Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Investigation – AO-2007-055

Preliminary

Procedures related event – Melbourne Airport, VIC

4 November 2007

HS-TJW

Boeing Company 777 - 2D7

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Published by: Australian Transport Safety Bureau
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ISBN and formal report title: see 'Document retrieval information' on page iiiii.

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
AO-2007-055	21 January 2008	15	978-1-921165-70-2

Publication title

Procedures related event - Melbourne Airport, VIC, 4 November 2007, HS-TJW, Boeing Company 777 – 2D7

Prepared by

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Reference No.

Jan2008/Infrastructure 8007

Acknowledgements

Lufthansa Systems AG for Figure 1.

The Boeing Company for Figure 3.

Abstract

On 4 November 2007, a Boeing Company 777–2D7 aircraft, registered HS-TJW, was being operated on a scheduled passenger service from Bangkok, Thailand, to Melbourne, Vic, with 17 crew and 277 passengers on board. During a non-directional beacon (NDB) non-precision approach to runway 16 at Melbourne Airport, the aircraft descended below the segment minimum safe altitude at 6.8 distance measuring equipment (DME, a measure in nautical miles). Soon after, the crew received two enhanced ground proximity warning system (EGPWS) cautions. The crew then levelled the aircraft and conducted a visual approach and landing on runway 16.

The investigation is continuing.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

The information contained in this preliminary report is derived from initial investigation of the occurrence. Readers are cautioned that there is the possibility that new evidence may become available that alters the circumstances as depicted in the report.

Sequence of events

On 4 November 2007, a Boeing Company 777–2D7 (777) aircraft, registered HS-TJW, was being operated on a scheduled passenger service from Bangkok, Thailand, to Melbourne, Vic, with 17 crew and 277 passengers on board. During a non-directional beacon (NDB) non-precision approach[1] to runway 16 at Melbourne Airport, the aircraft descended below the segment minimum safe altitude at 6.8 DME.[2] Soon after, the crew received two enhanced ground proximity warning system (EGPWS) cautions. The crew then levelled the aircraft and conducted a visual approach and landing on runway 16.

The flight deck crew consisted of the pilot in command, copilot and relief copilot. The copilot was the handling-pilot for the descent, approach and landing at Melbourne. The pilot in command was the monitoring pilot, and the relief copilot was positioned in an observer seat behind the pilot in command and copilot. The crew had received a notice to airmen (NOTAM) prior to the departure from Bangkok informing them that the Melbourne runway 16 instrument landing system (ILS) was not available for use.

The copilot reported that at about 10 minutes before top of descent he conducted a briefing for the NDB approach to runway 16. The pilot in command and copilot used an instrument approach chart produced by Lido[3] (Figure 1), which they attached to each control column. The crew reported that the approach briefing included an intention to conduct a constant angle approach path[4] using the vertical navigation (VNAV) mode of the automatic flight control system (see *Automatic flight control system* below).

