Australian Government
Australian Transport Safety Bureau

Descent below lowest safe altitude involving Boeing 777, 9V-SRP

40 km SSW of Canberra Airport, Australian Capital Territory, 22 February 2017

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Addendum

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What happened

On the morning of 22 February 2017, a Singapore Airlines Boeing 777-212, registered 9V-SRP, operated scheduled flight SQ291 from Singapore Changi Airport, Singapore, to Canberra Airport, Australian Capital Territory (ACT). There were 13 crew and 235 passengers on board. The instrument landing system (ILS) for runway 35 at Canberra was out of service at the expected arrival time.

Prior to descent to Canberra Airport, the flight crew reviewed the weather conditions for Canberra. Canberra weather observations indicated that the visibility was greater than 10 km and wind conditions favoured runway 35 to be used for landing. As the runway 35 ILS was not available, the flight crew prepared to conduct the Standard Arrival Route (STAR)[1] POLLI FOUR PAPA arrival (Figure 1 left) and associated RNAV-Z[2] approach[3] (Figure 2) for runway 35. As the aircraft was arriving from the west, the flight crew elected to commence the RNAV-Z approach from waypoint[4] SCBSG. The captain, acting as pilot monitoring,[5] entered the arrival and approach into the aircraft's flight management computer (FMC).

As the aircraft descended, air traffic control (ATC) instructed the flight crew to conduct the POLLI FOUR BRAVO arrival (Figure 1 right).

The flight crew had not briefed for this arrival and the first officer, who was pilot flying, identified that the POLLI FOUR BRAVO arrival led to the runway 35 VOR approach.[6] As the POLLI FOUR PAPA and POLLI FOUR BRAVO arrivals were very similar, the flight crew elected to reprogram the POLLI FOUR BRAVO arrival into the FMC while keeping the RNAV-Z approach. The flight crew intended to request the RNAV-Z approach from ATC upon first contact with the Approach controller. As the POLLI FOUR BRAVO arrival did not lead to the RNAV-Z approach, this created a discontinuity[7] in the programmed FMC flight path between the completion of the arrival at waypoint MENZI and the commencement of the approach. To correct this discontinuity, the first officer asked the captain to connect waypoint MENZI to the approach at waypoint SCBSI. In doing so, the waypoint SCBSG was erased from the programmed FMC approach.

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1 Standard arrival route (STAR): A published procedure followed by an aircraft from the enroute phase of the flight to the commencement of the approach.

