Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200501977

Interim Factual Report No. 2

Collision with Terrain
11 km NW Lockhart River Aerodrome
7 May 2005
VH-TFU
SA227-DC (Metro 23)

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Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office location: 15 Mort Street, Canberra City, Australian Capital Territory
Telephone: 1800 621 372; from overseas + 61 2 6274 6590
Accident and serious incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6274 6474; from overseas + 61 2 6274 6474
E-mail: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page v.

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DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
200501977	31 August 2006	107	1 921092 95 5

Publication title

Collision with Terrain, 11 km NW Lockhart River Aerodrome, 7 May 2005, VH-TFU, SA227-DC (Metro 23)

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Acknowledgements

Jeppesen Sanderson, Inc. for Figure 3.
Airservices Australia for Figure 4.
Bureau of Meteorology for Figure 12.

Abstract

This interim factual report contains factual information relating to the accident on 7 May 2005 involving Fairchild Aircraft SA227-DC Metro 23 aircraft, registered VH-TFU. The aircraft, with two pilots and 13 passengers, was being operated on an instrument flight rules (IFR) scheduled passenger service from Bamaga to Cairns with an intermediate stop at Lockhart River, Qld. At 1143:39 Eastern Standard Time the aircraft impacted terrain about 11 km north-west of the Lockhart River Aerodrome. At the time of the accident, the crew were conducting an area navigation global navigation satellite system (RNAV (GNSS)) non-precision instrument approach to runway 12. The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were no survivors. Additional factual information relating to wreckage and the aircraft, the flight data recorder, and a summary of survey and other research dealing with RNAV (GNSS) approaches is included. As the investigation is ongoing, in accordance with international convention, the report does not contain any analysis or findings relating to the factual information. The analysis and findings of the investigation will be provided in the final report. The investigation is continuing and, among other things, will include further work in the following aspects of the accident: the operator's management processes, standard operating procedures, flight crew training and checking, and document control; regulatory oversight of the operator's activities, including approvals and surveillance undertaken; and the design and chart presentation of RNAV (GNSS) approaches. Further safety action may also arise from this ongoing investigation and associated research.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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 fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. 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.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau is pleased to report positive safety action in its final reports rather than make formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

1 FACTUAL INFORMATION

1.1 History of the flight

On 7 May 2005, a Fairchild Aircraft SA227-DC Metro 23 aircraft, registered VH-TFU (Figure 1), with two pilots and 13 passengers, was being operated on an instrument flight rules (IFR) scheduled passenger service from Bamaga to Cairns with an intermediate stop at Lockhart River, Qld (Figure 2). At 1143:39 Eastern Standard Time[1] the aircraft impacted terrain about 11 km north-west of the Lockhart River Aerodrome. At the time of the accident, the crew were conducting an area navigation global navigation satellite system (RNAV (GNSS)) non-precision approach[2] to runway 12. The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were no survivors.

The accident site was located on the published Lockhart River Runway 12 RNAV (GNSS) final approach track at an elevation of 1,210 ft above mean sea level (AMSL). At that point on the approach, the minimum obstacle clearance altitude was 2,060 ft AMSL. The forecast conditions at the aerodrome included a broken[3] cloud base 1,000 ft above the aerodrome for periods of up to 60 minutes.

Figure 1: VH-TFU at Bamaga Aerodrome on a previous flight

The pilot in command and copilot commenced duty in Cairns for a return flight to Bamaga with intermediate stops at Lockhart River. The aircraft departed Cairns at 0838 and, as the pilot in command was recorded as making the radio transmissions,

1 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EDT), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

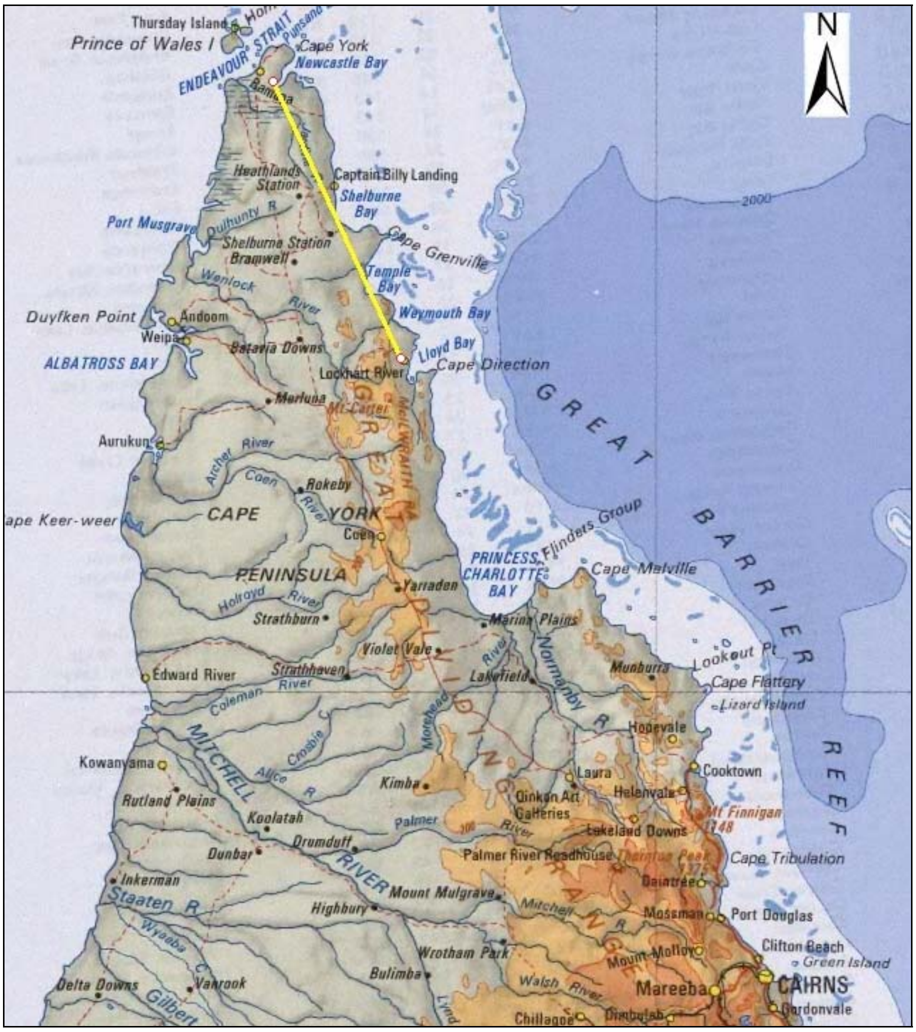
2 The term RNAV (GNSS) non-precision approach refers to an instrument approach, conducted with reference to information provided by the Global Navigation Satellite Systems, that does not have vertical path guidance. See Section 1.8 for further information.

3 Broken refers to 5 to 7 eighths of the sky obscured by cloud.

it was likely that the copilot was the handling pilot for the northbound flights[4]. The aircraft arrived at Bamaga at 1037 after an intermediate landing at Lockhart River.

The aircraft was then refuelled at Bamaga for the return flight to Cairns via Lockhart River. Prior to departing Bamaga, the pilot in command commented to the ground agent that the weather was ‘bad’ at Lockhart River and that due to weather conditions it may not be possible to land there. The aircraft departed Bamaga at 1112 and, as the copilot was recorded as making the radio transmissions during flight, it was likely that the pilot in command was the handling pilot for the accident flight.

Figure 2: Accident flight route



The following chronology of events leading up to the accident was constructed from data recovered from the flight data recorder (FDR), recording of radio communication between the crew and air traffic control (ATC), and broadcasts made by the crew on the Lockhart River common traffic advisory frequency (CTAF). The FDR and radio communications were correlated using the time stamp

4 The operator’s flight crew reported that the non-handling pilot was normally responsible for radio communications.

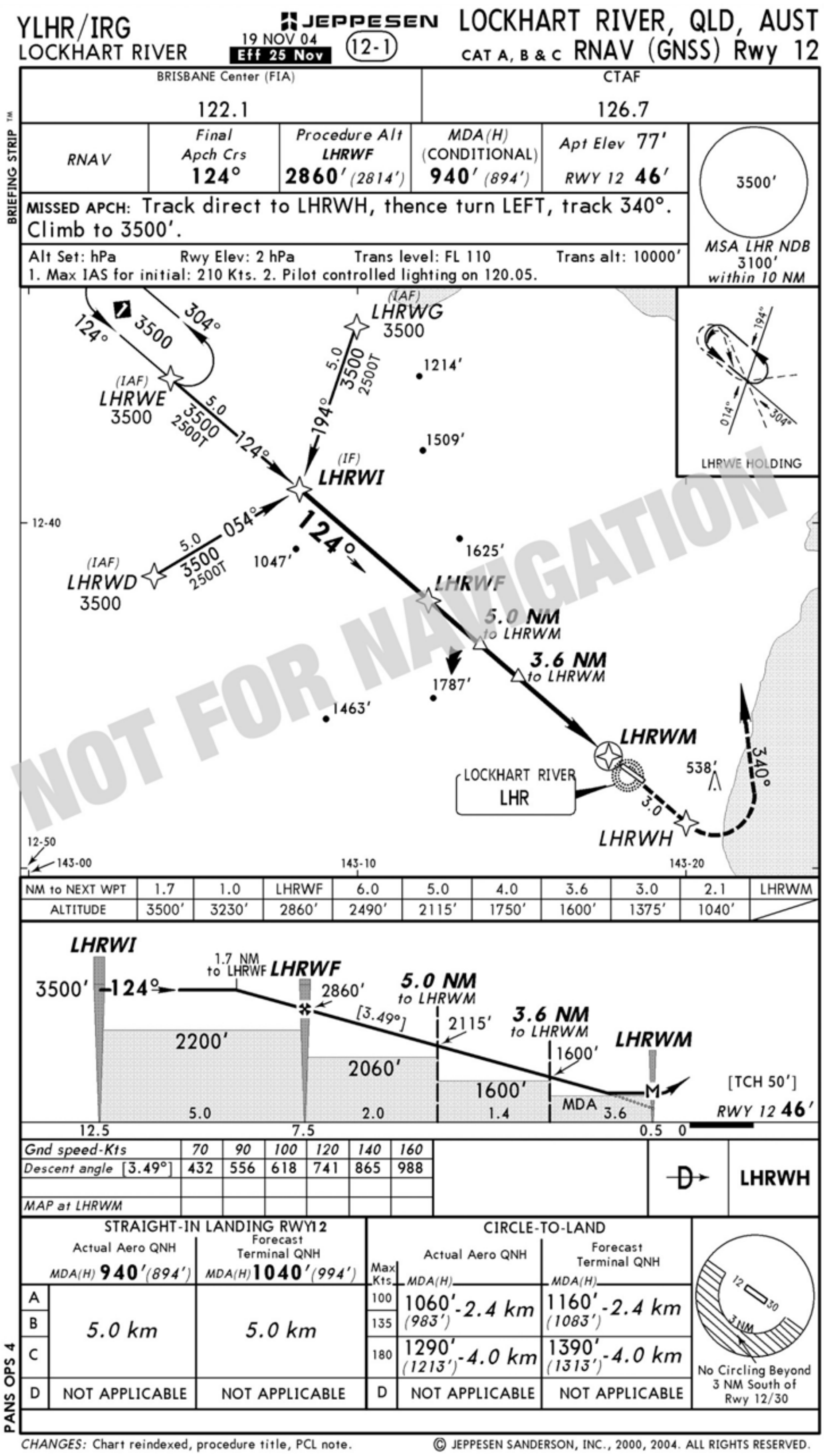
on the ATC voice recording (see section 1.11.1 and Appendix A). Conversations between the crew and other sounds in the cockpit during the last 30 minutes of the flight were not available due to a malfunction of the cockpit voice recorder (see section 1.11.2).

