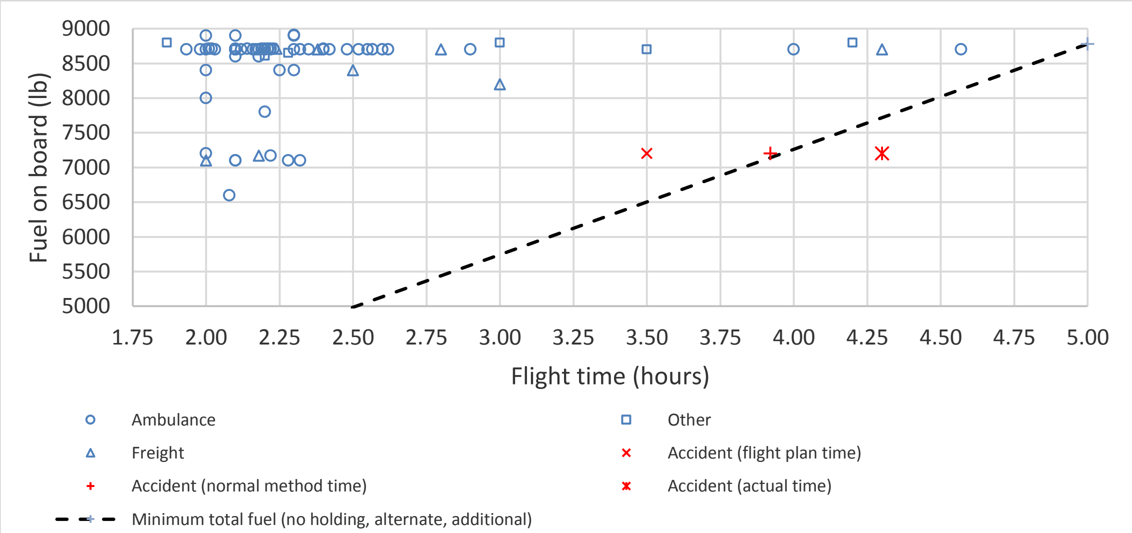
Most of the 76 flights to Norfolk Island departed with full fuel. More specifically:

- 60 departed with full fuel (1.87–4.57 hours flight time)
- 6 departed with 8,000–8,400 lb (2.00–3.00 hours)
- 1 departed with 7,800 lb (2.20 hours)
- 8 departed with full main tanks (2.00–2.30 hours)
- 1 departed with 6,600 lb (2.08 hours).[416]

Figure N2 shows the fuel on board and flight time of the 75 flights that landed at Norfolk Island, and compares these to the accident flight.[417] As can be seen in the figure:

- Both flights with a flight time of 4.25 hours or more departed with full fuel.
- All 3 flights with a flight time of 3.25–4.24 hours departed with full fuel.
- Most (3) of the 4 flights with a flight time of 2.75–3.24 hours departed with full fuel. The other flight was a 3.00-hour freight flight from Tonga during the day that departed with 8,200 lb.
- The longest flights that departed with full main tanks were 2 air ambulance flights of 2.30 hours from Sydney.

Figure N2: Fuel on board and flight time of the operator's Westwind flights to Norfolk Island (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

Fuel on board flights to Christmas Island

Almost all of the 52 flights to Christmas Island departed with full fuel. More specifically:

- 49 departed with full fuel (2.20–4.22 hours flight time)
- 2 departed with 8,000–8,100 lb (2.30–3.80 hours)
- 1 departed with 7,800 lb (2.80 hours).

Figure N3 shows the fuel on board and flight time of the 52 flights to Christmas Island, and compares these to the accident flight. As can be seen in the figure:

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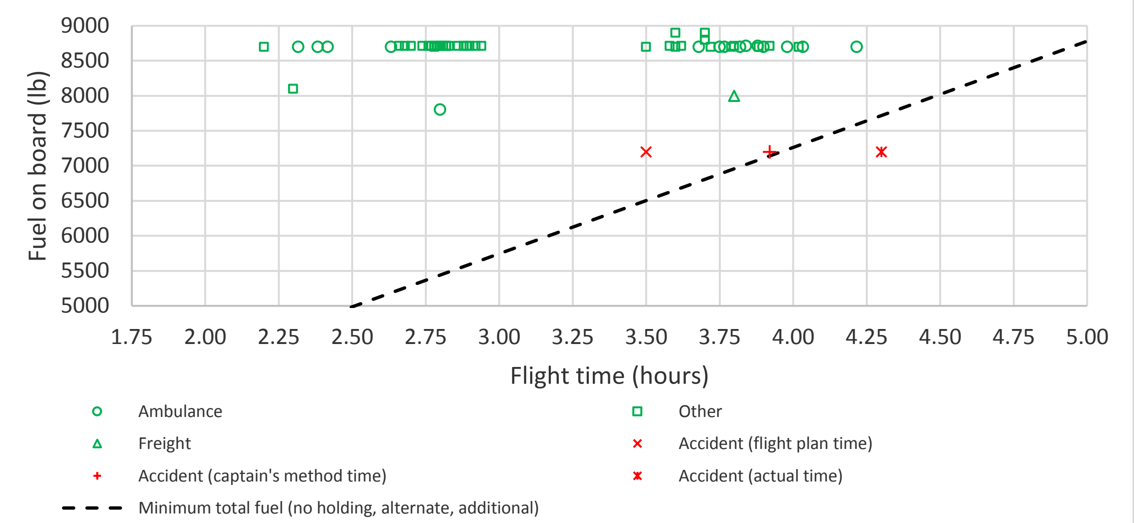
416 This flight was conducted with VH-NGA on 29 September 2009. At the time, the aircraft's fuel gauges were probably underreading by about 300 lb. It is therefore possible that this flight departed with full main tanks.

417 As the other flight did not land at Norfolk Island, its flight time to Norfolk Island is not known. However, as it departed from Sydney, it is likely to have had a flight time of 2.00-2.40 hours. This flight departed with full fuel.

- Almost all (23) of the 24 flights with a flight time of 3.25–4.24 hours departed with full fuel. The exception was a 3.80-hour freight flight during the day from Darwin that departed with 8,000 lb.
- Almost all (17) of the 18 flights with a flight time of 2.75–3.24 hours departed with full fuel. The exception was a 2.80-hour air ambulance flight at night from Broome that departed with 7,800 lb.

Figure N3: Fuel on board and flight time of the operator's Westwind flights to Christmas Island (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

Fuel on board flights to other remote aerodromes

Of the 57 flights to other remote aerodromes:

- 49 departed with full fuel (1.80–4.77 hours flight time)
- 4 departed with 8,000–8,200 lb (1.85–3.00 hours)
- 3 departed with 7,400–7,600 lb (1.80–3.00 hours)
- 1 departed with 6,800 lb (2.50 hours).

Figure N4 shows the fuel on board and flight time of the 57 flights to other remote aerodromes, and compares these to the accident flight. As can be seen in the figure:

- All 7 flights with a flight time of 4.25 hours or more departed with full fuel.
- All 21 flights with a flight time of 3.25–4.24 hours departed with full fuel.
- Most (13) of the 16 flights with a flight time of 2.75–3.24 hours departed with full fuel. The three exceptions were:
  - a 3.00-hour freight flight at night from Brisbane to Honiara that departed with 8,200 lb
  - a 2.80-hour freight flight at night from Brisbane to Honiara that departed with 8,000 lb
  - a 3.00-hour charter flight at night from Learmonth to the Cocos Islands that departed with 7,400 lb of fuel and carried passengers and freight (and it may have departed with as much fuel as possible).[418]
- The longest flight that departed with full main tanks or less was a 2.50-hour charter flight at night from Bonriki, Kiribati to Honiara that departed with 6,800 lb (just less than full main tanks).

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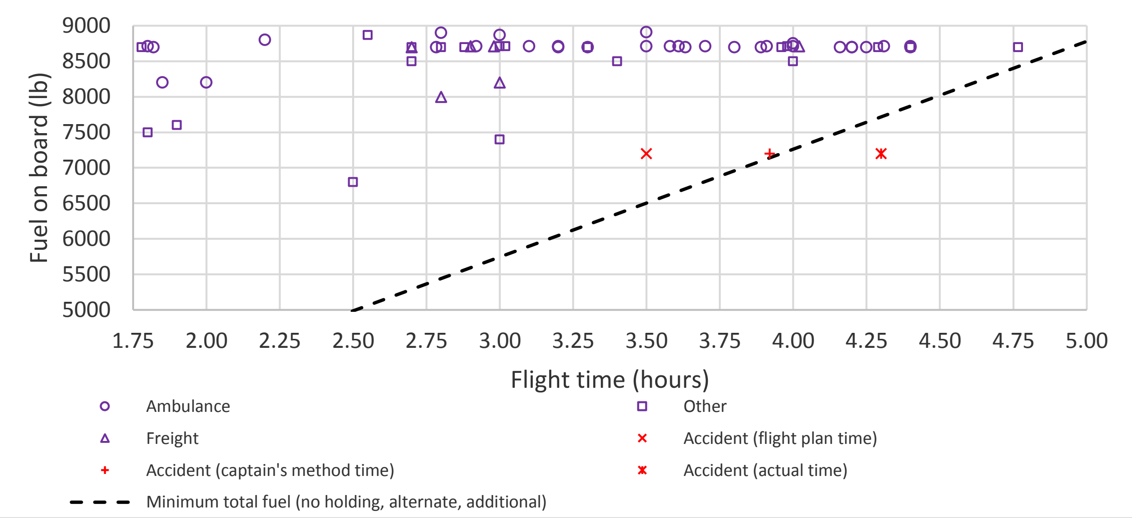
[418] This flight was conducted in a Westwind 1124, so 7,400 lb equated to full main tanks plus 300 lb. The two previous flights in this trip were conducted from Sydney to Alice Springs, and Alice Springs to Learmonth. Both departed with full main tanks.