2 Area navigation (RNAV) approach: An approach flown along a path of GPS waypoints.

3 Approach: A published procedure followed by an aircraft between the conclusion of the STAR and the airport runway.

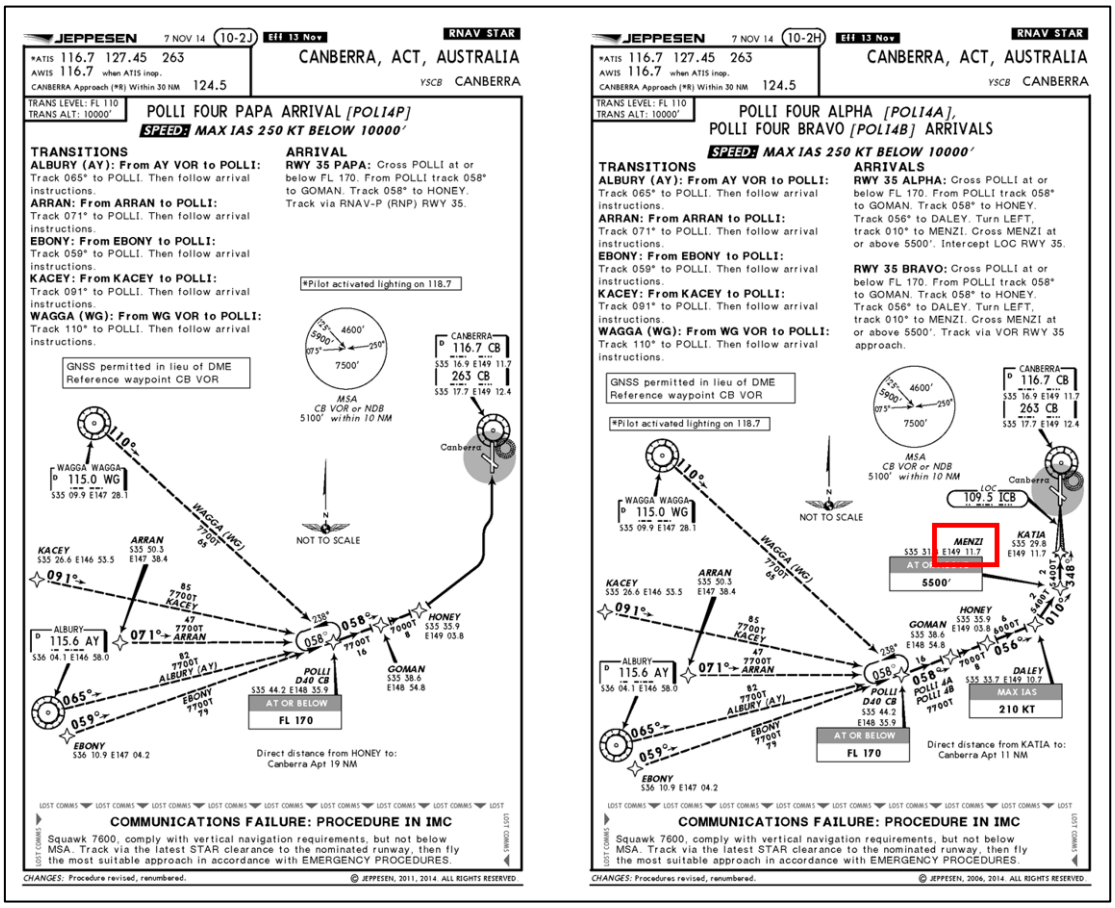
4 Waypoint: A defined position of latitude and longitude coordinates, primarily used for navigation.

5 Pilot Flying (PF) and Pilot Monitoring (PM): procedurally assigned roles with specifically assigned duties at specific stages of a flight. The PF does most of the flying, except in defined circumstances; such as planning for descent, approach and landing. The PM carries out support duties and monitors the PF's actions and the aircraft's flight path.

6 VHF omnidirectional range (VOR) approach: An approach flown using tracking guidance from a ground based VHF transmitter.

7 Discontinuity: Where there is a break in the FMC programmed flight path between waypoints or instrument flight procedures the FMC will indicate a discontinuity. The flight crew will need to input further information into the FMC to complete the programmed flight path.

Figure 1: POLLI FOUR PAPA (left) and POLLI FOUR BRAVO (right) arrivals



Source: Operator (annotated by ATSB)

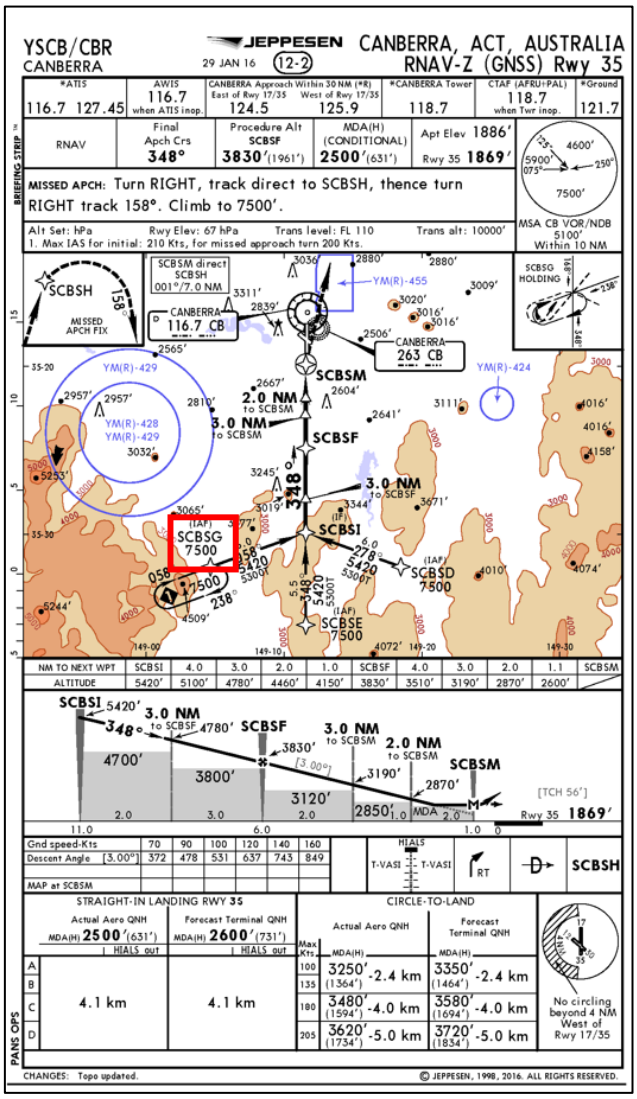
At 0905 Eastern Daylight-saving Time (EDT), the aircraft was about 70 km (38 NM) southwest of Canberra at flight level (FL) 120,[8] with the autopilot engaged. ATC instructed the flight crew to contact the Approach controller. After establishing contact with the flight crew, the Approach controller instructed the flight to continue descending to 9,000 ft above mean sea level (AMSL). The controller advised the flight crew to expect the VOR approach to runway 35.