Local time	Event	
1112:19	Aircraft took off from runway 13 at Bamaga.	
1114:33	The copilot advised Brisbane ATC that the aircraft had departed Bamaga at 1111 and it was on climb to flight level (FL) 180 with an estimated time of arrival (ETA) at Lockhart River at 1143. In response to a query from ATC regarding the proposed cruise level, the copilot advised that the level would be FL 170. ATC replied that there was no IFR traffic at that level.	
1124:36	In response to an ATC instruction, the copilot contacted Brisbane ATC on a different radio frequency.	
1128:32	Aircraft at top of climb at FL 170.	
1132:26	Aircraft commenced descent from FL 170.	
1133:06	The copilot advised Brisbane ATC that the aircraft had left FL 170 and requested traffic information. ATC provided traffic information on VH-PAR, an aircraft that was operating to the north of Lockhart River Aerodrome.	
	Altitude: 16,130 ft[5]	Indicated airspeed (IAS): 226 kts
1134:19	Brisbane ATC provided further information to the crew about the position of VH-PAR and advised that the area QNH[6] was 1011 hectopascals (hPa).	
	Altitude: 13,440 ft	IAS: 248 kts
1135:48	The copilot advised Brisbane ATC that the aircraft was on descent, passing 10,000 ft AMSL with an ETA at Lockhart River of 1138.	
	Altitude: 10,376 ft	IAS: 250 kts
1136:18	The copilot broadcast the aircraft's altitude and ETA of 1139 on the Lockhart River CTAF.	
	Altitude: 9,369 ft	IAS: 250 kts
1139:30	Aircraft briefly levelled and then began to climb.	
	Altitude: 3,505 ft	IAS: 229 kts
1139:50	Aircraft levelled.	
	Altitude: 3,992 ft	IAS: 195 kts
1139:56	Descent recommenced. The copilot broadcast on the CTAF that the crew were conducting the Runway 12 RNAV (GNSS) approach, and that the aircraft was at the 'Whisky Golf' (LHRWG) waypoint and tracking for the 'Whisky India' (LHRWI) waypoint (Figure 3).	
	Altitude: 3,992 ft	IAS: 192 kts

5 Pressure altitude data derived from the FDR was accurate to ±100 ft below 3,000 ft and calculated airspeed data was accurate to ±15 kts above 150 kts – see Appendix A for full details.

6 QNH is the barometric pressure setting that enables an altimeter to indicate altitude, that is, the height above mean sea level.

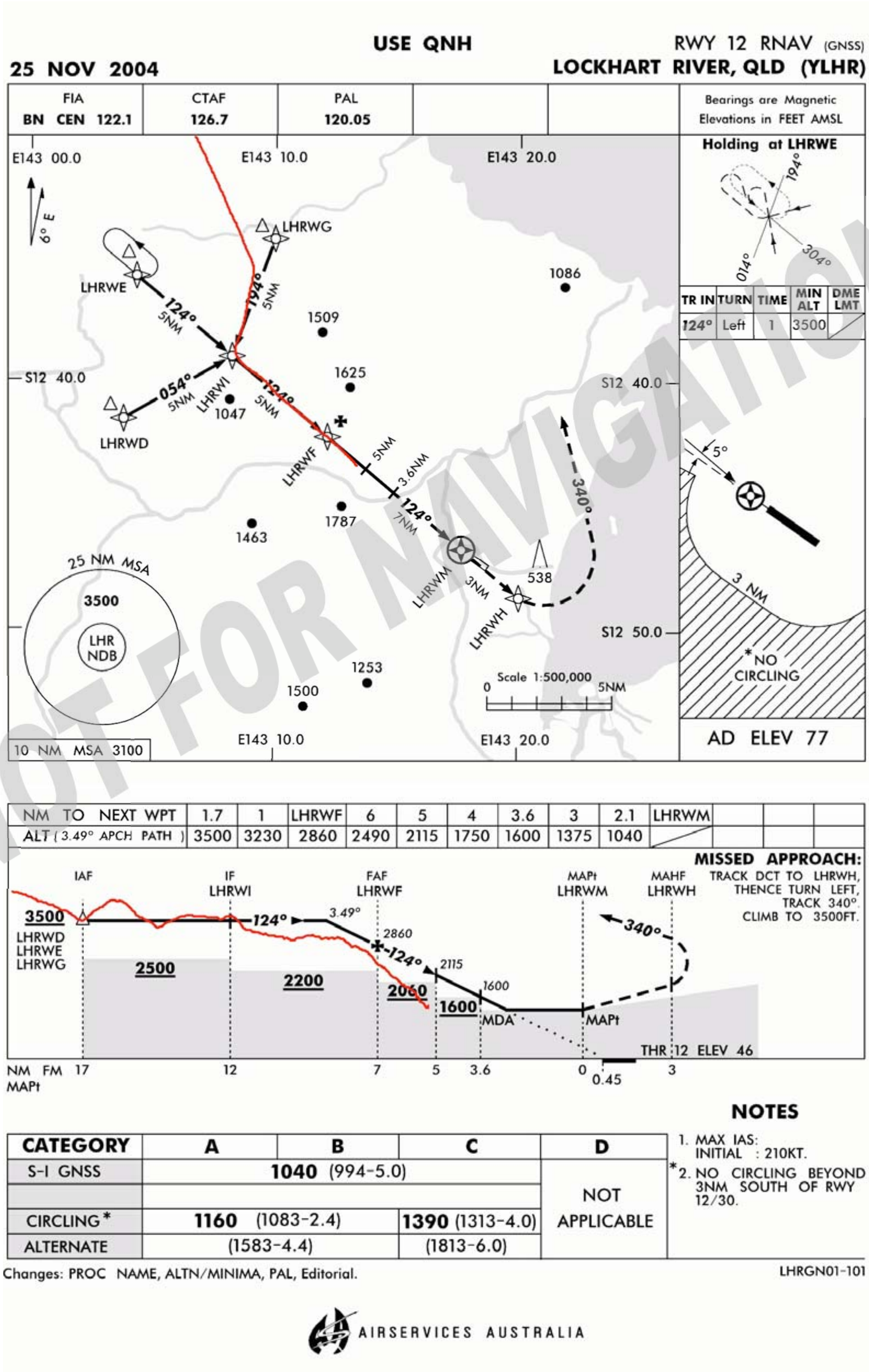
Figure 3: Lockhart River Runway 12 RNAV (GNSS) approach chart



1140:26	The copilot transmitted on the CTAF advising the pilot of VH-PAR that the weather conditions in the Lockhart River area were '… fairly dismal really. Bout 900 foot clear....[*indistinct*][7]'.	
	Altitude: 3,457 ft	IAS: 197 kts
1140:28	First stage (9º) of flap selected.	
	Altitude: 3,513 ft	IAS: 197 kts
1140:33	Aircraft levelled.	
	Altitude: 3,600 ft	IAS: 190 kts
1141:08	Aircraft over LHRWI waypoint.	
	Altitude: 3,619 ft	IAS: 178 kts
1141:11	Descent recommenced at 4.8 NM from the LHRWF waypoint. This was 3.1 NM before the descent point specified on the approach chart for the 3.49 degree constant angle approach path to the missed approach point (Figure 4).	
	Altitude: 3,588 ft	IAS: 179 kts
1141:52	Aircraft levelled.	
	Altitude: 2,998 ft	IAS: 188 kts
1142:19	Second stage (18º) of flap selected.	
	Altitude: 3,039 ft	IAS: 180 kts
1142:29	Descent recommenced at 1.3 NM from the LHRWF waypoint. This was 0.4 NM after the descent point specified for the constant angle approach path (Figure 4).	
	Altitude: 3,043 ft	IAS: 174 kts
After 1142:29 the aircraft rate of descent was greater than that required to achieve the recommended descent profile for the published approach procedure. The aircraft descended at an average rate of 1,500 ft/min, with some turbulence evident, over the 70 seconds prior to the impact.		
1142:58	Aircraft over the LHRWF waypoint.	
	Altitude: 2,397 ft	IAS: 174 kts
1143:11	Aircraft descends through the segment minimum safe altitude of 2,060 ft.	
	Altitude: 2,057 ft	IAS: 177 kts
1143:22	Aircraft 229 ft below the minimum segment altitude of 2,060 ft.	
	Altitude: 1,831 ft	IAS: 176 kts
1143:38	Minimum altitude recorded on the FDR.	
	Altitude: 1,292 ft	IAS: 158 kts
1143:39	Aircraft 5.5 NM prior to LHRWM waypoint.	
	End of recorded data.	

7 This word was subjected to forensic speech analysis and the second syllable could not be positively identified. The word may have been 'clearance' or 'clearing'.

Figure 4: Approach track and profile (in red) derived from FDR data overlayed on an extract of the Airservices Australia Runway 12 RNAV (GNSS) approach chart



At 1158, when the crew had not reported having landed at the Lockhart River Aerodrome, ATC declared an uncertainty phase. When attempts to contact the crew failed, a search for the aircraft was commenced. AusSAR[8] reported that an emergency signal from an ELT was not identified in the Lockhart River area at or about the time of the accident. At 1625, the burnt wreckage of the aircraft was located in the Iron Range National Park on the north-western slope of 'South Pap', a heavily timbered ridge, approximately 11 km north-west of the Lockhart River Aerodrome.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other	Total
Fatal	2	13		15
Serious				
None				
Total	2	13		15

1.3 Damage to aircraft

The aircraft was destroyed by impact forces and an intense, fuel-fed, post-impact fire.

1.4 Other damage

The impact, liberation of fuel and post-impact fire caused damage to vegetation.

1.5 Personnel Information

1.5.1 Pilot in command

At the time of the accident, the pilot in command had logged a total of 6,071 hours flying experience, of which 3,248 hours were on the Metro aircraft type. He held an air transport pilot (aeroplane) licence issued by the Civil Aviation Safety Authority (CASA), which included an endorsement for command on Metro 3 aircraft (covering all SA227 aircraft types). In addition, he held a command multi-engine instrument rating, which included an approval to conduct RNAV (GNSS) approaches. The pilot in command's initial command multi-engine instrument rating was issued on 13 November 1993; an approval to conduct RNAV (GNSS) approaches was added on 3 January 2003.