Figure N4: Fuel on board and flight time of the operator's Westwind flights to other remote aerodromes (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

Other aspects of fuel on board for flights to remote aerodromes

The operator conducted 68 of the 185 flights to remote aerodromes in 2007–2009. Of these, 59 (87 per cent) departed with full fuel and 5 (7 per cent) departed with full main tanks or less. All 21 flights with a flight time of 3.25–4.24 hours departed with full fuel. Similarly, all 6 flights with a flight time of 2.75–3.24 hours departed with full fuel. In summary, all 27 flights to a remote aerodrome during 2007–2009 with a flight time of 2.75–4.24 hours departed with full fuel.

For the 107 air ambulance flights to all remote aerodromes during 2002–2009:

- All 5 flights with a flight time of 4.25 hours or more departed with full fuel.
- All 26 flights with a flight time of 3.25–4.24 departed with full fuel.
- Almost all (8) of the 9 flights with a flight time of 2.75–3.24 hours departed with full fuel. The exception was the 2.80-hour flight from Broome to Christmas Island that departed with 7,800 lb.
- All 14 flights with a flight time of 2.32–2.74 hours departed with full fuel.
- The longest flight that departed with full main tanks was a 2.30-hour flight from Sydney to Norfolk Island.

Most (140) of the 185 flights to remote aerodromes departed from an Australian mainland aerodrome. There was no apparent difference in the amount of fuel on board for those flights departing from an Australian mainland aerodrome versus those departing from a remote aerodrome and/or non-Australian aerodrome. For example, for flights of 2.50–4.24 hours:

- Seventy-two flights departed from an Australian mainland aerodrome. Most (67) departed with full fuel. The exceptions included three freight flights that departed with 8,000–8,200 lb, the 3.00-hour charter flight to the Cocos Islands that departed with 7,400 lb and the 2.80-hour air ambulance flight to Christmas Island that departed with 7,800 lb.
- Twenty-nine flights departed from a remote aerodrome and/or non-Australian aerodrome. Almost all (28) departed with full fuel, with the exception being a 3.00-hour freight flight from Brisbane to Honiara that departed with 8,200 lb. The 28 flights that departed with full fuel included 11 flights to Norfolk Island.

Potential discretionary fuel on flights to remote aerodromes

For most of the flights to remote aerodromes, there was insufficient information available to determine the fuel planning requirements and therefore how much of the total fuel on board was discretionary fuel. Nevertheless, for indicative purposes, the ATSB estimated the minimum total fuel for a normal operation based on the recorded flight time. This estimate used the operator's 23 lb/minute method and included variable reserve, fixed reserve and taxi fuel, but did not include alternate, holding or additional fuel required for aircraft system failures.[419]

Figures N2, N3 and N4 show the estimated minimum total fuel for a normal operation, depicted by a dashed line. The distance above the line provides an indication of the potential amount of discretionary fuel (assuming no requirements for alternate, holding or additional fuel for aircraft system failures).

As discussed in appendix M, for a flight of 3.50 hours (the captain's submitted flight plan time), a fuel load of full main tanks (7,200 lb) had about 700 lb more fuel than the minimum total fuel required for a normal operation. For a flight time of 4.00 hours (the time obtained using the captain's normal method), a fuel load of full main tanks had little if any excess fuel than that required for a normal operation. The captain indicated that he thought he had about 200–300 lb of excess fuel for the accident flight.

As can be seen in the figures, almost all the flights to remote aerodromes had a substantial amount of excess fuel for a normal operation that could be used if required for alternate fuel, holding fuel or additional fuel for aircraft system failures. More specifically:

- Almost all (182) of the 184 flights (99 per cent) that landed at a remote aerodrome had more than 600 lb of excess fuel, and most (176 or 96 per cent) had more than 1,000 lb of excess fuel.
- All 27 flights that departed with less than full fuel had more than 1,000 lb of excess fuel (with 25 flights having at least 1,800 lb of excess fuel).
- All 10 flights that departed with full main tanks or less had more than 1,800 lb of excess fuel.
- All 48 flights with a flight time of 3.25–4.24 hours had more than 1,000 lb of excess fuel.

Using the operator's 23 lb/minute method, flights with a flight time of 4.30 hours or more will necessarily have less than 1,000 lb of excess fuel, even if they departed with full fuel. There were 8 flights to remote aerodromes with a flight time of 4.30–4.77 hours, which therefore had less than 1,000 lb of excess fuel. If the operator's hour-by-hour method was used, or the flight was planned using long-range cruise settings, the amount of excess fuel for these longer flights would have been larger. It is also likely that some of these very long flights had actual flight times that were longer than the planned times, and therefore the amount of excess fuel at the time of planning was probably larger.

The two flights with the lowest amount of excess fuel were:

- A 4.77-hour flight from Perth to the Cocos Islands during the day departed with full fuel and had 270 lb of excess fuel. This very long flight was a positioning flight for an aerial work (search) task.
- A 4.57-hour air ambulance flight from Apia to Norfolk Island at night departed with full fuel and had 570 lb of excess fuel. It is likely that this flight took longer than originally planned, and therefore the amount of excess fuel at the time of planning was probably larger. Further details of this flight are provided in *30 September 2009 flight from Apia to Norfolk Island* and appendix O.

For the 106 air ambulance flights that landed at a remote aerodrome:

- Except for 3 very long flights that departed with full fuel, all the flights had more than 1,000 lb of excess fuel.
- The 15 flights that departed with less than full fuel all had more than 2,250 lb of excess fuel.
- The 7 flights that departed with full main tanks all had more than 2,250 lb of excess fuel.

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419 The estimate of the total fuel required included 23 lb/minute, 400 lb for climb, 10 per cent variable reserve, 600 lb fixed reserve and 150 lb for taxi. The operator's 23 lb/minute method provided slightly higher estimates of the total fuel required, and lower estimates of the supplementary fuel, than the operator's hour-by-hour method.

Regarding the extent to which the excess fuel for the flights to remote aerodromes was discretionary fuel:

- In most cases there were probably no weather-related requirements to carry alternate or holding fuel. [420]
- For some of the flights, there would have been a requirement for additional fuel to allow for aircraft system failures. However, the amount required in most cases would probably have been much less than the amount of excess fuel available.
- The actual flight time may have been more than the planned flight time for many reasons, such as holding, missed approach or other unexpected delay encountered during flight.

Capacity for a diversion after a missed approach

Method

For most of the operator's flights to a remote aerodrome, there was no requirement to carry alternate or holding fuel. Nevertheless, the ATSB examined the capacity of flights to a remote aerodrome be able to divert after conducting a missed approach at the destination aerodrome in order to provide an indication of the amount of fuel that was generally carried for contingencies and for discretionary purposes. Such an examination also helped establish the proportion of flights to remote aerodromes that passed a point of no return (PNR) for normal operations prior to reaching the destination aerodrome.

For simplicity, the flight fuel required for a diversion from the remote aerodrome to the nearest suitable alternate aerodrome was initially estimated using a block speed of 380 kt, a fuel flow of 1,200 lb/hour and an additional allowance of 400 lb for the climb. The total fuel required was calculated by adding 10 per cent of the flight fuel (variable reserve) and adding 600 lb (fixed reserve).

These figures were considered to be a reasonable estimate of the fuel required for a Westwind 1124 in a nil-wind situation in an aircraft with a relatively-low weight.[421] They exceeded the figures estimated using the aircraft manufacturer's Operational Planning Manual (OPM) for each aircraft type by about 200 lb.[422]

Based on the estimated total diversion fuel, the flights were classified as:

- 'able to divert' if the recorded fuel remaining minus the estimated total diversion fuel had a margin of more than 200 lb
- 'unable to divert' if the margin was less than -200 lb
- 'potentially unable to divert' if the margin was between -200 lb and 200 lb.

For flights classified as potentially unable to divert, the ATSB obtained additional information and conducted a more detailed assessment of whether the flight could have diverted after a missed approach.

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420 The ATSB examined the weather forecasts for a sample of the flights to remote aerodromes. Most of the forecasts indicated no weather-related requirement for alternate or holding fuel.

421 The method of calculating the total diversion fuel did not include a specific allowance for an approach at the alternate aerodrome. However, it also did not consider the reduced fuel flow that occurs during descent, and the recorded fuel remaining also included a small amount of fuel burned after when a missed approach would have occurred.

422 Each OPM included diversion/short range charts to readily determine the fuel required for a diversion for different landing weights. The manual's figures assumed that the diversion was conducted at long-range cruise settings. The ATSB review used the chart for a landing weight of 15,000 lb for the Westwind 1124, and 16,000 lb for the Westwind 1124A. These were the highest landing weights in each OPM with an available chart.

Capacity for a diversion for flights to Norfolk Island

As indicated in Table N2, the closest suitable aerodrome to Norfolk Island for a diversion is Noumea. The total diversion fuel required was estimated to be 2,430 lb. This figure was slightly higher than the figures based on the OPM (2,250 lb) and the figure the operator provided to CASA during CASA's November 2009 special audit following the accident (2,363 lb).

For the 76 flights to Norfolk Island:

- 71 flights were classified as able to divert (all with a margin of at least 600 lb)
- 3 flights were classified as unable to divert
- 2 flights were initially classified as potentially unable to divert.