After the flight crew were advised to expect the VOR approach, they immediately requested the RNAV-Z approach. ATC instructed the flight crew to track to the commencement of the RNAV-Z approach at SCBSG and to expect the RNAV-Z approach. Due to high terrain to the south and southwest of Canberra, the RNAV-Z approach via SCBSG must be commenced from an altitude at or above the minimum sector altitude (MSA) of 7,500 ft. This altitude constraint is included in the FMC programmed flight path when selecting an approach using the arrivals/departures page in the FMC.[9]

[8] Flight level: at altitudes above 10,000 ft in Australia, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 120 equates to 12,000 ft.

[9] When an RNAV-Z approach is selected in the aircraft FMC, all waypoints associated with that approach are programmed into the FMC, including altitude constraints for each leg of the approach. When an individual waypoint is manually entered into the FMC, no altitude constraint is automatically associated with that waypoint.

Figure 2: RNAV-Z Approach



Source: Operator (annotated by ATSB)

After the controller advised the flight crew to expect the RNAV-Z approach, the captain manually re-entered SCBSG into the FMC without detecting that the 7,500 ft MSA constraint was now missing. The captain then manually connected SCBSG to SCBSI for the continuation of the approach.

At 0908, ATC cleared the flight for the RNAV-Z approach. After receiving clearance to conduct the RNAV-Z approach, the first officer entered the final approach fix crossing altitude of 3,900 ft[10] into the autopilot altitude selector. This directed the autopilot to continue descent to 3,900 ft.[11]

At 0909.16 in visual conditions, the aircraft tracked towards SCBSG. About 7.5 NM (13.9 km) prior to SCBSG, the aircraft descended below 7,500 ft (Figure 3). At 0909.37, as the aircraft descended to about 7,000 ft, the controller contacted the flight crew and advised that they were required to maintain 7,500 ft until SCBSG. The flight crew immediately disconnected the autopilot and

[10] The final approach fix crossing altitude was 3,830 ft. As the autopilot altitude selection is made in 100 ft graduations, the first officer elected to use 3,900 ft.

[11] Had the 7,500 ft minimum safe altitude constraint at SCBSG remained in the autopilot, the FMC would have automatically restricted descent to 7,500 ft until passing SCBSG. After passing SCBSG, the descent would then have recommenced and continued to 3,900 ft.

climbed the aircraft to 7,500 ft. After climbing to 7,500 ft, the first officer reconnected the autopilot with 7,500 ft as the selected altitude.