8 Australian Search and Rescue – in general terms, AusSAR coordinates the response to aviation search and rescue incidents across Australia.

The pilot's first flight with the operator as pilot in command occurred on 19 February 2001. He had passed a company flight proficiency base check and command multi-engine instrument rating renewal on 28 February 2005.

The pilot's logbook indicated that he had:

- operated as pilot in command on Metro aircraft into Lockhart River on 24 occasions prior to the accident flight
- completed 16 RNAV (GNSS) approaches at various locations between 3 January 2003 and 16 April 2005 (the date of the last log book entry)
- carried out one Runway 12 RNAV (GNSS) approach at Lockhart River, on 27 September 2004
- logged 8.4 hours flight time under instrument meteorological conditions within the preceding 90 days
- carried out three RNAV (GNSS) type approaches within the preceding 90 days
- completed one non-directional beacon (NDB) type approach within the preceding 90 days.

Prior to commencing duty on the day of the accident, the pilot in command was rostered free of duty for 19 hours and 7 minutes. He had returned from a period of 7 days leave, 3 days before the accident flight. During that 3 day period, he had completed 9 hours and 40 minutes of flight time and 12 hours 20 minutes of duty time. The pilot's colleagues reported that he was 'quite fit' and was 'relaxed due to just having finished a holiday'.

1.5.2 Copilot

The copilot had logged a total of 655 hours flying experience, of which 150 hours were as copilot on the Metro aircraft type. He was qualified to perform the duties of copilot on the Metro aircraft and, although he held a command instrument rating, it did not include approval to conduct RNAV (GNSS) approaches. His initial command multi-engine instrument rating was issued on 19 March 2004. The rating was renewed on 3 April 2005. The copilot's log book indicated that he had not completed any RNAV (GNSS) approaches.

The copilot passed a company flight proficiency base check with the operator on 22 December 2004 and he commenced operational duties with the operator on 28 February 2005. His logbook indicated that he had operated as a crew member into Lockhart River on three occasions before 7 May 2005. The first occasion was on 13 April 2005.

The copilot had no record in his logbook of completing any training for GPS navigation or RNAV (GNSS) approaches. The former was a CASA requirement for enroute navigation using a GPS receiver, and a prerequisite for doing an RNAV (GNSS) approach endorsement. An RNAV (GNSS) approach into Bamaga was demonstrated to the copilot by a supervisory pilot in visual meteorological conditions in April 2005.

Prior to commencing duty on the day of the accident, the copilot was rostered free of duty for 19 hours and 7 minutes. The day of the accident was his fifth consecutive duty day, prior to which he had been rostered free of duty for 4 days. During that 5-day period, he had completed 19 hours and 32 minutes of flight time, and 26 hours and 26 minutes of duty time. The pilot's family and colleagues reported that he was fit. They also reported that he had competed in a triathlon the weekend before the accident.

1.6 Aircraft Information

1.6.1 Aircraft data

Manufacturer	Fairchild Aircraft Corporation
Model	SA227-DC
Serial number	DC818B
Registration	VH-TFU
Year of manufacture	1992
Certificate of airworthiness issuing authority	Civil Aviation Safety Authority
Issue date	4 July 2003
Certificate of registration issuing authority	Civil Aviation Safety Authority
Issue date	2 July 2003
Total airframe hours/cycles	26,877.8 hrs / 28,529 cycles (see note)
Maintenance release issued on/at	17 April 2005/26,805.8 hrs
Maintenance release valid to	17 April 2006/26,975.8 hrs
Next scheduled maintenance due	26,955.8 hrs
Maximum take off weight	7,484 kg
Maximum landing weight	7,110 kg
Aircraft weight at time of occurrence	(see section 1.6.5)
Centre of gravity at time of occurrence	(see section 1.6.5)

Note: The aircraft's *Flight/Maintenance Log* dated 6 May 2005 (the day prior to the accident) indicated that the aircraft had completed 26,875.5 hours and 28,527 cycles. A cycle refers to a take off and landing. Based on the times and cycles recorded by the FDR, the aircraft had logged 26,877.8 hours and 28,529 cycles at the time the FDR recording ceased.

1.6.2 Engine and propeller data

Left engine

Manufacturer	Garrett General Aviation Services Division
Model	TPE331-12UHR-701G
Part number	3103870-7
Serial number	P70151C
Last significant maintenance completed	On 7 October 2004: hot section and gearbox inspection - the gearbox bull gear and pinion were replaced and the engine had a re-compensation (performance) check carried out.
Total time since new	21,510.5 hrs (see note)
Cycles since new	22,970 cycles (see note)
Time since last overhaul	4,233.5 hrs (see note)

Right engine

Manufacturer	Garrett General Aviation Services Division
Model	TPE331-12UAR-701G
Part number	3103870-4
Serial number	P7011C
Last significant maintenance completed	6 April 2005: hot section and gearbox inspection - the gearbox bull gear, pinion and gearbox diaphragm were replaced and the engine had a re-compensation (performance) check carried out.
Total time since new	21,960.0 hrs (see note)
Cycles since new	22,941 cycles (see note)
Time since last overhaul	3,496.0 hrs (see note)

Note: The engine total time, cycles since new and time since last overhaul includes the times and cycles recorded by the FDR on 7 May 2005.

Each engine was fitted with a McCauley Propeller Systems Model 4HFR34C652-J four blade, constant speed propeller.

1.6.3 Cockpit instruments and systems

Global positioning system navigation receiver

The aircraft was equipped with a Garmin GPS 155XL global positioning system (GPS) navigation receiver that conformed to the US Federal Aviation Administration (FAA) Technical Standard Order[9] TSO-C129a. The receiver was approved for IFR use as a primary means navigation system[10] for en-route navigation and non-precision approaches.

The GPS receiver and its display (Figure 5) were installed in the centre instrument panel to the right of the engine instruments. The panel-mounted receiver consisted of controls, a back lit liquid crystal display (LCD) and a data card slot. The controls for the various operating modes consisted of push-buttons, known as function keys, and a concentric rotary selector knob.

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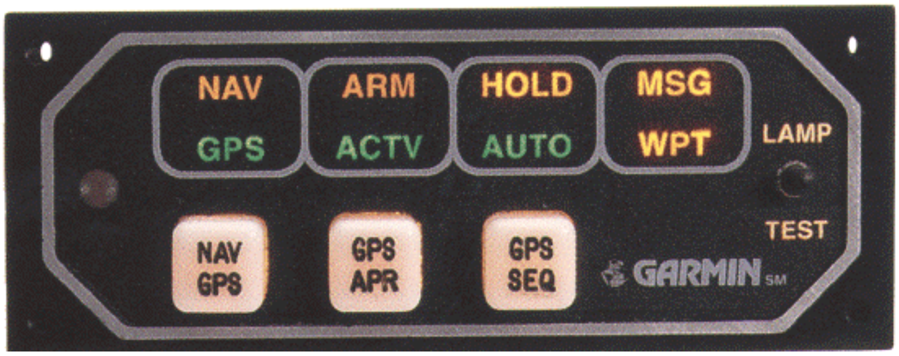
9 US Federal Aviation Administration Technical Standard Order C129a – *Airborne supplemental navigation equipment using the global positioning system (GPS)*, February 1996.

10 A primary means navigation system is defined as a navigation system that, for a given operation or phase of flight, must meet accuracy and integrity requirements, but need not meet full availability and continuity of service requirements. Safety is achieved by either limiting flights to specific time periods, or through appropriate procedural restrictions and operational requirements.

Figure 5: Garmin GPS 155XL navigation receiver

An MD-41 annunciation/control unit was installed on the pilot in command's instrument panel below the vertical speed indicator (Figure 6). Pressing the NAV/GPS switch on the unit enabled the pilot in command to select either VOR[11] or GPS information on the pilot in command's horizontal situation indicator (HSI). Other switches enabled the pilot in command to disarm or re-arm the GPS approach mode and to select manual or automatic sequencing of waypoints. The annunciations would indicate whether VOR or GPS data was being displayed on the pilot in command's HSI; whether the GPS approach mode was armed or active; whether manual sequencing of waypoints had been selected; and whether the GPS receiver had generated a message or waypoint alert.

Figure 6: MD-41 annunciation/control unit



Barometric altimeters

A Kollsman type 519-28702 pressure sensitive encoding altimeter was fitted on the pilot in command's instrument panel. The instrument displayed barometric corrected altitude on a counter drum pointer presentation (Figure 7). The counter drum indicated in ten thousands, thousands and hundreds of feet with the pointer making one revolution per thousand feet. The local barometric pressure was set by a knob located on the lower right corner of the instrument and displayed in inches of mercury and hPa in the two barometric pressure scale windows. The altimeter supplied altitude information to the altitude alerting system and transponder, and pressure altitude data (barometric aiding) to the GPS receiver.

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11 VOR refers to Very-High Frequency Omni-directional Radio Range.

Figure 7: Kollsman 519-28702 encoding altimeter

An Aerosonic 101735 series three pointer pressure sensitive altimeter was fitted to the copilot’s instrument panel. The instrument displayed barometric corrected altitude using three pointers for ten thousands, thousands and hundreds of feet (Figure 8).

Figure 8: Aerosonic 101735 three pointer altimeter

Radio altimeter system

The aircraft was equipped with a Rockwell Collins ALT55B radio altimeter system which comprised a receiver/transmitter, two antennae located on the lower surface of the fuselage, rearward of the wing, and a cockpit digital radio altimeter indicator (Figure 9). The system computed the aircraft’s height above ground level (AGL) directly below its flight path from 0 to 2,500 ft. This radio altitude data was provided to the ground proximity warning system (GPWS) computer. The digital DRI-55 indicator was located on the pilot in command’s instrument panel below the vertical speed indicator and GPS annunciation control unit.

Figure 9: DRI-55 digital radio altimeter indicator

The pilot in command could select a height from 0 to 980 ft on a rotating drum scale using the 'push test' radio altimeter decision height[12] knob. When the aircraft descended through the selected height, the GPWS computer generated an aural advisory callout 'minimums, minimums' and the decision height (DH) annunciator remained illuminated. A red warning flag came into view over the DH scale if the radio altitude computations stopped or there was a power failure to the radio altimeter unit or indicator.

Altitude alerting system

The aircraft was equipped with a Kollsman type 540-22722-004 altitude alerter (Figure 10), which provided automatic visual and aural signals to alert the flight crew that the aircraft was approaching, or departing from, a preselected altitude. The preselected altitude could be set on the alerter display unit located on the centre instrument panel above the GPS control unit. The alerting system received altitude information from the pilot in command's encoding altimeter.