Both of the flights initially classified as potentially unable to divert were freight flights that had 2,600 lb remaining after engine shutdown. Further analysis of these flights, including a review of forecast winds and temperatures, indicated they both probably had sufficient fuel to conduct a missed approach and then divert with the required fuel reserves.

In summary, there were 3 flights to Norfolk Island that did not have sufficient fuel to conduct a missed approach and then divert with the required fuel reserves. Basic details of these flights are provided in Table N3, and further details are provided in appendix O.

Table N3: Flights that were unable to divert after a missed approach at Norfolk Island

Date	Departure aerodrome	Type	Flight time (hours)	Fuel on board	Fuel remaining	Day / night
Jan 2004	Pago Pago	Ambulance	4.00	8,700 lb	2,000 lb	Day
Sep 2009	Apia	Ambulance	4.57	8,700 lb	1,500 lb*	Night
Oct 2009	Apia	Passenger	4.20	8,800 lb	1,800 lb	Night

* This may have been 1,800 lb (see main text).

Analysis of the 3 flights indicated:

- None of the flights had a weather-related operational requirement to carry alternate or holding fuel. However, the October 2009 flight was a passenger-carrying charter flight to a remote island, and therefore in accordance with CAO 82.0 it was required to carry alternate fuel.
- All of the flights departed with full fuel.
- All of the flights departed with sufficient fuel to allow for an aircraft system failure.
- Two of the flights had sufficient fuel to divert from the top of descent and land at Noumea with the required fuel reserves. The other flight (30 September 2009 flight from Apia) had a recorded fuel remaining after engine shutdown at Norfolk Island of 1,500 lb. This flight was conducted in VH-NGA. At the time of the flight, the aircraft's fuel quantity gauges were probably underreading by about 300 lb (see appendix F). Accordingly, the aircraft probably had about 1,800 lb remaining at engine shutdown, which would have meant it had sufficient fuel to divert from the top of descent.
- For all flights, the actual conditions were better than the alternate minima throughout the flight.

Capacity for a diversion for flights to Christmas Island

As indicated in Table N2, the closest suitable aerodrome to Christmas Island for a diversion is Jakarta, Indonesia. The total diversion fuel required was estimated to be 1,854 lb. This figure was slightly higher than the figures based on the OPM (1,755 lb) and similar to the figure the operator provided to CASA during the November 2009 special audit (1,842 lb).

For the 52 flights to Christmas Island:

- 50 were classified as able to divert
- 0 were classified as unable to divert

- 2 were initially classified as potentially unable to divert.

Both of the flights initially classified as potentially unable to divert were conducted in 2005 and both had 2,000 lb of fuel remaining after engine shutdown. One of the flights was an air ambulance flight, and the other flight was an aerial work flight without any passengers. Further analysis, including a review of the forecast winds and temperatures, indicated both of the flights probably had sufficient fuel to divert following a missed approach.[423]

Capacity for a diversion for flights to other remote aerodromes

For the 57 flights to other remote aerodromes:

- 30 were classified as able to divert
- 22 were classified as unable to divert
- 5 were initially classified as potentially unable to divert.

The 5 flights initially classified as potentially unable to divert were analysed further, and this analysis included a review of the forecast winds and temperatures. One of the flights was subsequently classified as unable to divert and the other 4 flights were classified as able to divert.

Therefore, 23 of the 57 flights were ultimately classified as unable to divert. For these 23 flights, almost all (22) departed with full fuel. The other flight was the 3.00-hour charter flight from Learmonth to the Cocos Islands that departed with 7,400 lb, which may have been as much fuel as possible.

The 23 flights classified as unable to divert included:

- 14 of the 26 flights to Honiara
- 4 flights to the Cocos Islands
- 2 flights to Banana, Kiribati
- 2 flights to the Marshall Islands
- 1 flight to Chuuk, Federated States of Micronesia.

The forecast and/or actual weather conditions were obtained for most of the flights that were unable to divert. In each case the conditions were better than the alternate minima.

All of the 23 flights that were unable to divert were to an aerodrome that had a single runway. All of these flights were international operations, except 3 of the 4 flights to the Cocos Islands. As discussed in *Other requirements for an alternate aerodrome*, the operator's OM implicitly required that international operations had sufficient fuel to divert unless they were conducted to an aerodrome with two separate runways.

Capacity for holding at the destination aerodrome

The ATSB also examined the fuel remaining to determine the capacity for holding after arriving at the destination aerodrome. As outlined in appendix M, the following figures were used:

- 600 lb equated to the fixed fuel reserve of 30 minutes
- 1,200 lb equated to at least 30 minutes holding plus the fixed fuel reserve
- 1,800 lb equated to at least 60 minutes holding plus the fixed fuel reserve
- 2,400 lb equated to at least 90 minutes holding plus the fixed fuel reserve.

If the holding was conducted at cruise levels rather than 1,500 ft, the capacity to hold would have been significantly increased.

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[423] For the aerial work flight, the calculations resulted in the flight having about 50 lb less than the required fuel to divert with a fixed reserve of 600 lb and the variable reserve. The calculations assumed the flight was conducted at FL 280 and followed the standard arrival into Jakarta. Given that a fixed reserve of 500 lb could have been used, and/or potentially a more favourable flight level obtained, the flight was classified as probably able to divert.

Table N4 shows the fuel remaining after engine shutdown for the 184 flights than landed at a remote aerodrome, classified by flight time.

Table N4: Fuel remaining for flights to remote aerodromes

Flight time	Number of flights with fuel amount remaining				Total flights	Average fuel remaining
	600–1,100 lb	1,200–1,700 lb	1,800–2,300 lb	2,400+ lb		
4.50+ hours		1	1		2	1,460 lb
4.25–4.49 hours		1	4	2	7	2,071 lb
3.75–4.24 hours			19	10	29	2,293 lb
3.25–3.74 hours			5	14	19	2,720 lb
2.75–3.24 hours				38	38	3,856 lb
2.25–2.74 hours				35	35	4,277 lb
1.75–2.24 hours				54	54	4,869 lb
Total	0	2	29	153	184	2,963 lb

As indicated in the table, most of the flights had a significant amount of fuel remaining. More specifically:

- Most of the 184 flights (153, or 83 per cent) had at least 2,400 lb remaining and almost all (182, or 99 per cent) had at least 1,800 lb remaining. None of the flights had less than 1,500 lb remaining.
- All 27 flights that departed with less than full fuel had at least 2,400 lb of fuel remaining (with 26 flights having at least 2,900 lb remaining).
- All 10 flights that departed with full main tanks or less had at least 2,900 lb of fuel remaining.
- All 48 flights with a flight time of 3.25–4.24 hours had at least 1,800 lb of fuel remaining.

Figure N5 shows the fuel on board prior to engine start and the fuel remaining after engine shutdown for the 26 flights to remote aerodromes that were classified as unable to conduct a missed approach and then divert. It also compares these flights to the accident flight in terms of the:

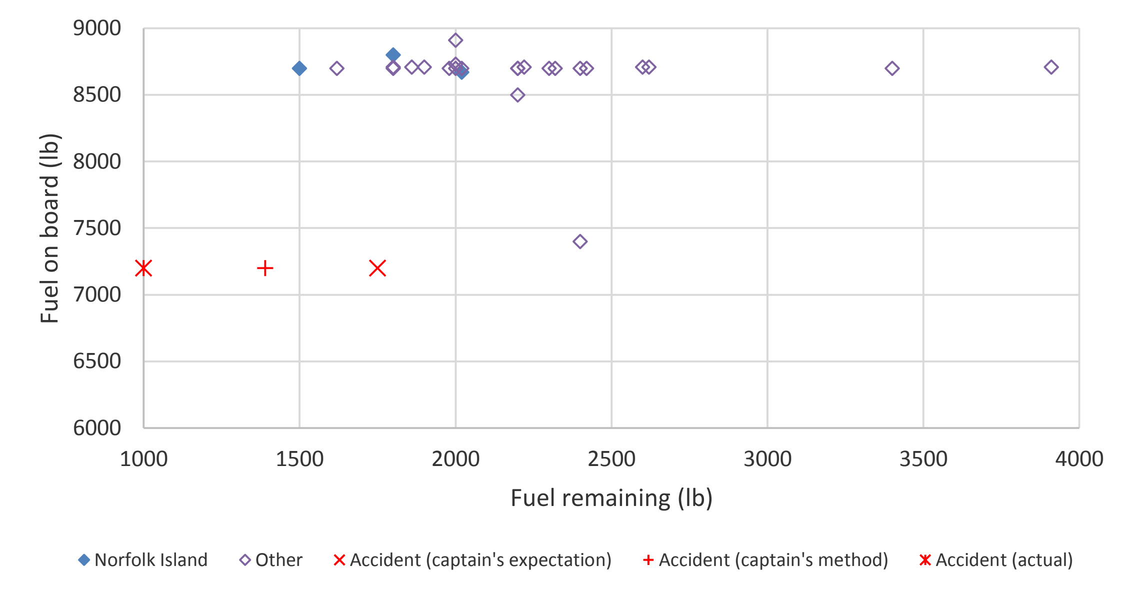
- the captain's initial recollection of what he expected to have remaining (1,700–1,800 lb)
- the estimated fuel remaining based on using the captain's normal fuel planning method (1,390 lb)
- the estimated fuel on board during the accident flight if the first approach was successful (1,000 lb).