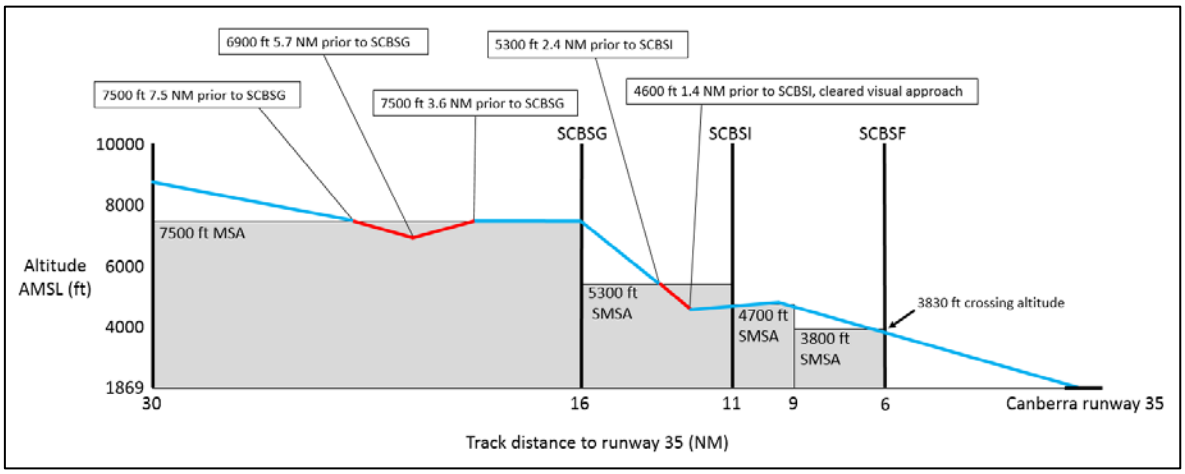
At 0911:24, after the aircraft passed SCBSG, the first officer selected the final approach fix crossing altitude of 3,900 ft in the autopilot altitude selector and the aircraft commenced descending. The segment minimum safe altitude (SMSA)[12] for the leg of the approach from SCBSG to SCBSI was 5,300 ft.

As the aircraft descended through about 6,000 ft, and before they had passed SCBSI, the first officer sighted the runway. The first officer advised the captain that they wished to manually fly the aircraft and conduct a visual approach to runway 35. The captain agreed and the first officer disconnected the autopilot and commenced a manual visual approach. The flight crew did not advise ATC that they were visual and had sighted the runway, or that they had elected to conduct a visual approach.

At 0912.37, about 2.1 NM (3.9 km) prior to passing SCBSI on the segment between SCBSG and SCBSI, the aircraft descended below 5,300 ft. As the aircraft descended to about 4,600 ft the captain commented that the aircraft approach profile was becoming low. At the same time, the controller contacted the flight crew and advised them that the aircraft was below the SMSA and that they were required to maintain 5,300 ft until passing SCBSI. The first officer immediately levelled the aircraft at about 4,600 ft. The flight crew advised the controller that they had the runway and terrain in sight. The controller then cleared the flight to conduct a visual approach. After being cleared for a visual approach, the first officer commenced a climb to about 5,000 ft and re-established the aircraft on the desired approach profile.

At 0917, the aircraft landed on runway 35. The aircraft was not damaged and no persons were injured.

Figure 3: Arrival and approach profile



Source: ATSB, derived from Airservices Australia radar data

Captain comments

The captain of 9V-SRP provided the following comments:

- The runway 35 ILS was not available, therefore the RNAV-Z approach was selected as this approach provided the lowest available minimum descent altitude (MDA).[13] The captain did not

[12] The segments of an RNAV approach between the waypoints include a SMSA. The SMSA are included to provide aircraft with terrain clearance during the approach. When conducting an approach, aircraft should not descend below the SMSA to ensure terrain clearance.

[13] Minimum descent altitude is the lowest altitude to which an aircraft conducting an instrument approach which does not include glideslope guidance may descend. The flight crew must be visual to continue the approach below this altitude or conduct a missed approach.

expect to receive, and had not prepared, for the POLLI FOUR BRAVO arrival and associated VOR approach.

- After receiving the POLLI FOUR BRAVO arrival, the captain elected to delay requesting the RNAV-Z approach until in contact with the Approach controller. The captain was not sure how the clearances were coordinated between different ATC units in Australia and believed it would be simpler to request the approach directly from the Approach controller.
- As the POLLI FOUR BRAVO arrival tracked via MENZI, this presented a smooth transition to the RNAV-Z approach at SCBSI. The captain did not expect ATC to instruct the flight crew to track via SCBSG as this required a left turn from their position to SCBSG, then a right turn to SCBSI, then another left turn onto final approach.
- The waypoint SCBSG should have been added to the FMC programmed flight path by selecting the SCBSG transition using the arrivals/departures page of the FMC. This would have ensured the SCBSG 7,500 ft altitude constraint remained programmed into the FMC.
- ATC should have been advised when they became visual and elected to conduct a visual approach.
- At the time the first officer commenced the visual approach, the runway 35 T-VASIS[14] was not visible.
- During the visual approach, the flight crew used runway visual perspective and attitude along with a check of expected altitudes at specified distances from the runway to assess the approach profile.