Figure 10: Kollsman type 540-22722-004 altitude alerter

As the aircraft approached 1,000 ft above or below the preselected altitude, an aural tone sounded for 2 seconds and the altitude alert light on the display unit illuminated. The light remained illuminated until the aircraft approached 300 ft above or below the preselected altitude. If the aircraft subsequently departed from the preselected altitude by more than ±300 ft the aural tone and light would again activate. The light would remain illuminated until the aircraft returned to within 300 ft of the preselected altitude or until the flight crew selected a new altitude.

12 Decision height is the specified height above ground level at which the missed approach must be initiated if the required visual reference to continue the approach to land has not then been established.

Ground proximity warning system

The aircraft was equipped with an approved Honeywell Mark VI GPWS. The GPWS provided visual and aural alerts and warnings to the flight crew when the aircraft was being flown in proximity to terrain directly underneath the aircraft and the aircraft operating parameters and configuration were within computed alerting envelopes. The GPWS cockpit annunciator lights and switches were located on the left side of the glare shield panel (Figure 11).

Figure 11: GPWS cockpit annunciator lights/switches[13]

The GPWS computer received indicated airspeed and vertical speed information from an air data module, radio altimetry data from the radio altimeter, glideslope information from the instrument landing system unit, and flap and landing gear position signals.

The GPWS provided six modes of alerts and warnings to the flight crew. The mode 2 alert and warning were designed to warn the crew when an excessive terrain closure rate existed. When that situation existed, the GPWS generated an aural 'terrain terrain' alert message with the red GPWS warning annunciator light illuminating on the glare shield panel. The alert was immediately followed by an aural 'pull up' warning message. The generation of the mode 2 messages was influenced by radio altitude, indicated airspeed, vertical speed, position of the landing gear and flap, and position of the GPWS flap over-ride switch.

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13 Insert annunciator switches have been superimposed to enhance clarity.

Data derived from the FDR was analysed by Honeywell to determine if the conditions, that would cause the GPWS computer to generate an excessive terrain closure rate alert, should have been satisfied in the period preceding the collision with terrain. Honeywell engineers determined that the flight profile of the aircraft was such that the GPWS should have generated a number of alerts and warnings of the terrain closure rate (Appendix B).

The Honeywell diagram depicted the alert and warning messages that would have been generated if the GPWS was operating normally. The Honeywell assessment relied heavily on an estimation of radio altitude, as radio altitude was not one of the parameters recorded by the FDR. Honeywell determined that at about 29 seconds before impact, the terrain closure rate should have been sufficient to generate both the alert 'terrain terrain' and the warning 'pull up' messages until about 24 seconds before impact. Three 'terrain terrain' alerts should have sounded at about 21 seconds, 18 seconds, and 14 seconds before impact. The alert 'terrain terrain' and the warning 'pull up' messages should have sounded again at about 6 seconds before impact.

Due to the absence of CVR information, the investigation was not able to determine if the GPWS functioned as designed. Several of the operator's pilots reported that they conducted a GPWS test prior to each flight and that the system was operational prior to the accident.

The Civil Aviation Safety Authority (CASA) amended Civil Aviation Order (CAO) 20.18 in 2000. The amended CAO specified that certain aircraft had to be fitted 'by the end of June 2005'with an approved GPWS, which had a predictive terrain hazard warning function[14]. The requirement included aircraft that had a maximum take-off weight of more than 15,000 kg, or carried 10 or more passengers, were engaged in regular public transport, or charter, operations, and operated under the IFR. The operator reported they were intending to comply with the CAO requirement and fit the enhanced GPWS to VH-TFU by 30 June 2005.

Autopilot

Civil Aviation Order (CAO) 82.3 specified that two pilots were required to operate an aircraft in which more than nine passenger seats could be fitted and the aircraft was to be used in regular public transport operations. CAO 20.18 required that an aircraft engaged in regular public transport operations under the Instrument Flight Rules had to be equipped with an approved automatic pilot unless the aircraft was equipped with fully functioning dual controls. In that case, the second pilot was required to hold a commercial pilot (aeroplane) licence with an endorsement for that type of aeroplane and at least a copilot (aeroplane) instrument rating.

The aircraft was not fitted with an autopilot, nor was an autopilot required by provisions of the above CAOs. This aspect of the aircraft's operation was the subject of recommendation R20060003 issued to CASA by the ATSB on 24 January 2006 (Section 2 Safety Action).

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14 GPWS with a predictive terrain warning function was also known as enhanced GPWS (EGPWS) or terrain awareness warning system (TAWS).

Emergency locator transmitter

The aircraft was fitted with an Artex ELT 110-4 emergency locator transmitter (ELT).

Serviceability of the cockpit instruments and systems

A review of the aircraft's maintenance documentation indicated that for the period from 8 January to 6 May 2005 there were no reported unserviceabilities with the above listed cockpit instruments and systems. The copilot's flight instrument lighting was recorded as unserviceable, see section 1.6.4.

1.6.4 Aircraft airworthiness and maintenance

Aircraft history

A review of the aircraft maintenance documentation showed that the aircraft had been imported from the United States and issued with an Australian certificate of airworthiness on 4 July 2003. At that time, the aircraft had a total time in service (TTIS) of 24,704 hours.

Aircraft system of maintenance

The aircraft had been maintained as a Class A[15] aircraft in accordance with the operator's approved system of maintenance. That system was approved by the Civil Aviation Safety Authority (CASA) under the provisions of Civil Aviation Regulations 1988 (CAR), r. 39(2)(a).

The approved system of maintenance for the operator's Metro aircraft was based on the aircraft manufacturer's scheduled inspection program comprising six phase and structural inspections. The phase inspections were to be conducted every 170 hours aircraft time in service, with all six inspections being completed over a 1,020 hour cycle every 12 months. The approved system of maintenance included an IFR radio inspection that was scheduled for completion every 340 hours aircraft time in service.

The aircraft was issued with an operator's maintenance release, Form TM 9 serial number 005, on 17 April 2005. The maintenance release was valid until 17 April 2006 or 26,975.8 hours, whichever came first. Maintenance required prior to the expiry of the maintenance release was recorded in the operator's *Flight/Maintenance Log*, which was carried onboard the aircraft. The log was completed by flight crew whenever there was a maintenance issue with the aircraft. Copies of the log were normally forwarded to the operator's Maintenance Controller and maintenance facility at the completion of each day's operations. Any entry in the log, other than a permissible unserviceability listed in the

15 Civil Aviation Regulations 1988, r.2(1) defined the term Class A aircraft to mean '… an Australian aircraft, other than a balloon, that satisfies either or both of the following paragraphs:
(a) the aircraft is certificated as a transport category aircraft;
(b) the aircraft is being used, or is to be used, by the holder of an Air Operator's Certificate which authorises the use of that aircraft for the commercial purpose.'

operator's approved minimum equipment list (MEL), would result in the aircraft being deemed unserviceable until the defect was rectified and the entry was signed off by a licensed aircraft maintenance engineer.

The last recorded entry in the log was on 5 May 2005 regarding the unserviceability of the copilot's flight instrument lighting. That unserviceability was covered by the MEL, which permitted operation of the aircraft with those lights being unserviceable. The MEL required rectification work on the lights to be carried out by 16 May 2005.

An extensive search was conducted at the accident site for aircraft documentation, but the original *Flight/Maintenance Log* was not located, and very little documentation was recovered from the site due to the intense, fuel-fed, post-impact fire. There was no other evidence found to indicate that the aircraft was other than serviceable at the commencement of the accident flight.

1.6.5 Weight and balance

While a load sheet relating to the accident flight could not be located, the investigation estimated that the weight of the aircraft at the time of the accident was below the maximum take-off and landing weights specified in the aircraft's *Approved Airplane Flight Manual*. However the centre of gravity position could not be conclusively determined (see Appendix C).

1.7 Meteorological information

1.7.1 Area forecast

The valid Bureau of Meteorology (BoM) forecast that was available to the crew prior to departure from Cairns, for meteorological forecast area 45[16] indicated that there would be isolated showers in the area until 1200. The wind direction up to FL 140 was from the southeast and wind speeds were between 15 and 20 kts. The forecast indicated broken stratus cloud with a base of 1,000 ft, tops of 3,000 ft in precipitation. There was scattered[17] cumulus 2,000 to 9,000 ft with the base at 4,000 ft over land. There was also scattered stratocumulus 4,000 to 8,000 ft over the sea and east coast ranges, becoming locally broken. The visibility for this forecast indicated 4,000 m in showers of rain.

1.7.2 Aerodrome forecasts

Original aerodrome forecast

The BoM issued the following terminal aerodrome forecast (TAF) for Lockhart River Aerodrome at 0416 on 7 May 2005. This TAF was available to the crew prior to departure from Cairns.

16 Meteorological forecast area 45 included the route from Cairns to Bamaga.

17 Scattered refers to 3 to 4 eighths of the sky obscured by cloud.

TAF YLHR 061816Z 2008 12014KT 9999 - SHRA SCT030
T 24 26 28 28 Q 1011 1013 1013 1011

TAF Interpretation

Terminal aerodrome forecast for Lockhart River Aerodrome, issued on 7 May 2005 at 0416 local time, with a validity period from 0600 to 1800 local time. Wind 120 degrees true at 14 knots; visibility 10 km or greater; light rain showers; cloud, three to four eighths sky coverage, with a cloud base of 3,000 ft above aerodrome elevation.

Temperature and QNH at the commencement of the validity period, 0600 will be 24 degrees C and 1011 hPa; at 0900 will be 26 degrees C and 1013 hPa; at 1200 will be 28 degrees C and 1013 hPa; at 1500 will be 28 degrees C and 1011 hPa.

Amended aerodrome forecast

The BoM issued the following amended TAF at 0922 on 7 May 2005.

TAF AMD YLHR 062321Z 2308 13015G25KT 9999 – SHRA FEW010
BKN025
TEMPO 2302 4000 SHRA BKN010
INTER 0208 4000 SHRA BKN010
T 25 27 27 25 Q 1013 1012 1011 1012

Amended TAF Interpretation

Terminal aerodrome forecast amended for Lockhart River Aerodrome, issued on 7 May 2005 at 0921 local time, with a validity period from 0900 to 1800 local time. Wind 130 degrees true at 15 knots, gusting to 25 knots; visibility 10 km or greater; light rain showers; cloud of one to two eighths coverage with a base of 1,000 ft and five to seven eighths coverage with a base of 2,500 ft above aerodrome elevation.

For periods of 30 minutes or more, but less than one hour, between 0900 and 1200, the visibility will be 4,000 m in moderate rain showers; and the cloud cover broken with a base of 1,000 ft above aerodrome elevation.

For periods of less than 30 minutes, between 1200 and 1800, visibility will be 4,000 metres in moderate rain showers, and the cloud broken coverage with a base of 1,000 ft above aerodrome elevation.