As can be seen in the figure, almost all (25) of the 26 flights departed with full fuel. For these 25 flights:

- Six flights had 2,400 lb or more fuel remaining after engine shutdown (at least 90 minutes holding plus the fixed reserve).
- Six flights had 2,100–2,300 lb of fuel remaining after engine shutdown (at least 75 minutes holding plus the fixed reserve).
- Eleven flights had 1,800–2,000 lb of fuel remaining after engine shutdown (at least 60 minutes holding plus the fixed reserve).
- One flight had 1,600 lb of fuel remaining (at least 45 minutes holding plus the fixed reserve). This was a charter flight to the Cocos Islands that carried no passengers or freight. It landed at night, and the forecast and actual weather conditions were significantly better than the alternate minima.
- One flight had 1,500 lb of fuel remaining (at least 45 minutes holding plus fixed reserve). This was the 4.57-hour air ambulance flight from Apia to Norfolk Island. This flight was conducted in VH-NGA on 30 September 2009. The fuel quantity gauges were probably underreading by about

300 lb at the time, and therefore the aircraft may have had 1,800 lb of fuel remaining after engine shutdown. The forecast and actual conditions were better than the alternate minima.

Figure N5: Fuel on board and fuel remaining after engine shutdown for the 26 flights to remote aerodromes where the fuel remaining was insufficient to divert (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

The flight that did not depart with full fuel was the charter flight to the Cocos Islands that departed with 7,400 lb and had 2,400 lb of fuel remaining. As noted above, this 3.00-hour flight from Learmonth carried passengers and freight and may have departed with as much fuel as possible. The flight landed at night about 30 minutes prior to civil twilight, and therefore the crew would have encountered daytime conditions if they were required to hold due to an airport lighting problem. The forecast conditions were better than the alternate minima and the actual conditions were significantly better than the alternate minima.

Semi-remote aerodromes

Overview

In addition to remote aerodromes, the ATSB also examined flights to ‘semi-remote aerodromes’. These were defined for Westwind 1124/1124A aircraft as a destination aerodrome where there was no suitable alternate aerodrome available for normal operations within 240 NM. The review considered a suitable alternate aerodrome for normal operations to be one that had:

- an instrument approach procedure
- a sealed runway with a length suitable for a Westwind landing and a subsequent take-off with a normal fuel load
- runway lighting available (if the landing was conducted at night)
- available fuel
- suitable customs and immigration facilities with no significant advance notice required (for non-Australian aerodromes).

In other words, the semi-remote aerodromes were similar to the remote aerodromes, except that for the semi-remote aerodromes there was an alternate aerodrome(s) available within 240 NM that could be used for an emergency landing. However, these alternate aerodromes were not suitable for normal, commercial operations.

The selected data set contained 199 flights that landed at a semi-remote aerodrome with a flight time of at least 1.75 hours and a flight distance of at least 600 NM. The 199 flights included:

- 182 flights to Noumea[424]
- 8 flights to Makassar, Indonesia
- 6 flights to Rarotonga, Cook Islands
- 2 flights to Malé, in the Maldives
- 1 flight to Manado, Indonesia.

Fuel on board flights to semi-remote aerodromes

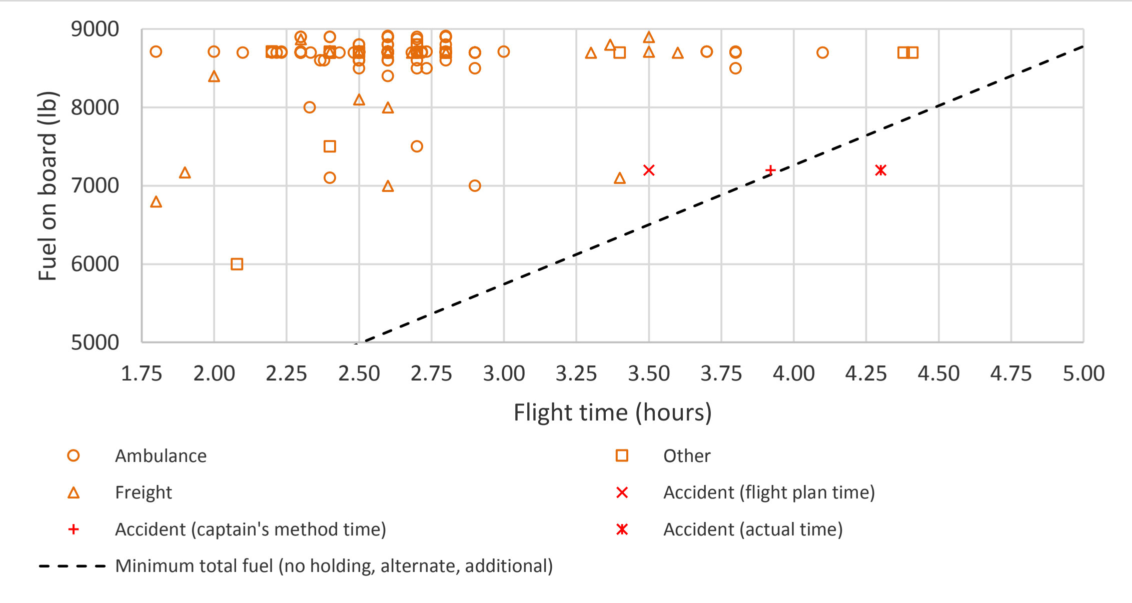
Most of the operator's 199 flights semi-remote aerodromes departed with full fuel. More specifically:

- 185 departed with full fuel (1.80–4.40 hours flight time)
- 5 departed with 8,000–8,400 lb (2.00–2.60 hours)
- 2 departed with 7,500 lb (2.40–2.70 hours)
- 5 departed with full main tanks (1.90–3.40 hours)
- 1 departed with 6,800 lb (1.80 hours) and 1 departed with 6,000 lb (2.08 hours).

Figure N6 shows the fuel on board and flight time of the 199 flights that landed at a semi-remote aerodrome, and compares these to the accident flight. As can be seen in the figure:

- Both flights with a flight time of 4.25 hours or more departed with full fuel.
- Almost all (12) of the 13 flights with a flight time of 3.25–4.24 hours departed with full fuel. The other flight was a 3.40-hour freight flight from Hihifo to Noumea during the day that departed with full main tanks.
- Almost all (18) of the 19 flights with a flight time of 2.75–3.24 hours departed with full fuel. The other flight was a 2.90-hour air ambulance flight during the day from Singapore to Makassar that departed with full main tanks.

Figure N6: Fuel on board and flight time of the operator's Westwind flights to semi-remote aerodromes (2002–2009)



Source: ATSB, derived from data provided by Pel-Air Aviation.

[424] The nearest suitable alternate aerodrome to La Tontouta Airport in Noumea for normal operations was Port Vila, Vanuatu (285 NM away). However, Noumea Magenta Airport was located 21 NM south-east of La Tontouta. Although not suitable for normal commercial operations for a Westwind 1124/1124A aircraft, Magenta was suitable for use in an emergency.

As discussed in *Overview of flights to remote aerodromes*, the operator conducted 27 flights to Honiara during the day. These flights were not considered flights to a semi-remote aerodrome, as a suitable aerodrome (Munda) was available within 240 NM. Nevertheless, these flights appeared to be similar to other flights to remote or semi-remote aerodromes. Most of the flights (22) departed with full fuel. The remaining flights including 2 freight flights that departed with as much fuel as possible (3.10–3.80 hours) and three other flights (1.80–2.70 hours).

Capacity for a diversion and/or holding

All 182 flights to Noumea had sufficient fuel to conduct a missed approach and then divert to Port Vila. For the 17 flights to other semi-remote aerodromes:

- 8 were classified as able to divert
- 5 were classified as unable to divert
- 4 were classified as potentially unable to divert.

The 5 flights classified as unable to divert all departed with full fuel. They included:

- Two charter flights to Malé landed during the day and had 1,200 lb of fuel remaining after engine shutdown (at least 30 minutes holding plus fixed reserve). These flights were planned well in advance and had a very experienced flight crew on board, and one of the flights carried no passengers. In addition, the airport had an ILS instrument approach.
- Three air ambulance flight to Rarotonga landed during the day and had 2,400 to 2,800 lb of fuel remaining after engine shutdown (at least 90 minutes holding plus fixed reserve).

The 4 flights classified as potentially unable to divert included:

- Three flights to Rarotonga departed with full fuel and had 2,900–3,000 lb of fuel remaining after engine shutdown. These flights were not analysed further, but it was considered likely that at least some would have been able to conduct a missed approach and then divert to a suitable aerodrome. The flights included 2 air ambulance flights and 1 charter flight.
- One air ambulance flight to Makassar during the day departed with 7,000 lb and had 2,400 lb of fuel remaining after engine shutdown. Further analysis of this flight indicated it had sufficient fuel to conduct an approach and divert to the nearest suitable aerodrome for normal operations.

As noted above, all of the flights to a semi-remote aerodrome had other aerodromes available closer to the suitable alternate aerodrome that could have been used to conduct an emergency landing if required.

Most of the flights had a significant amount of fuel remaining. More specifically:

- Most of the 184 flights (196, or 98 per cent) had at least 2,400 lb of fuel remaining.
- Almost all (13) of the 14 flights that departed with less than full fuel had at least 2,400 lb of fuel remaining. The exception was the 3.40-hour freight flight to Noumea, which departed with full main tanks and had 2,000 lb remaining.