Operator report

The operator conducted an investigation into the incident which identified the following points:

- The flight crew fixated on flying the RNAV-Z approach as the crew had briefed and planned for this approach. The approach briefing did not include reversion to conventional navigation.
- Standard operating procedures direct the flight crew to advise ATC when the flight crew have established visual conditions and are flying a visual approach.
- The company operations manual states that flight crew must check FMC waypoints against the arrival chart, the navigation display map and the control display unit. This check shall include the verification of any altitude and speed constraints.
- The flight crew training manual directs flight crew to avoid making manual entries when an approach or transition is available in the FMC, to prevent input errors or omissions.
- Any transition to a visual approach should only be made when the appropriate cues to ascertain vertical profile such as T-VASIS are clearly visible.

Related occurrences

A number of ATSB investigations have examined occurrences relating to deviations in flight path involving foreign crew operating within Australia. Of these, three are summarised below, full reports are available at the *ATSB website*.

ATSB investigation AO-2011-086

At 2019 at night on 24 July 2011, a Boeing Company 777-3D7 aircraft, operated by Thai Airways, was conducting a runway 34 VOR approach to Melbourne Airport, Victoria. During the approach, the tower controller observed that the aircraft was lower than required and asked the flight crew to check their altitude. The tower controller subsequently instructed the crew to conduct a go-around. However, while the crew did arrest the aircraft's descent, there was a delay of about 50 seconds before they initiated the go-around and commenced a climb to the required altitude.

[14] T-VASIS: a 'T' shaped visual approach slope indicating system that uses high intensity lighting to assist pilots identify the correct approach path to the runway.

The ATSB established that the pilot in command may not have fully understood some aspects of the aircraft's automated flight control systems and probably experienced 'automation surprise' when the aircraft pitched up to capture the VOR approach path. As a result, the remainder of the approach was conducted using the autopilot's flight level change mode. In that mode the aircraft's rate of descent is unrestricted and therefore may be significantly higher than that required for an instrument approach. In addition, the flight crew inadvertently selected a lower than stipulated descent altitude, resulting in descent below the specified segment minimum safe altitude for that stage of the approach and the approach not being managed in accordance with the prescribed procedure.

ATSB investigation AO-2010-027

On 4 and 29 May 2010, an Airbus A330-343E aircraft, was being operated by AirAsia X to the Gold Coast, Queensland. On both occasions, there was low cloud and reduced visibility on arrival at the Gold Coast.

During VOR approaches conducted at Gold Coast Airport on both days, the flight crews descended the aircraft below the segment minimum safe altitudes. As a result, the aircraft descended to an altitude where there was no longer separation assurance from terrain and aircraft operating outside controlled airspace.

ATSB investigation AO-2008-080

On 17 December 2008, a Boeing Company 737-4MO aircraft, operated by Garuda Indonesia, made a significant diversion around weather at night while en route to Darwin, Northern Territory. The aircraft was cleared to conduct the runway 11 VOR approach via the initial approach fix NASUX. After the weather diversion, it was more convenient for the flight crew to make a pilot intercept of the 285 radial from the VOR but there was a period of misunderstanding as a result of a breakdown in the application of standard radiotelephony readbacks.

The flight crew left the previously-cleared altitude of 3,000 ft on descent although they had not been cleared to do so. When this became apparent, no updated clearance for a pilot intercept of the 285 radial was issued by the controller. The aircraft continued to descend on the basis of the runway 11 VOR descent profile, even though it was not conducting the runway 11 VOR approach.

The flight crew used the position calculated by the aircraft's inertial reference system (IRS) to intercept the 285 radial, instead of using the signal from the VOR. The IRS position was not accurate enough for this, and the aircraft tracked to outside of the stipulated 5 degrees tolerance either side of the 285 radial. From then on, the aircraft was no longer 'established' on the 285 radial even though it was below the minimum sector altitude in cloud. When it broke through the cloud, the aircraft was clearly not aligned with the runway and a missed approach was carried out.

ATSB Comment

Over recent years, the number of active VORs has reduced as part of the Airservices Australia *Navigation Rationalisation Project*. Global navigation satellite system (GPS) is now the primary means of navigation for instrument flight rules aircraft, including RNAV approaches where an ILS is not available.