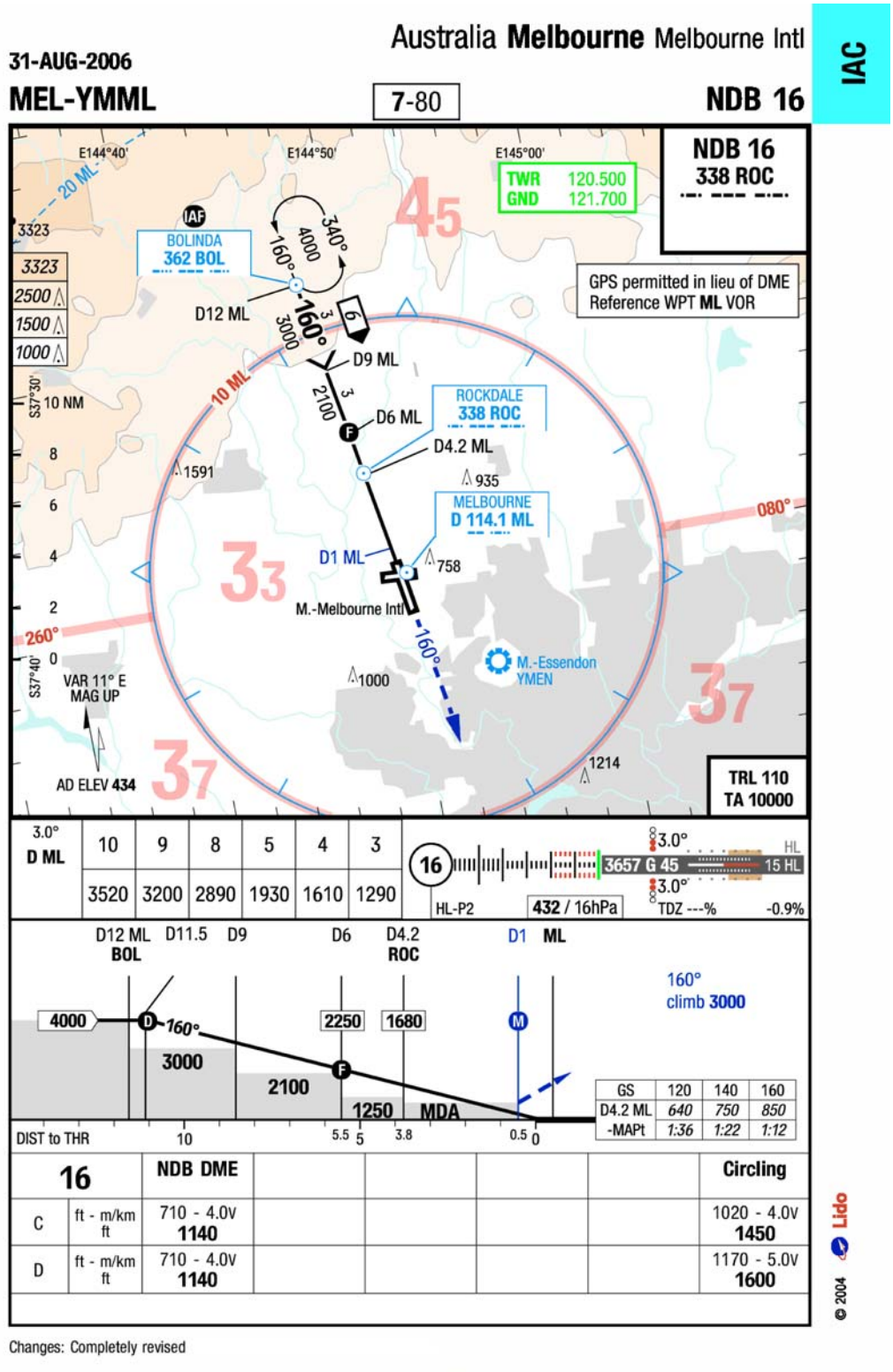
1 The non-directional beacon (NDB) is a ground-based aid. An NDB instrument approach provides lateral guidance to the missed approach point but does not provide vertical guidance to the minimum descent altitude. The aircraft was equipped with two automatic direction finding (ADF) receivers that displayed the bearing of the aircraft from an NDB.

2 Distance measuring equipment (DME) is a ground-based aid that provides distance information in nautical miles. The aircraft was equipped with two DME receivers that displayed the distance from a DME. The Melbourne DME was located about 900 m south-east of the runway 16 threshold.

3 Lido instrument approach charts were part of the *Lido RouteManual.*

4 The constant angle approach path followed the 3 degree descent gradient published on the approach chart.

Figure 1: Melbourne Runway 16 NDB approach chart



The navigation database in the aircraft's flight management computers (FMCs) contained the runway 16 ILS approach and included the Bolinda and Rockdale NDBs associated with that approach (Figure 1). The database did not contain the runway 16 NDB approach. The copilot reported that he entered into the FMCs the final approach fix waypoint at 6 DME with an altitude constraint of 2,100 ft above mean sea level (AMSL). Other segment minimum safe altitude constraints associated with the NDB approach were not entered into the FMCs.