Flights involving the captain of the accident flight

The captain conducted 9 flights to remote aerodromes. These included:

- 3 flights from Sydney to Norfolk Island (2.08–2.35 hours)
- 1 flight from Apia to Norfolk Island (4.57 hours)
- 2 flights from Perth to Christmas Island (3.75–3.77 hours)
- 1 flight from Darwin to Christmas Island (3.90 hours)
- 1 flight from Sydney to Honiara (4.25 hours)
- 1 flight from Port Vila, Vanuatu to Funafuti, Tuvalu (2.20 hours).

With regard to these flights:

- All the flights were air ambulance operations.
- Six flights were conducted at night (including the 4 flights to Norfolk Island, 1 flight to Christmas Island and 1 flight to Honiara).
- Eight of the flights were conducted as captain. The flight from Darwin to Christmas Island was conducted as a first officer.
- Almost all (8) flights departed with full fuel. A 2.08-hour flight from Sydney to Norfolk Island on 29 September 2009 departed with 6,600 lb.
- Seven flights had sufficient fuel to conduct a missed approach and then divert to an alternate aerodrome. The other flights were:
  - an April 2009 flight from Sydney to Honiara that departed with full fuel and had 2,400 lb remaining after engine shutdown
  - the 30 September 2009 flight from Apia to Norfolk Island that departed with full fuel and had 1,500 lb remaining after engine shutdown.

The captain also conducted 12 flights to semi-remote aerodromes. These included:

- 11 flights from Sydney to Noumea (2.40–2.72 hours), including 8 flights as captain and 3 flights as a first officer. All of these flights departed with full fuel and all had sufficient fuel remaining to conduct a missed approach and divert to a suitable alternate aerodrome.
- 1 flight from Auckland to Rarotonga (3.80 hours) as a first officer. This flight departed with full fuel and had 2,800 lb remaining after engine shutdown, which may have been sufficient fuel to conduct a missed approach and divert to a suitable alternate aerodrome.

Flights involving the first officer of the accident flight

The first officer conducted 5 previous flights to remote aerodromes. These included:

- 3 flights from Sydney to Norfolk Island (2.10–2.35 hours)
- 1 flight from Sydney to Honiara (4.25 hours)
- 1 flight from Port Vila to Funafuti (2.20 hours).

With regard to these flights:

- All the flights were air ambulance operations.
- Four flights were conducted at night (including the 3 flights to Norfolk Island and the flight to Honiara).
- Four flights were conducted with the captain of the accident flight (including 2 flights to Norfolk Island, the flight to Honiara and the flight to Funafuti).
- All flights departed with full fuel.
- Four flights had sufficient fuel to conduct a missed approach and then divert to an alternate aerodrome. The other flight was the April 2009 flight from Sydney to Honiara that departed with full fuel and had 2,400 lb remaining after engine shutdown.

The first officer also conducted 6 flights to semi-remote aerodromes. These included:

- 5 flights from Sydney to Noumea (2.00–3.80 hours). All of these flights departed with full fuel and all had sufficient fuel to conduct a missed approach and divert to a suitable alternate aerodrome.
- 1 flight to Rarotonga. This flight departed with full fuel and had 2,400 lb remaining after engine shutdown, which was insufficient fuel to conduct a missed approach and divert to a suitable alternate aerodrome.

Summary

None of the operator's previous 185 Westwind flights to remote aerodromes were similar to the accident flight in terms of the fuel on board and flight time (that is, a passenger-carrying flight at night to a remote aerodrome that departed with only full main tanks for a planned flight of 3.50–4.00 hours). More specifically, none of the flights over 2.50 hours departed with full main tanks, and none of the non-freight flights over 3.00 hours departed with less than full fuel. Similar results were obtained for 199 flights to semi-remote aerodromes.

Twenty-six of the 185 flights to remote aerodromes did not arrive at the destination aerodrome with sufficient fuel to conduct a missed approach and then divert to a suitable alternate aerodrome. Almost all (25) of these flights departed with full fuel. The other flight may also have departed with as much fuel as possible, and it had 2,400 lb remaining after engine shutdown, which was more than sufficient fuel for over 90 minutes holding (excluding the fixed reserve).

If he used his normal flight planning method for the accident flight, and departed with full main tanks, the captain should have expected to land at Norfolk Island with about 1,400 lb remaining. Only two of the 26 previous flights that were unable to divert had less than 1,800 lb of fuel remaining after engine shutdown. In both cases the flights departed with full fuel.

Appendix O – Review of Westwind flights from Samoa/American Samoa to Norfolk Island

Overview

The operator conducted 3 previous flights in Westwind 1124/1124A aircraft to Norfolk Island during 2002–2009 that departed from Apia, Samoa and 1 flight that departed from nearby Pago Pago, American Samoa. These were the operator's 4 longest Westwind flights to Norfolk Island, with the flight time ranging from 4.00–4.57 hours. Table O1 summarises the details of the 4 flights. As noted in appendix N, 3 of the 4 flights did not have sufficient fuel to conduct a missed approach at Norfolk Island and then divert.

Table O1: Flights from Apia or Pago Pago to Norfolk Island

Date	Departure aerodrome	Type	Flight time (hours)	Fuel on board	Fuel remaining	Day / night
Jan 2004	Pago Pago	Ambulance	4.00	8,700 lb	2,000 lb	Day
Apr 2007	Apia	Freight	4.30	8,700 lb	2,600 lb	Night
Sep 2009	Apia	Ambulance	4.57	8,700 lb	1,500 lb*	Night
Oct 2009	Apia	Passenger	4.20	8,800 lb	1,800 lb	Night

* This may have been 1,800 lb (see main text).

January 2004 flight

During 20–21 January 2004, a Westwind 1124 conducted an air ambulance trip from Sydney to Pago Pago via Norfolk Island, and return to Sydney via Norfolk Island. Information associated with the flight from Pago Pago to Norfolk Island included:

- The aerodrome forecast (TAF) for Norfolk Island valid at the time of departure included scattered cloud at 3,000 ft, broken cloud at 4,000 ft and visibility at least 10 km. These conditions were better than the alternate minima.
- The flight departed with full fuel.
- At 90 minutes prior to landing, a METAR reported few cloud at 3,500 ft, broken cloud at 5,900 ft, visibility at least 10 km, and a temperature-dewpoint difference of 10°C. Subsequent METARs were similar or better.
- There was 2,000 lb remaining after engine shutdown at Norfolk Island.
- The en route wind and temperature conditions were not able to be obtained.

Based on the available information:

- There was no operational requirement to carry alternate or holding fuel.
- The aircraft probably had sufficient fuel to divert from the top of descent and land at Noumea with the required fuel reserves.
- It is very unlikely the aircraft had sufficient fuel to conduct a missed approach at Norfolk Island and divert to Noumea, New Caledonia with the required fuel reserves.
- The aircraft would have had sufficient fuel to hold at low altitude at Norfolk Island for over 60 minutes (excluding the fixed reserve) after conducting a missed approach.
- During the flight to Norfolk Island, the aircraft had sufficient fuel to allow for an aircraft system failure.

April 2007 flight

During 24–25 April 2007, a Westwind 1124 conducted a freight trip from Sydney to Tahiti, French Polynesia and return. The trip involved flights from Sydney to Tahiti via Noumea and Apia, and then return via Apia and Norfolk Island. Information associated with the flight from Apia to Norfolk Island included:

- The TAF for Norfolk Island included showers of rain, scattered cloud at 1,500 ft, broken cloud at 2,000 ft, and visibility at least 10 km. These conditions were better than the alternate minima.
- The flight departed Apia with full fuel and no freight.
- At 105 minutes prior to landing, a METAR reported scattered cloud at 1,100 ft, scattered cloud at 1,400 ft, visibility at least 10 km and a temperature-dewpoint difference of 1°C.
- At 68 minutes prior to landing, an amended TAF was issued, which included rain showers, broken cloud at 1,500 ft, broken cloud at 2,500 ft and visibility at least 10 km.
- At 45 minutes prior to landing, a SPECI was issued, which reported few cloud at 900 ft, broken cloud at 1,200 ft, visibility at least 10 km and a temperature-dewpoint difference of 1°C.
- At 15 minutes prior to landing, another SPECI was issued, which reported broken cloud at 900 ft and broken cloud at 1,200 ft, with the other conditions unchanged.
- There was 2,600 lb remaining after engine shutdown at Norfolk Island.
- One of the pilots recalled that the weather was marginal when they arrived at Norfolk Island, but they successfully landed off the first approach. He believed they had sufficient fuel to divert to Noumea if they required.

Based on the available information:

- There was no operational requirement to carry alternate or holding fuel when planning the flight. However, the observed weather conditions deteriorated to below the alternate minima about 15 minutes prior to landing. These conditions were still better than the landing minima.
- The aircraft had sufficient fuel to divert to conduct a missed approach and divert to Noumea with the required fuel reserves.
- The aircraft would have had sufficient fuel to hold at low altitude at Norfolk Island for over 90 minutes (excluding the fixed reserve) after conducting a missed approach.
- During the flight from Apia to Norfolk Island, the aircraft had sufficient fuel to allow for an aircraft system failure.