Temperature and QNH at the commencement of the validity period, 0900 will be 25 degrees C and 1013 hPa; at 1200 will be 27 degrees C and 1012 hPa; at 1500 will be 27 degrees C and 1011 hPa; at 1800 will be 25 degrees C and 1012 hPa.

At 0932, Brisbane ATC advised the crew:

> Tango foxtrot uniform…hazard alert[18] for you. An amended aerodrome forecast has just come out on Lockhart River. It now has a tempo period from two three zero zero till zero two zero zero. Visibility four thousand metres, moderate rain, cloud broken one thousand, and it also shows wind gusts in the main body of the TAF. Wind one three zero degrees, one five, gusting two five knots.

The pilot in command acknowledged and requested the QNH. The controller advised that the QNH from 0900 local time was 1013 hPa.

1.7.3 Actual weather observations

The BoM Automatic Weather Station (AWS) located at the Lockhart River Aerodrome was configured to record data at 10 minute intervals. It recorded wind, temperature and rainfall data. In the period from 1140 until 1150, which encompassed the estimated time at which the aircraft collided with the terrain, the AWS recorded the following:

> Average wind direction 136 degrees; average wind speed 9kt, maximum wind speed 14 kt; air temperature from 24.6°C to 26.0 degrees C and QNH 1013.1 hPa.

Observations were made at the aerodrome at 0900, 1200 and 1500 on the day of the accident. The 1200 synoptic observation was recorded as:

> Temperature 25.4 degrees C; dew point[19] temperature 23.5 degrees C; mean sea level pressure 1012.8 hPa; wind from the south-east at 8 knots; rainfall 0.4mm; present weather, rain within past hour; past weather, moderate intermittent rain.

The visible satellite imagery covering the Cape York region at 1125 on the day of the accident is shown in Figure 12.

Based on the 0900 observer's report, the AWS recordings between 1100 and 1200 and the visible satellite image of 1125, the BoM estimated that the weather conditions in the Lockhart River area at the time of the accident were overcast, with broken low cloud, with a cloud base between 500 ft and 1,000 ft AMSL. The wind was from the south-east at between 10 and 15 knots, with occasional squally rain showers and intermittent drizzle. Those general conditions were confirmed by persons at Lockhart River.

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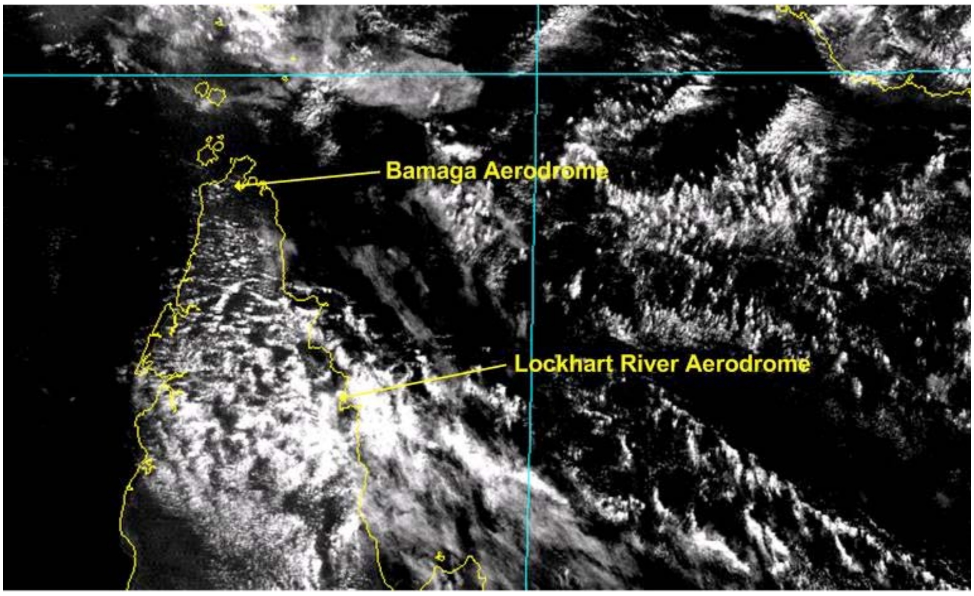
18 Hazard alerts relating to weather are issued when observations, pilot reports, or amended forecasts at the destination have unexpectedly deteriorated below the instrument flight rules or visual flight rules alternate minima. Tempo period refers to temporary fluctuations in meteorological conditions, lasting for periods of less than one hour in each instance. This covered the period when the aircraft was making the approach to land.

19 Dewpoint refers to the temperature at which, under ordinary conditions, condensation begins in cooling mass of air.

Figure 12: Satellite picture 1125, 7 May 2005



1.8 Aids to navigation

1.8.1 Global navigation satellite systems (GNSS)

Background

Global navigation satellite systems (GNSS) are capable of extremely accurate position fixing using a constellation of orbiting satellites. The first operational satellite system was the Global Positioning System (GPS) operated by the US Department of Defence. GPS uses a passive ranging method with the satellites being the active transmitters and the aircraft equipment being the passive receiver. The receiver calculates the position of the aircraft using the known position of four or more satellites and the times of arrival of the signals from each of those satellites. The GPS has been used in Australian aviation as a source of primary means navigation since December 1995 for en-route IFR navigation and since January 1998 for non-precision approaches.

System integrity

The integrity of the system was based on its ability to provide warnings to flight crew if a GPS satellite was transmitting erroneous signals. The Garmin GPS 155XL receiver fitted to VH-TFU provided integrity monitoring by a software function termed Receiver Autonomous Integrity Monitoring (RAIM). The RAIM function verified the integrity of position information from each satellite by using signals from multiple satellites and barometric information provided by the pilot in command's encoding altimeter. The RAIM function was continuously performed by the receiver to either detect the failure of a satellite or to determine if the fault detection could not occur because of the geometry of the satellite constellation. In either case the receiver would warn the crew that the system was not to be used for navigation.

The availability of the RAIM function was dependent on the number and geometry of satellites visible to the receiver. Airservices Australia[20] provided a RAIM Prediction Service for flight planning purposes for aerodromes with an approved RNAV (GNSS) approach. No RAIM outages were predicted for Lockhart River Aerodrome on the day of the accident. The pilot of an aircraft engaged on an unrelated search and rescue mission approximately 200 NM east of Lockhart River Aerodrome reported a 'RAIM failure' between 1120 and 1150 which lasted for between 10 and 50 seconds.

Examination of the recorded satellite data for the duration and route of the accident flight found that there were no system anomalies and that the satellite constellation provided adequate signals for navigation. There were ten satellites in view at Lockhart River at the time of the accident, all with an elevation greater than 5 degrees above the horizon.

An indicator of how close the GPS satellite constellation is to the optimum geometric relationship with the aircraft receiver is the Dilution of Precision (DOP) figure. The horizontal value of DOP (HDOP) indicates the level of accuracy of the latitude and longitude computations by the GPS receiver. A low value of HDOP indicates better constellation geometry and a lower error in position computations. The calculated HDOP at Lockhart River at the time of the accident was less than 1, and would have resulted in little effect on the accuracy of lateral navigation information being provided by the aircraft's GPS receiver.

Interference

The possibility that navigation information provided to the crew from the aircraft GPS receiver was corrupted by on board use of portable electronic devices was examined. The investigation reviewed all mobile telephone activity at the Lockhart River base station. No telephone calls were recorded as being transmitted through this base station during the latter part of the accident flight. The likelihood of interference occurring from other electronic sources was considered remote, as the FDR information showed that the aircraft accurately tracked along the RNAV (GNSS) approach from the turn at waypoint LHRWI for about 6.5 NM until the point of impact.

Waypoint co-ordinates

Waypoint co-ordinates for RNAV (GNSS) non-precision approaches were stored in a navigation database on a data card, similar to a computer flash memory card. The data card was inserted into the aircraft's GPS receiver. The data card co-ordinates could not be edited by the flight crew. The updated database was downloaded from the Jeppesen website every 28 days by the operator's administration personnel in Brisbane who loaded the information onto Garmin GPS data cards, which were then forwarded to the Cairns Base. The data cards were inserted into the aircraft's GPS unit by one of the operator's flight crew. The database in use in the aircraft at the time of the accident was valid from 14 April 2005 until 12 May 2005. It was standard practice for the pilots to verify that the correct database was in place before programming the GPS before each flight.

20 Airservices Australia was the air traffic services provider.

There were no problems reported by the operator's pilots with this database. The investigation subsequently verified that the co-ordinates for the Lockhart River Runway 12 RNAV (GNSS) approach waypoints were correct.

The data card was not located in the aircraft wreckage.

1.8.2 Ground-based navigation aids

Lockhart River Aerodrome was serviced by a ground based non-directional beacon (NDB) for which an instrument approach procedure had been designed. There were no notices to airman valid on the day of the accident indicating that there were any operational abnormalities with the NDB. There were no reports received to indicate any failure or malfunction of the NDB on the day of the accident.

The aircraft was equipped with an automatic direction finding receiver that was able to display the bearing of the aircraft from the NDB. The *En-Route Supplement Australia* (ERSA) was an Australian operational document published by Airservices Australia and used by pilots. The ERSA indicated that the range of the NDB was 30 NM over land. A notice in the same section indicated that fluctuations in the bearing indication of up to 30 degrees could be expected from 8 NM in the sector approaching the NDB of between 300 and 325 degrees magnetic. The track of the aircraft from Bamaga was outside that sector.

1.9 Communications

All communications between air traffic services (ATS) and the crew were recorded by ground-based automatic voice recording equipment for the duration of the flight. Radio transmissions made by the crew on the Lockhart River common traffic advisory frequency (CTAF) were recorded on the aerodrome automatic voice recording equipment. The quality of the aircraft's recorded transmissions was good. Radio transmissions from the aircraft did not indicate any aircraft anomalies.

1.10 Aerodrome information

Lockhart River was a non-towered aerodrome[21] that was 77 ft above mean sea level and had a single runway that was aligned in the 12/30 (119 degrees/299 degrees magnetic) direction. The runway width was 30 m and the length was 1,500 m. The runway strip width was 90 m. It had one windsock located on the northern side of the strip.

The aerodrome was located on a coastal plain 4.5 km west of the Lockhart River township. The Great Dividing Range was nearby with the terrain rising to over 800 ft to the south-west and west within about 8 km of the aerodrome (Figure 13). The highest terrain in the vicinity was Mount Tozer at 1,787 ft, which was located 11 km west-north-west of the aerodrome and about 4 km south of the accident site at South Pap. There was a valley between Mt Tozer and the accident site.