Internationally, the prevalence of VOR approaches is even further reduced. This reduces the exposure of international flight crew to VOR approaches and therefore reduces the familiarity of international flight crew with the conduct of a VOR approach.

This incident, along with the previous occurrences identified above, highlight the importance of familiarity with this approach type. However, this familiarity may be reduced for foreign flight crews operating into Australia.

The air traffic services provider in Australia, Airservices Australia, advised that all of the runway connected STARs have been removed from the VOR approaches at Melbourne, Adelaide and all

but one at Perth to discourage their use. While the VOR approaches are still available on request, flight crews are assigned only instrument approach procedures that are connected to STARs.

Safety analysis

The flight crew planned to conduct the POLLI FOUR PAPA arrival and RNAV-Z approach. When ATC issued instructions for the POLLI FOUR BRAVO arrival and VOR approach, the flight crew accepted the POLLI FOUR BRAVO arrival while preparing to conduct the RNAV-Z approach, instead of the associated VOR approach. This lead to a discontinuity in the programmed flight path between the arrival and approach. The flight crew did not select the entry to the approach in the FMC and manually entering the waypoint SCBSG. As the waypoint was manually entered, the 7,500 ft altitude constraint was not included into the FMC programmed flight path. This missing altitude constraint was not detected by the flight crew.

The flight crew entered the altitude of 3,900 ft into the autopilot altitude selector prior to commencing the approach. With the autopilot engaged, the aircraft descended through 7,500 ft prior to commencing the approach at SCBSG. The flight crew did not detect that the aircraft had descended through the 7,500 ft MSA. The approach controller identified the error and alerted the flight crew.

Once established visual with the runway, the flight crew elected to conduct a manually flown visual approach without advising ATC, and did not receive a clearance to discontinue the RNAV-Z and conduct a visual approach. The aircraft then descended below the standard profile which led to the aircraft descending below the 5,300 ft SMSA prior to passing SCBSI.

Findings

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

- The captain manually entered the waypoint SCBSG into the FMC instead of selecting the RNAV-Z approach via waypoint SCBSG. This removed the 7,500 ft altitude constraint.
- The crew did not identify the aircraft had descended below the 7,500 ft minimum sector altitude prior to passing SCBSG.
- Prior to passing SCBSI, the flight crew elected to conduct a visual approach without advising air traffic control, the flight crew then descended the aircraft below the 5,300 ft segment minimum safe altitude.
- The aircraft was in visual conditions at all times.

Safety message

This incident highlights the importance of preparation and communication prior to commencing a phase of flight. Requesting a preferred clearance early allows ATC to ensure that a clearance can be provided, or if not available, allows the flight crew time to prepare for a different clearance.

The Australian air traffic control provider, Airservices Australia, document: *Standard Instrument Arrival Routes (STARS)* provides further information to assist flight crew in adhering to clearances when conducting arrivals and approaches.

This incident also underlines the importance of adhering to standard operating procedures (SOPs). By deviating from SOPs and manually entering the waypoint, the crew removed a protection which was in place to prevent data input errors.

The ATSB has identified numerous accidents worldwide that were the result of simple human errors in data calculation or entry.

The *ATSB SafetyWatch* highlights the broad safety concerns that come out of our investigation findings and from the occurrence data reported to us by industry.

Data input errors-such as the wrong figure being used as well as data being entered incorrectly, not being updated, or being excluded-happen for many different reasons.

The consequences of these errors can range from rejected take-offs through to collisions with the ground. Errors can occur irrespective of pilot experience, operator, aircraft type, location and take-off performance calculation method.

General details

Occurrence details

Date and time:	22 February 2017 – 0909 AEDT	
Occurrence category:	Incident	
Primary occurrence type:	Flight below minimum altitude	
Location:	40 km SSW of Canberra Airport, Australian Capital Territory	
	Latitude: 35° 18.42' S	Longitude: 149° 11.70' E

Aircraft details

Manufacturer and model:	The Boeing Company 777-212	
Registration:	9V-SRP	
Operator:	Singapore Airlines	
Serial number:	33369	
Type of operation:	Air Transport High Capacity	
Persons on board:	Crew – 13	Passengers – 235
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	Nil	

About the ATSB

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; and 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.

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety 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.

About this report

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope, fact-gathering investigation was conducted in order to produce a short summary report, and allow for greater industry awareness of potential safety issues and possible safety actions.