September 2009 flight

During 29–30 September 2009, a Westwind 1124A (VH-NGA) conducted an air ambulance trip from Sydney to Apia via Norfolk Island. Due to a tsunami warning at Apia, the aircraft had to fly from Apia to Nadi, Fiji before returning to Apia to pick up the patient, and then returning to Sydney via Norfolk Island. Information associated with the flight from Apia to Norfolk Island included:

- The captain of the 18 November 2009 accident flight was the captain.
- The TAF for Norfolk Island valid at the time of departure included showers of rain, scattered cloud at 1,500 ft, broken cloud at 3,500 ft and visibility at least 10 km. These conditions were better than the alternate minima.
- The flight departed Apia with full fuel.
- At 103 minutes prior to landing, a METAR reported scattered cloud at 5,300 ft, visibility at least 10 km and a temperature-dewpoint difference of 7°C. A METAR issued 43 minutes prior to landing provided similar information.
- The flight record indicated there was 1,500 lb remaining after engine shutdown at Norfolk Island. As noted in appendix F, VH-NGA's fuel quantity gauges in mid-September 2009 were probably underreading on average by about 300 lb. Therefore it is likely that the fuel remaining was about 1,800 lb.
- Both crew later recalled there was nothing unusual with the flight levels used, there were no problems encountered during the flight, and the weather conditions were fine when they landed at Norfolk Island.

Based on the available information:

- There was no operational requirement to carry alternate or holding fuel when planning the flight.
- The aircraft did not have sufficient fuel to conduct a missed approach at Norfolk Island and then divert to Noumea with the required fuel reserves.
- Based on the recorded fuel remaining after engine shutdown (1,500 lb), the aircraft did not have sufficient fuel to divert to Noumea from the top of descent, including a variable and fixed reserve. However, if the aircraft had 1,800 lb of fuel remaining at engine shutdown (that is about 2,100 lb at top of descent), it would have had sufficient fuel to divert from the top of descent.
- Based on the recorded fuel remaining, the aircraft had sufficient fuel to hold at low altitude at Norfolk Island for over 45 minutes (excluding the fixed reserve) after conducting an instrument approach and then a missed approach. However, if the aircraft had 1,800 lb of fuel remaining after engine shutdown, it would have had sufficient fuel for over 60 minutes holding (excluding the fixed reserve) after conducting a missed approach.
- During the flight from Apia to Norfolk Island, the aircraft had sufficient fuel to allow for an aircraft system failure.

October 2009 flight

On 30 September 2009, a Westwind 1124A conducted a passenger-carrying charter trip from Sydney to Apia via Norfolk Island. It then conducted a passenger-carrying charter flight from Apia to Sydney via Norfolk Island on 5 October 2009. Information associated with the flight from Apia to Norfolk Island included:

- The aircraft and crew had been in Apia for several days prior to the flight. The Westwind standards manager was the captain.
- The TAF for Norfolk Island valid at the time of departure included scattered cloud at 3,500 ft and visibility at least 10 km.
- The flight departed with full fuel.
- At 120 minutes prior to landing, a METAR reported scattered cloud at 3,500 ft, scattered cloud at 4,300 ft, overcast cloud at 6,000 ft, visibility at least 10 km and a temperature-dewpoint difference of 7°C.
- At 60 minutes prior to landing, a METAR reported overcast cloud at 5,800 ft, visibility at least 10 km and a temperature-dewpoint difference of 9°C.
- The flight landed at night.
- There was 1,800 lb remaining after shutdown at Norfolk Island.
- Both crew later recalled that there was nothing unusual with the flight levels used, there were no problems encountered during the flight, and the weather conditions were fine when they landed at Norfolk Island.

Based on the available information:

- There was no weather-related operational requirement to carry alternate or holding fuel when planning the flight. However, as the flight was a passenger-carrying charter flight to a remote island, CAO 82.0 required that the flight carried alternate fuel.
- Given the forecast winds, the flight could not be planned to fly from Apia to Norfolk Island, conduct a missed approach and then divert to Noumea with the required variable and fixed reserves.
- The aircraft had sufficient fuel to divert to Noumea from the top of descent, including variable and fixed reserves.
- The aircraft did not have sufficient fuel to conduct a missed approach at Norfolk Island and then divert to Noumea with the required fuel reserves.

- The aircraft had sufficient fuel to hold at low altitude at Norfolk Island for over 60 minutes (excluding the fixed reserve) after conducting a missed approach.
- During the flight from Apia to Norfolk Island, the aircraft had sufficient fuel to allow for an aircraft system failure.

When interviewed during the reopened investigation, the Westwind standards manager initially recalled that when the flight was planned it met the requirements of CAO 82.0. He said there was a significant delay while taxiing at Apia while the crew waited for an airways clearance as Auckland air traffic services could not locate its copy of the flight plan, which reduced the fuel on board at departure. The flight record showed that the time between starting to taxi and the take-off was 27 minutes, suggesting a fuel burn prior to take-off of about 270 lb, which was a little more than normal.

The standards manager also recalled that he would have planned the flight on the basis of in-flight replanning. However, even on the basis of in-flight re-planning from the top of descent, the flight could not be planned to fly to Norfolk Island, conduct a missed approach and then divert to Noumea with the required variable and fixed reserves.

Other trips involving flights to Apia

In addition to the 4 flights from Apia or Pago Pago to Norfolk Island, the operator conducted several other trips in Westwind aircraft that involved flights from Apia back to Australia. Five of these trips were conducted back via Auckland, and another was conducted back via Noumea (Table O2).

Table O2: Flights from Apia to other destinations

Date	Destination aerodrome	Type	Flight time (hours)	Fuel on board	Fuel remaining	Day / night
Jan 2005	Auckland	Ambulance	3.60	8,700 lb	2,000 lb	Day
Jan 2005	Auckland	Ambulance	4.00	8,700 lb	1,600 lb	Night
Feb 2005	Auckland	Ambulance	4.20	8,700 lb	2,000 lb	Day
May 2006	Auckland	Charter	4.50	8,700 lb	1,700 lb	Night
Oct 2008	Noumea	Ambulance	3.80	8,500 lb	2,700 lb	Night
Oct 2009	Auckland	Ambulance	4.77	8,700 lb	1,600 lb	Night

For both the January 2005 flights, the weather at Norfolk Island was below the landing minima, precluding the viable use of Norfolk Island as a refuelling stop. The first of these flights involved transporting a patient from Apia to Sydney, and the second involved transporting a patient from Apia to Melbourne.

For the October 2009 flight, the patient was transported from Apia to Auckland, and therefore the trip had no need to return via Norfolk Island.

For the other 3 flights, the reason why the aircraft returned via Auckland or Noumea could not be determined. The February 2005 and October 2008 air ambulance flights involved transporting a patient from Apia to Sydney, and the May 2006 charter flight appeared to be returning back empty to Sydney via Apia.

Appendix P – Safety trend indicator

Overview

From 2000, the Civil Aviation Safety Authority developed and used the safety trend indicator (STI) as part of its surveillance processes (see *Safety trend indicator (STI)*). Separate STI forms were developed for assessing an organisation with an air operator's certificate (AOC) and an organisation with a maintenance certificate of approval (COA).

The AOC STI form had four parts:

- inspection details (which asked for basic details such as the operator's name and the date the STI was completed)
- about the operator (which asked basic questions about the operator and its operations)
- questions and guidance (which asked 30 safety indicator questions, which required a 'yes', 'no' or 'don't know' response)
- additional comments (which allowed the inspector to provide additional information or explain particular answers).

The following sections provide the questions from the 'about the operator' and 'questions and guidance' sections.

About the operator

Question	Options
Is this form being filled out after you have been involved in a site visit to this organisation? (regardless of whether the visit was part of a scheduled CASA audit)	Yes No
When was the last scheduled CASA audit of this organisation? (do not count ramp checks)	Just completed prior to filling in this form Less than 3 months ago 3–6 months ago 6–12 months ago 12–18 months ago More than 18 months ago New organisation – no audits completed
Size of largest aircraft operated	Under 10 seats 10 to under 30 seats 30 to 100 seats 101 to 200 seats More than 200 seats
How many aircraft are routinely operated?	1 aircraft 2–3 aircraft 4–5 aircraft 6–10 aircraft 11–20 aircraft More than 20 aircraft
Primary type of aircraft operated	Fixed wing
Passenger carrying work as a percentage of total operations	Under 25% of total 26%–50% of total
Primary type of operations undertaken	HCRPT LCRPT

	Special category RPT General transport charter Closed transport charter Recreational charter / joyflight Flying training Cargo Aerial work with ‘participating passengers’ (e.g. Doctor, film crew) Aerial work with flight crew only
Age of oldest aircraft operated	Under 10 years old 10–20 years old 21–30 years old Over 30 years old
Overall judgement of the performance of this organisation relative to other organisations carrying out similar work(it is assumed that all organisations are operating at or above the minimum standard)	Much better Somewhat better About average Somewhat worse Much worse Don’t know/not sure
Overall judgement of the performance of this organisation compared to 12 months ago	Much better Somewhat better About the same Somewhat worse Much worse Don’t know/not sure

Questions and guidance (safety indicator questions)

1.	Is this a new start-up organisation i.e. has it been operating less than 12 months? (a name change should not be counted as restarting the clock if all or most other factors remain the same)
2.	Has the organisation been subject to takeover or change of ownership within the last 12 months?
3.	Have any of the key people had less than 12 months experience with this particular organisation? (any person able to influence policy, practice, procedure, or culture are 'key people' e.g. CP, CFI, Head of Check and Training, Fleet Manager etc)
4.	Has there been a significant change to organisational structure or areas of responsibility in the preceding 12 months?
5.	Are there indications the organisation is suffering financial stress?
6.	Has the organisation introduced new aircraft, new routes, or made significant changes to procedures or processes within the last 12 months?
7.	Has the operation been subject to significant expansion or contraction within the last 12 months? (i.e. staff members, numbers of aircraft serviced etc.)
8.	Have any safety alerts been issued to the organisation within the preceding 12 months?
9.	Has the organisation failed to satisfactorily acquit RCAs by the acquittal date in the last 12 months? (CASA may need to prompt for acquittal regularly, this may reflect poor administration, a poor attitude to safety etc.) - if no RCAs issued in last 12 months, refer to last time RCA issued
10.	Have any of the key people been counselled over the last 12 months?
11.	Has the organisation been subject to CASA initiated enforcement action within the past 12 months? (i.e. short term reissues/suspension/show cause/ restriction etc.)