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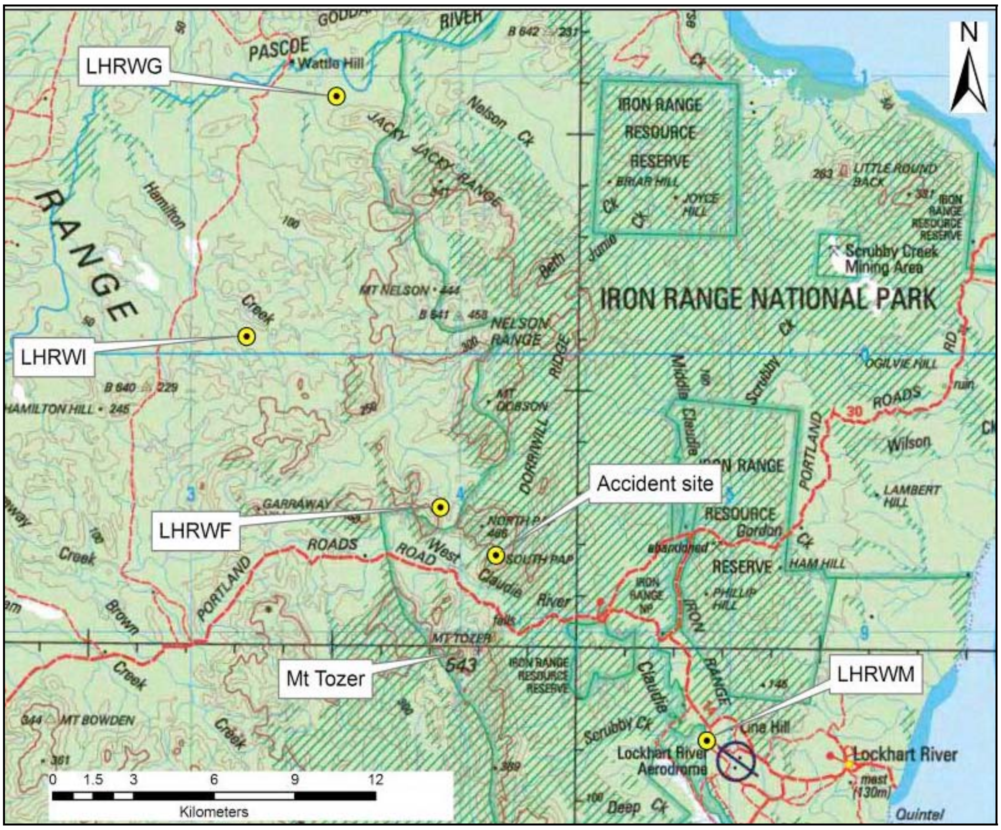
21 A non-towered aerodrome was a term for an aerodrome not served by an operating air traffic control tower.

Figure 13: Topographical map of Lockhart River area



1.11 Flight recorders

The aircraft was equipped with a flight data recorder and a cockpit voice recorder. The recorders were recovered from the accident site and transported to the ATSB laboratories in Canberra.

1.11.1 Flight data recorder (FDR)

The FDR contained approximately 100 hours of data[22], including data relating to the entire accident flight. Analysis of the data provided valuable information about the aircraft's flight profile leading up to the accident. The FDR Factual Report is attached at Appendix A.

Figure 4 on page 6 shows an Airservices Australia Runway 12 RNAV (GNSS) instrument approach chart for Lockhart River overlayed with the FDR derived flight profile of the aircraft. It is apparent that the crew was accurately tracking after the LHRWG waypoint. Some excursions from the recommended vertical profile can be seen after passing LHRWG. After passing LHRWF waypoint, the aircraft descended below the segment minimum safe altitude of 2,060 ft.

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22 The FDR compressed the flight data prior to it being recorded and, as a result, the recording duration of the recorder exceeded the minimum requirement of retaining the most recent 25 hours.

1.11.2 Cockpit voice recorder (CVR)

Analysis of the 30 minute CVR tape indicated that it contained a mixture of electrical pulses and fragments of conversations that were identified as being from previous flights and ground operations. Technical advice was sought from the US National Transportation Safety Board and the UK Air Accidents Investigation Branch to confirm the investigation's findings. Recorder specialists from both organisations verified that recovery of useable data from the CVR was not possible.

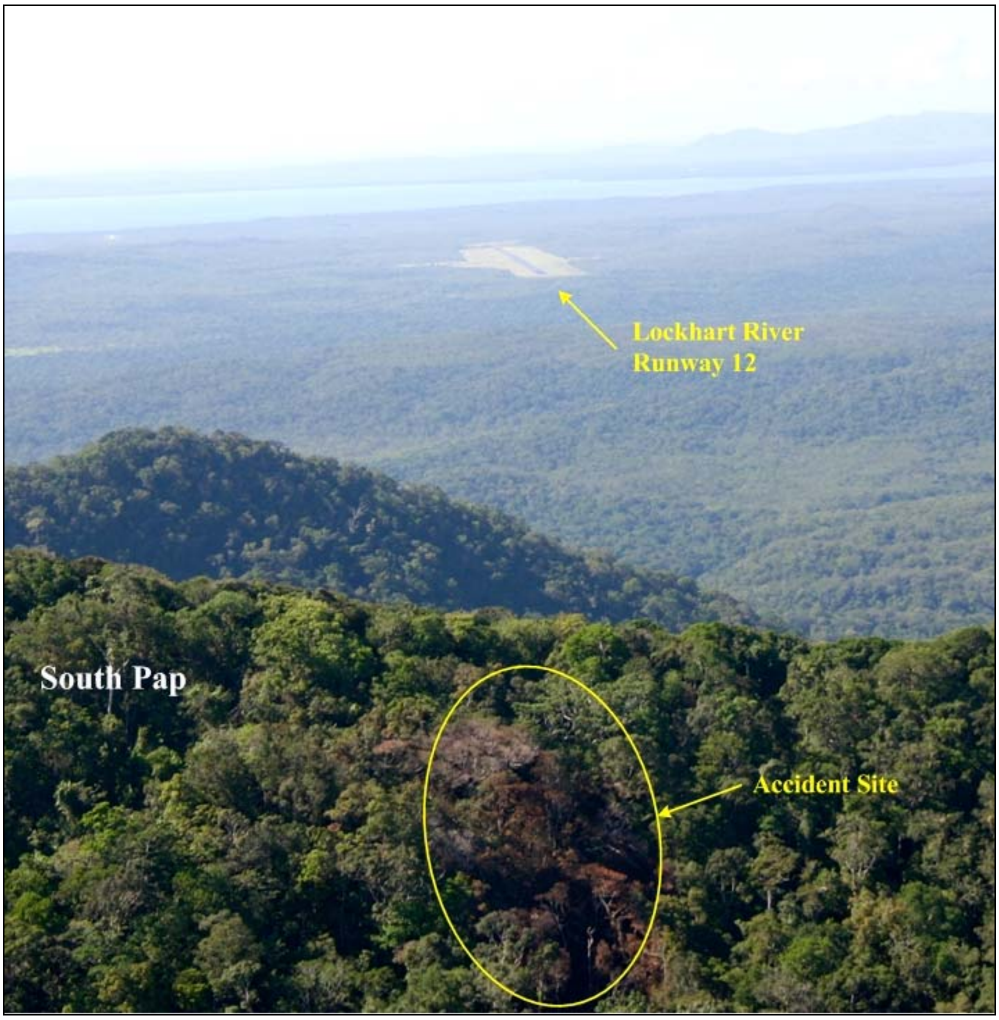
The serviceability of cockpit voice recorder systems was the subject of two recommendations (R20060005 to CASA and R20060006 to Department of Transport and Regional Services) issued by the ATSB on 10 February 2006 (Section 2 Safety Action). The ATSB is continuing to analyse the CVR data in an attempt to further understand the malfunction of the CVR system.

1.12 Wreckage and impact information

1.12.1 Accident site description

The accident site was located on the north-west side of South Pap, a ridge in the Iron Range National Park. The wreckage lay in dense tropical rainforest, at an elevation of 1,210 ft (369 m), on a bearing of about 304 degrees magnetic from the threshold of runway 12, at a distance of 11 km (Figure 14). The height of the initial impact with trees was about 90 ft below the crest of the ridge.

Figure 14: General view of the accident site looking toward the south east



1.12.2 General wreckage description

The aircraft had entered the rainforest canopy in an approximately wings level attitude at a flight path descent angle of about 4 degrees, with the landing gear and wing flaps extended. The aircraft pitch attitude at the time of collision with the trees could not be determined. The aircraft began to break up immediately after entering the rainforest and destruction of the aircraft was consistent with successive impacts with trees and large boulders during the impact sequence. The wreckage trail was about 120 m in length and aligned on a track of about 101 degrees magnetic.

As the aircraft flew through the crowns of the trees, the outboard sections of both wings and the blades of both propellers were separated from the aircraft (Figure 15).

Figure 15: Wing section showing impact damage with a tree trunk or branch

The aircraft continued along a descending flight path contacting tree trunks and branches. This resulted in further sections of both wings, the engines and sections of the horizontal stabiliser and elevators being torn off. The nose of the aircraft then contacted boulders and broke up. The remaining left wing structure then impacted a rock outcrop causing the fuselage to roll to the right approximately 50 degrees (Figure 16).

Figure 16: View along the direction of travel showing the rock outcrop and main wreckage in the background

The remaining wreckage then continued about 20 m up the steeply sloping ground before stopping, and was then consumed by an intense, fuel-fed, post-impact fire (Figure 17).

Figure 17: The rear fuselage section

1.12.3 Structure

The aircraft structural damage was consistent with the application of excessive structural loads during the impact sequence, and the effects of the subsequent fire. No pre-existing defects likely to have contributed to the aircraft break-up were found.

1.12.4 Flight controls

No evidence was found of any pre-existing defect or malfunction of any part of the flight control system.

1.12.5 Engines and propellers

Both engines and propellers sustained severe impact damage. There was evidence that both engines were delivering similar power at impact. The damage to the blades was consistent with the propellers rotating at power, at normal operating RPM.[23]

There was no evidence of any pre-existing problems with the engines.

1.12.6 Landing gear

The landing gear hydraulic actuators were found with their piston shafts bent in the extended position, indicating that the landing gear was extended at the time of impact.

1.12.7 Cockpit instruments and systems

Impact damage to the cockpit area resulted in most of the instruments and systems being destroyed. However, the following components were recovered from the accident site and examined at the ATSB engineering laboratory.

Global positioning system annunciator/control unit

Examination of light globes from the GPS annunciator/control unit indicated that the aircraft system was receiving electrical power at impact. The three switches that formed part of the unit were not located in the wreckage (Figure 18).

23 See Appendix A for engine parameters as recorded by the flight data recorder.

Figure 18: MD-41 annunciation/control unit

Barometric altimeters

The pilot in command's altimeter was impact damaged with the glass face broken but still attached to the unit. The drum scale indicated an altitude of 1,200 ft and the pointer 63 ft. The barometric pressure scale setting was 1010.5 hPa (Figure 19).