12.	Within the last 12 months has the organisation been the subject of any adverse safety comment warranting further investigation?
13.	Within the last 12 months has the organisation been involved in a reported accident?
14.	Within the last 12 months has the organisation been involved in a reported incident for which the organisation was at least partially responsible?
15.	Does the organisation operate from more than one location without adequate procedures to ensure proper communication between sites?
16.	Taken as a whole, does the organisation operate under more difficult conditions than other operators? (e.g. hilly terrain, complex airspace structure, exposure to mixed operations, adverse climate etc)
17.	Does this organisation apply for an abnormally high number of PUS or special flight permits?
18.	Is the morale within the organisation low? (e.g. judged from talking to staff, presence of IR problems, CAIR reports, abnormal staff turnover etc.)
19.	Are the aircraft regularly utilised to the limit of their performance? (e.g. maximum range, maximum take off weight, maximum landing weight etc)
20.	Are most operational staff throughout the organisation putting in abnormally high levels of overtime or otherwise showing signs of fatigue/overwork?
21.	Do key operational people (eg Chief Pilot, CFI) appear to have the full confidence of his/her subordinates? (refers not only to their flying skills but also their integrity, leadership ability, interpersonal skills etc)
22.	Are the organisational policy processes and procedures well described in their documentation? (indicated by an appropriately comprehensive and detailed operational document set which defines procedures, responsibilities and processes for this particular organisation)
23.	Are the organisation's documented processes generally applied in practice? (e.g. staff are aware of the documented procedures and regularly refer to them, the documented procedures are updated and reflect what actually happens)
24.	Do senior management take an active and constructive role in decision making? (i.e. do not bypass middle management, take an active role in setting policy and strategies)
25.	Is aviation safety identifiable as a major organisational priority? (i.e. does not take second place to short term profit seeking, staff are not complacent about safety/feel that an accident could happen to them)
26.	Does the organisation have a mature, well functioning safety system? (i.e. presence of safety reporting, recording, and feedback systems, safety management adequately funded, management committed to improving safety, e.g. ATSB 'Indicate' program in use etc.)
27.	Does the organisation have a strong commitment to ongoing staff training? (i.e. of both flying and ground staff) (e.g. staff training courses are organised in company time, are compulsory and attendance is recorded)
28.	Does the organisation have procedures to address the root causes of problems rather than applying superficial fixes? (e.g. a formal functioning corrective action system- underlying reasons for the problem are addressed in order to stop the problem from recurring)
29.	Are procedures in place to continually review the ongoing appropriateness of current practices? (i.e. is there an active commitment to exploring new or improved methods)
30.	Is there evidence of an adequate system to ensure common policy is applied and followed by the separate operational elements? (e.g. regular standardisation meetings held under the supervision of a senior manager - for organisations with very few staff answer 'yes')

Appendix Q – ATSB investigation analysis model

Overview

To assist with identifying potential safety factors during a safety investigation, the ATSB uses an analysis model that has been adapted from the well-known Reason model of organisational accidents.[425]

The basic elements of the model are shown in Figure Q1. As indicated in the figure, types of safety factors (and safety issues) can be represented as a series of levels, including:

- occurrence events (including technical problems)
- individual actions
- local conditions
- risk controls (including preventive and recovery controls)
- organisational influences.

A 'safety factor' is an event or condition that increases risk. A 'safety issue' is a safety factor that (a) can reasonably be regarded as having the potential to adversely affect future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Figure Q2 provides examples of potential safety factors (in aviation, marine and rail transport) at each level of the model.

It should be noted an analysis model is only one element of an investigation analysis framework. In addition, just because a potential safety factor is identified, this does not mean there is sufficient evidence to conclude that it existed or had an influence. Further discussion of the model and other investigation analysis aspects is provided by Walker and Bills (2008).[426]

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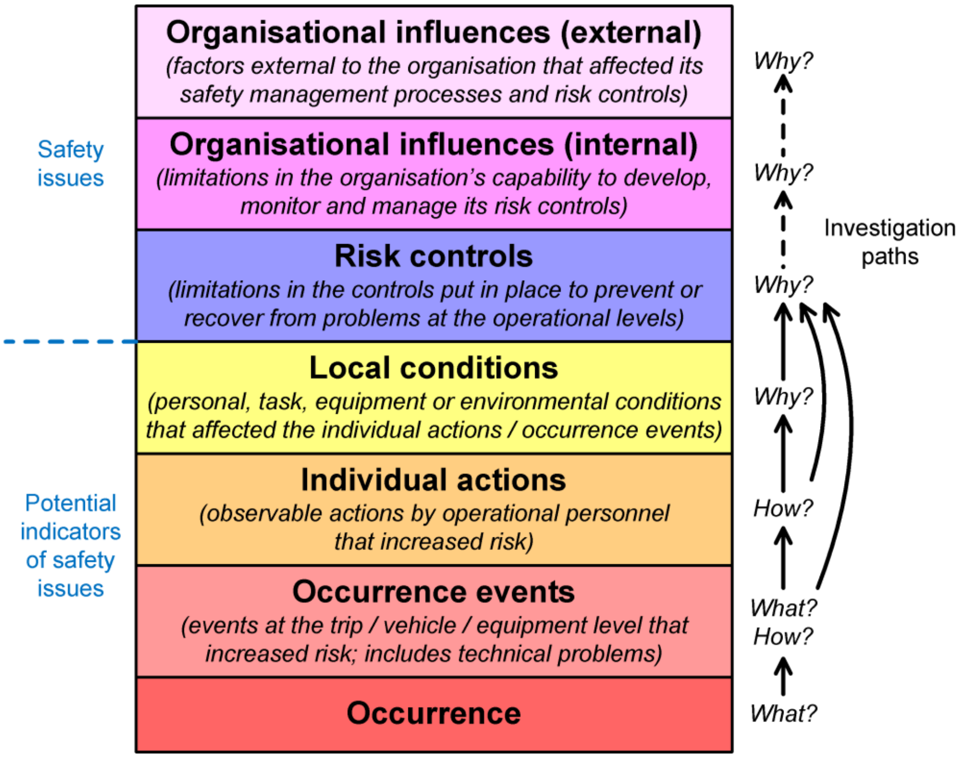
425 See: Reason J 1995, 'A systems approach or organizational error', *Ergonomics*, vol. 38, pp.1708-1721; Reason J 2007, Managing the risk of organizational accidents, Ashgate Aldershot UK.

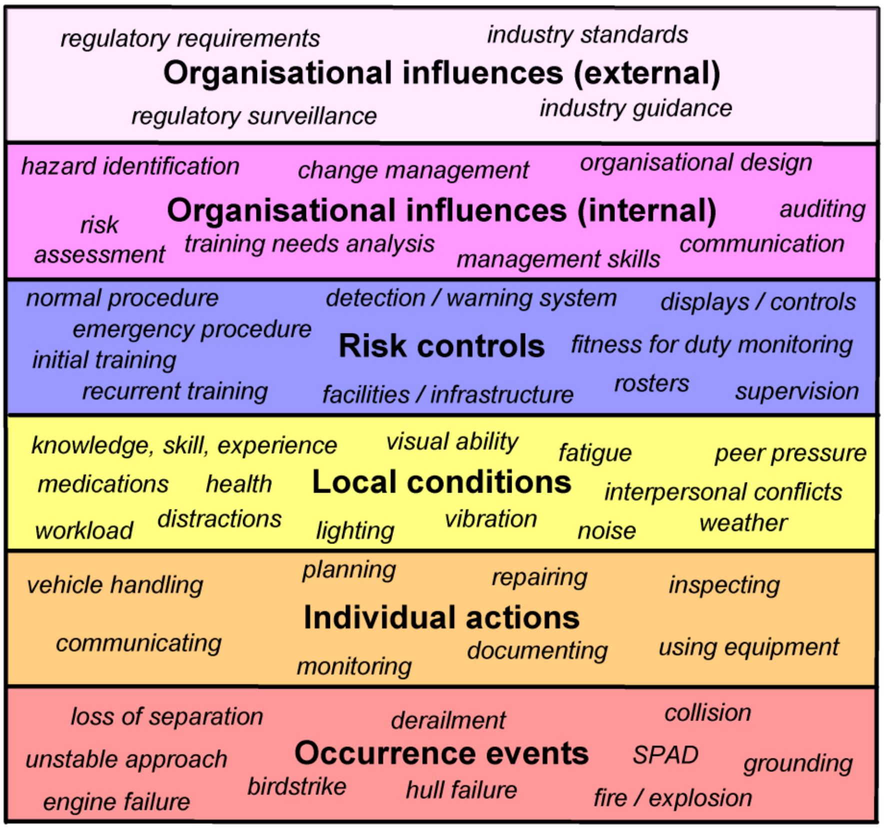
426 Walker MB & Bills K 2008, *Analysis, causality and proof in safety investigations*, ATSB Transport Safety Research Report AR-2007-053. Some minor aspects of the model in the 2008 report are slightly different to the model shown in this appendix.