Figure 19: Pilot in command's encoding altimeter

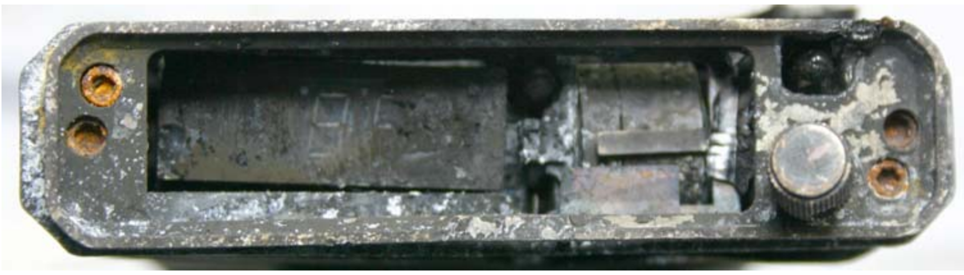
The copilot's altimeter was severely damaged by the impact, with the glass face destroyed, the instrument face depressed inward and the three pointers missing from the spindle. There were numerous marks on the face, including two marks near the numeral marking '2' which may have been contact marks from the 'hundreds' pointer. The barometric pressure scale setting was 1012 hPa (Figure 20).

Figure 20: Copilot's altimeter

Digital radio altimeter indicator

Examination of the digital radio altimeter indicator unit (Figure 21) showed that the decision height setting was about 920 ft, with the warning flag in view. Examination of the light globes from the decision height annunciator and circuit card was inconclusive.

Figure 21: DRI-55 digital radio altimeter indicator



1.12.8 Components not located in wreckage

All major components were accounted for at the accident site with the exception of the following components, which were considered relevant to the investigation, but were not located in the wreckage:

- outboard section of the right aileron
- left front baggage compartment door
- one propeller blade
- GPS navigation receiver
- radio altimeter transmitter/receiver and antennae
- altitude alerter

- GPWS computer and air data module
- emergency locator transmitter.

It is likely that those missing components were either thrown well clear of the main wreckage site during the impact sequence and lost in the thick vegetation, or had been consumed by the intense post-impact fire.

1.13 Medical and pathological information

There was a delay between the discovery of the aircraft wreckage and the recovery of the flight crew and the time of the post-mortem examinations. This delay placed constraints on the information that was collected during the examinations.

There was no evidence found during the post-mortem examination of each crew member of physiological factors that would have affected their performance.

Due to the nature of the samples recovered from the crew, toxicological examination for the detection of alcohol was not able to be performed. Toxicological examination of tissue samples from both crew members did not reveal the presence of any drugs.

Within the limitations imposed on the samples because of their condition, there was no evidence of in-flight incapacitation of crew or passengers from either toxic fumes or fire.

1.14 Fire

Site examination indicated that the aircraft fuel tanks were disrupted during the impact sequence resulting in an intense post-impact fire that consumed most of the fuselage and cabin interior. The ignition of the fuel probably resulted from electrical arcing and/or contact with high-temperature engine components. There was no evidence of an in-flight fire.

1.15 Survival aspects

The accident was not considered to be survivable due to the severity of the impact forces.

1.16 Tests and research

1.16.1 Perceived pilot workload and perceived safety of RNAV (GNSS) approaches safety study

Below is a summary of a large research study conducted by the ATSB that is linked to this investigation. The full report of this study is also available from the ATSB internet site (www.atsb.gov.au).

Objectives

The objective of this research project was to gain an understanding of the experiences and perceptions of RNAV (GNSS) approaches in Australia from pilots who are currently using these approaches. Specific objectives were to understand pilot perceptions of:

- pilot workload during an RNAV (GNSS) approach;
- ability to maintain situational awareness during an RNAV (GNSS) approach;
- ease of approach chart use during an RNAV (GNSS) approach;
- how safe RNAV (GNSS) approaches are; and
- which aspects of RNAV (GNSS) approach and chart designs contribute to these perceptions.

Methodology

A survey was mailed to all Australian pilots with an RNAV (GNSS) approach endorsement on their instrument rating. The first part of the survey asked for assessments on a range of approach types, including visual (day), visual (night), instrument landing system (ILS), distance measuring equipment (DME) Arrival, Very-high-frequency omni-directional radio range (VOR) /DME, NDB, and RNAV (GNSS) approaches. This was done so perceptions about the RNAV (GNSS) approach could be contrasted with other approaches. Assessments were given for the following Likert scales[24]: preparation time and effort; mental workload; physical workload; time pressure; approach plate interpretability; situational awareness; and safety.

Part 2 of the survey involved open-ended answers to questions specifically dealing with the RNAV (GNSS) approach. Respondents were asked to write which aspects of the RNAV (GNSS) approach contributed to mental workload, physical workload, time pressure, approach plate interpretability, and safety. Separately, they were asked to indicate if any aspects of the RNAV (GNSS) approach could be improved, what were the circumstances in which they were the most difficult, and were there any particular locations where they were difficult. Part 2 also queried respondents about training and equipment, and asked them to indicate the details of any incident they had been involved in during an RNAV (GNSS) approach.

Part 3 of the survey involved pilot experience, both in general and for each approach type specifically. It also asked respondents to indicate their main method of flying each approach, either using autopilot or by hand-flying, and whether they conducted each approach mainly inside or outside of controlled airspace.

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24 Likert scales are continuous rating scales. All scales had seven points (1 representing low/easy/safe and 7 representing high/difficult/dangerous) except situational awareness which had a four point scale (1 representing no experienced losses of situational awareness, 2 few losses, 3 losses sometimes, and 4 losses often).

Demographic data

There were 748 surveys completed and returned to the ATSB, a response rate of 22%. Survey responses were received from pilots from a broad spectrum across the aviation industry. Survey responses were received pilots across a broad spectrum of the aviation industry Respondents were placed in groups based on the main aircraft type they operated using aircraft performance categories. The three main groups were Category A aircraft (typically small single and twin-engine aircraft), Category B aircraft (typically larger twin-engine propeller aircraft), and Category C aircraft (typically high capacity RPT airliners). A Metro 23 aircraft was in the category B aircraft approach performance category.

Findings

Pilot workload was perceived as being higher for the RNAV (GNSS) approach than all other approaches except the non-directional beacon (NDB) approach, which involved similar workload levels.

Respondents indicated they have had trouble maintaining situational awareness more often on the RNAV (GNSS) approach than each of the other approaches except for the NDB approach.

Respondents indicated that they perceived the RNAV (GNSS) approach as safer than an NDB approach, equivalent to a visual approach at night, but perceived it as less safe than all other approaches included in the survey.

The runway alignment of RNAV (GNSS) approaches was reported as increasing safety by 30% of respondents.

There were some differences between the responses from pilots from Category C aircraft (mostly high capacity aircraft) and those from Category A and B aircraft. The slower Category A and B aircraft results were as above. However, pilots from Category C aircraft typically rated workload, situational awareness and safety as no worse than other non-precision approaches. These differences were likely to have been due to two main reasons. Firstly, the Category C conduct RNAV (GNSS) approach mostly using autopilots and have more sophisticated autopilot systems and vertical navigation (VNAV) capabilities not available to the slower and less complex aircraft. Secondly, high capacity airline pilots mostly conducted RNAV (GNSS) approaches inside controlled airspace while the Category A and B aircraft mostly operated RNAV (GNSS) approaches outside controlled airspace where the latter increased workload levels during an approach. More detailed approach briefings and company approach procedures in high capacity airlines probably also contribute to the differences found.

The concern most respondents had regarding the design of RNAV (GNSS) approaches was that they did not use references for distance to the missed approach point on the approach chart and global positioning system (GPS) or flight management system (FMS) display. This response was common from respondents in all types of aircraft categories, and was listed as affecting all areas of this survey. It was one of the most common issues influencing mental workload, approach chart interpretability, and perceived safety, influenced physical workload and time pressure assessments, and the most common aspect of the approach that trainees took the longest to learn. The inclusion of distance to the missed approach point on the cockpit display and approach chart was also the most common improvement suggestion by respondents.

Short and irregular segment distances, and multiple minimum segment altitude steps were also identified as a major concern for many pilots. They were listed as the most common reason why pilots experience time pressures and were one of the most commonly mentioned contributions to mental workload, physical workload, lack of approach chart interpretability, and perceived lack of safety. These sub-optimal characteristics were common in the list of aerodromes considered to have the most difficult RNAV (GNSS) approaches, including Lockhart River.

Approach chart interpretability was rated as more difficult for the RNAV (GNSS) approach than all other approaches, and by all aircraft performance categories. Unlike the non-directional beacon (NDB) and ILS approach charts, ease of interpretation did not increase with the number of approaches conducted per year.

The naming convention of using five capital letters for waypoint names with only the final letter differing to identify each segment of the approach was reported to cause clutter on the charts and GPS and FMS displays, and also to increase the chance of a pilot misinterpreting a waypoint.

The amount of time and effort required to prepare for an RNAV (GNSS) approach was reported as higher than for all other approaches.

Most (86%) respondents considered their RNAV (GNSS) endorsement training to have been adequate. Of the 14% who considered it not to have been adequate, the most common reason given was that not enough approach practice had been given.

Flight instructors who answered the survey indicated that the most common problem trainees had with learning the RNAV (GNSS) approach was maintaining situational awareness, often related to becoming confused about which segment they were currently in and how far away they were from the runway threshold.

There were 49 respondents who reported that they had been involved in an incident involving RNAV (GNSS) approaches. The most common incident (15 respondents) was commencing the descent too early due to a misinterpretation of their position, and a further three respondents indicated that they misinterpreted their position but that this was discovered before they started to descend too early. Another five incidents were reported from other losses of situational awareness. A further four respondents indicated that they had descended below the constant angle approach path and/or minimum segment steps.

1.16.2 Flight crew RNAV (GNSS) approach workload measurement

Objectives

The objective of this separate study was to measure pilot workload of the Lockhart River runway 12 RNAV (GNSS) approach. This was performed in a Level D flight simulator[25]. Specific objectives related to comparing subjective and objective pilot

25 A level D flight simulator is capable of simulating the entire flight characteristics and systems operation of a particular type of aircraft. It is fitted with high fidelity motion, sound and visual systems to provide realistic sensory cues.

workload during the runway 12 RNAV (GNSS) approach, which had variable distance segments and a 3.49 degree constant angle approach path with:

- the Lockhart River runway 30 RNAV (GNSS) approach which had 5 NM segments and a 3 degree constant angle approach path (as recommended by ICAO)
- the autopilot engaged and disengaged.

Methodology

A de Havilland Canada DHC-8 flight simulator was used with a type endorsed airline flight crew consisting of a senior pilot in command and a junior copilot. After flying approaches and landings into Lockhart River and Bamaga with the copilot as the handling pilot, similar to what was likely to have occurred on the day of the accident, the crew conducted the Lockhart River runway 12 RNAV (GNSS) approach. The runway 12 approach was operated with the pilot in command as the handling pilot, the autopilot disengaged, in instrument meteorological conditions (IMC) and with some turbulence, as occurred on the accident flight. The crew then conducted the Lockhart River runway 30 RNAV (GNSS) approach under the same conditions, followed by the runway 12 RNAV (GNSS) approach again, but this time using autopilot.