Figure Q1: ATSB investigation analysis model



Source: ATSB

Figure Q2: Examples of potential safety factors at different levels in the ATSB investigation analysis model



Source: ATSB

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Glossary

A	
AAIB	Air Accidents Investigation Branch (UK)
AEDT	Australian Eastern Daylight-saving Time
A/D	Analogue to digital
A/G	Air/ground
AC	Advisory circular
ACARS	Aircraft communication addressing and reporting system
ACAS	Airborne collision avoidance system
ADF	Automatic direction finder
ADF	Australian Defence Force
ADI	Attitude director indicator
AFM	Airplane Flight Manual
AFTN	Aeronautical fixed telecommunication network
AGL	Above ground level
AHPI	Authorisation holder performance indicator
AHSQ	Air operator certificate holder safety questionnaire
AIM	Aeronautical Information Manual
AIP	Aeronautical information publication
ALERFA	Alert phase
ALT	Altitude
AML	Aircraft maintenance log
AMM	Aircraft Maintenance Manual
AMSA	Australian Maritime Safety Authority
ANAO	Australian National Audit Office
ANSV	Agenzia Nazionale per la Sicurezza del Volo
AoA	Angle of attack
AO	Audit observation
AOC	Air Operator’s Certificate
AOCM	Air Operator Certification Manual
ARAC	(US FAA) Aviation Rulemaking Advisory Committee
ARFOR	Area forecast
ASR	Aircraft survey report
ASSP	Aviation Safety Surveillance Program
ATA	Actual time of arrival
ATC	Air traffic control
ATO	Air transport operations
ATPL	Air Transport Pilot Licence
ATS	Air traffic services
ATSB	Australian Transport Safety Bureau
AUMCC	Australian Mission Control Centre
AUTO	Automatic
AWB	Airworthiness bulletin
AWIS	Automatic weather information service

AWS	Automatic weather station

B

BASI	Bureau of Air Safety Investigation
BKN	Broken
BMMF	Bio-mathematical model of fatigue
BoM	Bureau of Meteorology

C

C	Celsius
CAA	Civil Aviation Authority
CAAF	Civil Aviation Authority of Fiji
CAAP	Civil Aviation Advisory Publication
CAM	Cockpit area microphone
CAO	Civil Aviation Order
CAR	Civil Aviation Regulation
CAS	Calibrated airspeed
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulations
CASS	Commercial Air Service Standard
CAT	Commercial air transport
CAT 1	Category one
CBT	Computer-based training
CD	Consultation draft
CCL	Certification compliance checklist
CFIT	Controlled flight into terrain
CFSR	Climate Forecast System Reanalysis
CICC	Computer interface communications cable
CIR	Command instrument rating
CMI	Compliance Management Instruction
COA	Certificate of approval
CP	Critical point
CPL	Commercial Pilot Licence
CRM	Crew resource management
CSM	Civil Aviation Safety Authority Surveillance Manual
CSMU	Crash-survivable memory unit
CTAF	Common traffic advisory frequency
CVR	Cockpit voice recorder

D

DDAAFS	Directorate of Defence Aviation and Air Force Safety
DETRESFA	Distress phase
DGAC	Direction Générale de l'Aviation Civile
DGPS	Differentially-corrected global positioning system
DME	Distance measuring equipment
DP	Discussion paper

E

EAM	Eastern Aero Marine
EDTO	Extended diversion time operation
EGPWS	Enhanced Ground Proximity Warning System
ELT	Emergency locator transmitter
EMS	Emergency medical service
ENR	En route
EPIRB	Emergency position indicating radio beacon
ERC	Emergency response centre
ERSA	En route Supplement Australia
ESC	Emergency services coordinator
ETA	Estimated time of arrival
ETI	Estimated time interval
ETP	Equi-time point

F

FAA	(US) Federal Aviation Administration
FAF	Final approach fix
FAID	Fatigue Audit InterDyne
FAR	(US) Federal Aviation Regulation
FAR	False alarm ratio
FAST	Fatigue Avoidance Scheduling Tool
FCOM	Flight Crew Operating Manual
FDR	Flight data recorder
FIR	Flight information region
FIS	Flight information service
FL	Flight level
FMS	Fatigue management system
FNL	Final
FOI	Flying operations inspector
FPFM	Flight planning and fuel management
FRA	(US) Federal Railroad Administration
FRMS	Fatigue risk management system
ft	Feet

G

GA	General aviation
GEN	General
GEO	Geostationary Earth orbit
GFS	Global Forecast System
GNSS	Global Navigation Satellite System
GPS	Global positioning system
GPWS	Ground proximity warning system
GPWT	Grid point wind and temperature
GUV	General utility vehicle

H

HF	High frequency
HFM	Human factors management
HHMPI	Hand-held multi-purpose interface
HOSP	Hospital aircraft
HOTC	Head of training and checking
hPa	Hectopascals
HSI	Horizontal situation indicator
HUET	Helicopter underwater escape

I

IAI	Israel Aircraft Industries
IAS	Indicated airspeed
ICUS	In command under supervision
ICAO	International Aviation Civil Organization
IFISO	International flight information service officer
IFLS	Individual fatigue likelihood score
IFR	Instrument Flight Rules
ILS	Instrument landing system
IMC	Instrument meteorological conditions
INCERFA	Uncertainty phase
ISA	International standard atmosphere
ITSR	Independent Transport Safety Regulator
ITT	Inter-turbine temperature

J

JAR	Joint Aviation Requirements
JRCC	Joint rescue coordination centre

K

kg	Kilogram
kHz	Kilohertz
km	Kilometres
kt	Knot

L

L	Litres
lb	Pounds
LEO	Low-altitude Earth orbit
LLZ	Localiser
LPSD	Last point of safe diversion

M

m	Metre
M	Mach
M	Magnetic
MAD	Mean absolute deviation

MAP	Management action plan
MATS	Manual of Air Traffic Services
MDA	Minimum descent altitude
MED 1	Medical flight, priority 1
MEOSAR	Medium-altitude Earth orbiting satellite system for search and rescue
METAR	Aviation routine weather report
MHz	Megahertz
MOS	Manual of Standards
MSA	Minimum sector altitude
MSM	Management system model
MT	Medical transport
MTOW	Maximum take-off weigh

N

NAA	National aviation authorities
NAIPS	National Aeronautical Information Processing System
NCEP	National Centers for Environmental Prediction
NCN	Non-compliance notice
NDB	Non-directional beacon
NM	Nautical mile
NMC	Navigation Management Computer
NMS	Navigation Management System
NOTAC	Notice to Aircrew
NOTAM	Notice to Airmen
NPRM	Notice of proposed rule making
NSSP	National surveillance selection process
NSW	New South Wales
NTSB	National Transportation Safety Board (US)
NWP	Numerical weather prediction
NZ	New Zealand
NZ GEOLUT	NZ geostationary satellite tracking station

O

OAR	Organisation annual return
OAT	Outside air temperature
OEI	One-engine inoperative
OM	Operations manual
OPC	Office of Parliamentary Counsel
OPM	Operational Planning Manual
OVC	Overcast

P

PAPI	Precision approach path indicator
PBN	Performance-based navigation
PI	Portable interface
PLB	Personal locator beacon
PNR	Point of no return

POD	Probability of detection
PSD	Point of safe diversion
PSWR	Prior-sleep wake rule

Q

QNH	Altimeter subscale setting to obtain elevation or altitude above sea level

R

RAAF	Royal Australian Air Force
RCA	Request for corrective action
RCCNZ	Rescue Coordination Centre New Zealand
REX	Regional Express Holdings Limited
RFC	Regional forecasting centre
RNAV	Area navigation
RPT	Regular public transport
ROV	Remotely operated vehicle
RSU	Ruggedized service unit
RSWT	Route sector wind and temperature
RVSM	Reduced vertical separation minima

S

SAFE	System for Aircrew Fatigue Evaluation
SAR	Search and rescue
SARPS	Standards and recommended practices
SCAT-1	Special category-1
SCT	Scattered
S/D	Synchro to digital
SEEP	Safety equipment and emergency procedures
SELCAL	Selective calling
SG	Specific gravity
SIGMET	Significant weather
SIGWX	Significant weather (forecast chart)
SKC	Sky clear
SMC	Safety management committee
SMG	Safety management group
SMM	Safety Management Manual
SMS	Safety management system
SOM	System of maintenance
SOP	Standard operating procedure
SPECI	Aviation special weather report
SPFIB	Specific pre-flight information bulletin
SPM	Surveillance Procedures Manual
SRM	Safety risk management
SSR	Secondary surveillance radar
STI	Safety trend indicator
SWPSF	South West Pacific Safety Forum

T

T	True
TAD	Terrain alerting and display
TAF	Aerodrome forecast
TAS	True airspeed
TAWS	Terrain awareness and warning system
TCAS	Traffic alert and collision avoidance system
TEM	Threat and error management
TSB	Transportation Safety Board (of Canada)
TTF	Trend-type forecast

U

UHF	Ultra-high frequency
ULB	Underwater locator beacon
UK	United Kingdom
Unicom	Universal communications
US	United States
UTC	Coordinated Universal Time

V

VFR	Visual flight rules
VHF	Very high frequency
VNI	Vertical navigation indicator
VOLMET	Routine broadcast of selected operational meteorological information
VOR	VHF Omni-directional Radio Range
V_{REF}	Reference landing speed
V_{SO}	Stall speed

W

WAFC	World Area Forecast Centre
WAFS	World Area Forecast System

X

Y

Z

ZFW	Zero fuel weight

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation

Fuel planning event, weather-related event and ditching involving Israel Aircraft Industries Westwind 1124A, VH-NGA
6.4 km WSW of Norfolk Island Airport, on 18 November 2009

AO-2009-072 (reopened)

Final – 23 November 2017