Pilot workload was measured using both objective and subjective measures. The simulator sessions were video taped and aircraft control and trim manipulations were counted for each pilot. A second objective workload measure was the number of verbal communications and words spoken in total. These measures were converted to a rate per minute as the two approaches occurred over different elapsed times. At the end of each flight, each pilot completed the subjective workload questionnaire NASA-TLX[26]. This had six scales (mental demand, physical demand, temporal demand, performance, effort, and frustration) and used 7 point Likert scale judgements (see footnote 24). Weightings were obtained by each pilot rating the importance of each scale at the end of the session.

Findings

With the autopilot disengaged, the runway 12 RNAV (GNSS) approach differed from the less complex runway 30 approach only in verbal communication. There were no differences in the amount of aircraft manipulation or subjective pilot workload. The subjective workload ratings probably reflected the similar aircraft manipulation required. However, more communications were required, and the pilot not flying was required to communicate more words and more sentences for each minute than during the runway 30 approach.

The approach to runway 12 with the autopilot engaged resulted in a significant reduction in the amount of aircraft control manipulation and trim adjustments required by the handling pilot. As a result, the handling pilot had more attention available for other tasks, as was seen by an increased number of communications

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26 The subjective workload questionnaire used was the NASA-task load index, as described by Hart & Staveland (1988) in P. A. Hancock & N Meshkati (Eds.), *Human Mental Workload* (pp. 139-184).

from him. This in turn reduced the amount of communication that was needed from the non-handling pilot. As a result, subjective pilot workload (mental demand and effort scales in particular) was considerably lower for both pilots when the autopilot was engaged.

1.17 Organisational and management information

1.17.1 Navigation charts

Pilots employed by the operator were expected to use maps and charts produced by Jeppesen Sanderson Inc. (Jeppesen) and both pilots held current subscriptions to the Jeppesen chart amendment service. Although those charts were produced by Jeppesen, they were developed from data published by Airservices Australia. Due to the post-impact fire, the investigation was unable to determine whether both crew members were carrying the appropriate charts for the flight.

1.17.2 Human factors management

The company operations manual included the following requirement:

> All new company pilots shall complete the Human Factors Management (HFM) induction course…within 6 months of joining the company; and
>
> All company pilots shall complete a recurrent HFM course…every 15 months.

This requirement had been in the operations manual since October 2000. Human factors management courses are designed to teach flight crew the non-technical skills essential for operating in a multi-pilot team in a complex time-critical environment. No record could be located to indicate that the pilot in command had completed the Human Factors Management Induction Course or any Human Factors Management recurrent training course since commencing employment with the operator in 2001. There was also no record of the copilot having completed the Human Factors Management Induction Course since his appointment in 2004. However, he was still within the 6 months period as specified in the operations manual.

1.17.3 RNAV (GNSS) approaches

The company operations manual included the following requirements that related to the use of GPS for non precision approaches (GPS/NPA), such as the Lockhart River Runway 12 RNAV (GNSS) approach:

> Flight crew are to:
>
> - hold endorsements for GPS Primary means navigation and GPS/NPA
>
> - have been assessed as proficient
>
> - meet the GPS recency requirements.

The operator did not have a requirement for flight crew to hold an RNAV (GNSS) endorsement on their instrument rating. The operator did not track pilot recency for RNAV (GNSS) approaches.

Factors for a crew to consider when using GNSS to conduct a non-precision approach such as the Lockhart River 12 RNAV approach were provided in the company operations manual. This guidance included the following:

> Activation of the GPS NPA will cancel the active flight plan and tracking guidance will be to the Initial Approach Fix selected.
>
> Note: Distance information will be to the next position in the approach not the destination.

1.18 On-going investigation issues

The investigation is continuing and among other things, will include further work in the following aspects of the accident:

- the operator's management processes, standard operating procedures, flight crew training and checking, and document control
- regulatory oversight of the operator's activities, including approvals and surveillance undertaken
- the design and chart presentation of RNAV (GNSS) approaches.

Further safety action may also arise from this ongoing investigation and associated research.

2 SAFETY ACTIONS

The following safety recommendations were issued during the course of the investigation.

2.1 Safety recommendation R20060002

Date issued: 24 January 2006

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review and clarify the legal requirements concerning the qualifications for two-crew (pilot) operation during the conduct of instrument approaches in air transport operations. The review should assess the safety benefit arising from ensuring that when an instrument approach is conducted in an aircraft required to be operated by a two-person flight crew, both flight crew members are qualified to conduct the type of approach being carried out.

2.1.1 Response from Civil Aviation Safety Authority

Date Received: 3 April 2006

The Civil Aviation Safety Authority advised the ATSB on 3 April 2006 that it has amended Civil Aviation Order 40.2.1, Instrument Ratings, to clarify the requirement for all instrument rating holders to hold an endorsement for any navigation aid being used to navigate an aircraft (including instrument approaches of which they are a crew member. The amendment does, however, provide an exemption for co-pilot crew members who do not hold an endorsement but have received equivalent training and demonstrated proficiency in the use of the navigation aid while participating in an operator's cyclic training and proficiency programme. The amendment became effective on 25 March 2006.

ATSB Note: The wording of Civil Aviation Order 40.2.1 paragraph 13.3.4 prior to the amendment of 25 March 2006:

> For the purposes of regulation 5.16, it is a condition of each instrument rating that the holder of the rating must use only the types of navigation aids or procedures endorsed in the holder’s personal log book when exercising the authority given by the rating.

The amended wording of CAO 40.2.1 paragraph 13.3.4 is:

> For regulation 5.16, it is a condition of each instrument rating that the holder may act as pilot in command or co-pilot of an aircraft being flown under the IFR only if each navigation aid or procedure that is used to navigate the aircraft during flight has been endorsed in his or her personal log book.

Response Status: Closed - Accepted

2.2 Safety recommendation R20060003

Date issued: 20 January 2006

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the adequacy of current legislation and regulations:

- to assess the safety benefit that could be achieved from the fitment of a serviceable autopilot to all aircraft currently on the Australian civil aircraft register, engaged on scheduled air transport operations
- with a view to ensuring that all aircraft placed on the Australian civil aircraft register after a specified date and intended to be engaged on scheduled air transport operations are equipped with a serviceable autopilot.

2.2.1 Response from Civil Aviation Safety Authority

Date Received: 16 August 2006

CASA has conducted a preliminary review of Civil Aviation Order (CAO) 20.18 and examined the history of changes as they relate to fitment of autopilot equipment. The relevant current provisions in CAO 20.18 have existed since about 1960 and are consistent with current provisions of the US Federal Aviation Administration (FAA) and the European Joint Aviation Authorities (JAA).

A review of CASA data to identify the 'population' of RPT Operators and aircraft that are affected revealed a total of 52 aircraft, 80% of which are the Metro SA227. Some feedback indicates that the standard autopilot approved for this aircraft type is widely known within the aviation industry to be unreliable old technology and expensive. This may account for the fact that few Metro SA227 aircraft are fitted with autopilots. All Australian aircraft operating in high capacity regular public transport operations have approved autopilots fitted.

CASA will consult industry through the Standards Consultative Committee (SCC) before deriving a conclusion on the matter.

Furthermore, CASA has extracted relevant Crew Resource Management/training and Human Factors material out of draft Civil Aviation Safety Regulation Part 121A and is developing a Civil Aviation Advisory Publication. This material is currently with CASA senior managers for comment.

Response Status: Monitor

2.3 Safety recommendation R20060005

Date issued: 10 February 2006

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the maintenance requirements for cockpit voice recording systems and flight data recording systems against international standards such as EUROCAE ED-112 and ICAO Annex 6 with the aim of improving their reliability and increasing the availability of data to investigators

2.3.1 Response from Civil Aviation Safety Authority

Date Received: 16 August 2006

The maintenance and testing requirements for flight data recorders (FDR) and cockpit voice recorders (CVR) are not explicitly defined in Australian regulations. ICAO Annex 6 requirements are accepted as the minimum requirement to be met by operators when submitting Schedules of Maintenance for CASA approval. ICAO Annex 6, Part 1, Attachment D, Flight Recorders, provides guidance for pre-flight checking, inspection and calibration of flight data recording and cockpit voice recording systems.

CASA guidance in relation to flight data recorder maintenance is set out in CAAP 42L-4(0), and includes reference to ICAO Annex 6 and EUROCAE ED-112.

In light of this recommendation, CASA will review the maintenance requirements for flight data recorders and cockpit voice recorders against the relevant international standards, and will consider in particular whether minimum requirements for such maintenance should be prescribed.

In the interim, CASA will review the existing guidance material with a view to providing more specific maintenance interval guidelines.

CASA will be providing additional training in the maintenance of FDR/CVR systems for airworthiness personnel. This will enhance their knowledge in these systems and will assist them when evaluating aircraft systems of maintenance.

Response Status: Closed - Accepted

2.4 Safety recommendation R20060006

Date issued: 10 February 2006

The Australian Transport Safety Bureau recommends that the Department of Transport and Regional Services, with the assistance of the Civil Aviation Safety Authority, pursues further the development of proposals to amend the provisions of Part IIIB of the *Civil Aviation Act 1988*. While recognising the need to have protections to prevent inappropriate disclosure and use of Cockpit Voice Recorder information, the proposals to amend the CA Act should take into account the need to enable approved maintenance organisations to replay in-flight Cockpit Voice Recorder data for legitimate maintenance and testing purposes.

2.4.1 Response from Department of Transport and Regional Services

Date Received: 24 February 2006

In relation to R20060006, I understand that the Australian Transport Safety Bureau (ATSB) is already working on this issue.[27] The Aviation Operations Branch within the Department of Transport and Regional Services is prepared to assist the ATSB as necessary.

Response Status: Monitor

2.4.2 Response from Civil Aviation Safety Authority

Date Received: 16 August 2006

CASA notes that this recommendation is primarily directed to DOTARS [Department of Transport and Regional Services], which is responsible for administration of Part 111B of the *Civil Aviation Act 1988*. In accordance with the recommendation, CASA will cooperate with the Department in the development of any proposals to amend the provisions of Part 111B.

However, CASA notes that there may be no need for a maintenance check of the CVR to be conducted by actually listening to the tape. It is likely that a functional system check can confirm the fidelity of the equipment rather than actually needing to listen to the tapes.

Response Status: Monitor

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27 As of 21 August 2006, the Australian Government Office of Parliamentary Counsel is expected to draft the amendments to the *Civil Aviation Act 1988* during the Spring Sittings of Parliament 2006.

3 APPENDICES

Appendix A: Technical Analysis Report

Appendix B: Honeywell GPWS Mk-VI Simulation

Appendix C: Estimated Aircraft Weight and Balance

Media Release