At 1232:05 Eastern Daylight Saving Time,[5] air traffic control (ATC) cleared the crew to conduct the ARBEY FOUR ARRIVAL standard arrival route (STAR) to runway 16. The aircraft's flight data recorder (FDR) indicated that the crew initiated the descent from flight level (FL) 370[6] at 1241:52 with the autopilot engaged in the (VNAV) and lateral navigation (LNAV) modes.

The crew selected flight level change mode at 1259:20 at an altitude of 10,230 ft. At 1303:55, when the aircraft was about 20 NM north-west of the airport descending through 9,037 ft, the controller transmitted to the crew 'Descend to 4,000 cleared to runway 16 NDB approach'. The copilot used the flight level change mode to continue the descent to 4,000 ft and the crew configured the aircraft for the initial approach. During the descent the crew reported that they heard the crew of a preceding aircraft report that the cloud base was 1,700 ft.[7]

When the aircraft was about 1 NM from the Bolinda NDB (Figure 1), the crew selected 1,190 ft on the autopilot flight director system (AFDS) mode control panel (MCP).[8] This altitude was 50 feet above the published minimum descent altitude for the approach.[9] The aircraft overflew the Bolinda NDB at 1306:31 while level at 4,000 ft and the copilot reported that at that time he was unsure whether ATC had cleared the crew to conduct the NDB approach. Remaining level at 4,000 ft, the copilot sought confirmation from the pilot in command that they were cleared for the approach before commencing further descent.

The descent was commenced beyond the published descent point for the constant angle descent at 11.5 DME. The copilot reported that, as the aircraft was above the constant angle approach path, he selected flight level change mode to descend the aircraft.[10] The FDR indicated that the aircraft started to descend from 4,000 ft at

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5 The 24-hour clock is used in this report to describe the local time of day, Eastern Daylight Saving Time (EDST), as particular events occurred. Eastern Daylight Saving Time was Coordinated Universal Time (UTC) + 11 hours.

6 Flight level is a surface of constant atmospheric pressure related to a datum of 1013.25 hPa, expressed in hundreds of feet; flight level 370 approximated 37,000 ft AMSL.

7 At 1304:25 the crew of another aircraft transmitted to Melbourne ATC that they were '… on the ground Avalon cancel SARWATCH … and the cloud base is about 1,700 ft at Avalon'. Avalon Aerodrome is located on the western coast of Port Phillip Bay and about 20 NM to the south west of Melbourne Airport.

8 Selecting an altitude on the MCP ensured that the aircraft would not descend below that altitude.

9 The operator's procedures required the crew set the minimum descent altitude plus 50 ft to ensure that if a missed approach was initiated, descent below the minimum descent altitude did not occur during the missed approach.

10 Flight level change mode does not reference the altitude constraints entered in the FMC (see *Automatic flight control system*).

1307:23 at 9.9 DME. Lateral navigation during the approach continued to be controlled using LNAV mode.

Soon after commencing the approach, the crew configured the aircraft for landing and at 1308:21 they selected the landing reference speed of 142 kts on the MCP. The FDR indicated that the rate of descent averaged 1,500 ft/min during the 114 second descent, with a maximum of 1,808 ft/min when the aircraft was 8.5 DME. The aircraft descended below the 2,100 ft segment minimum safe altitude step at 6.8 DME (Figure 2).

As the aircraft descended below the cloud base, the pilot in command and relief copilot reported that they were both attempting to visually locate the runway. The handling copilot reported that his scan was partially diverted from the flight instruments to also looking out of the aircraft.

At 1309:08 the aircraft was about 6.25 DME descending through 1,544 ft, which was below the 2,100 ft segment minimum safe altitude. At this time, the enhanced ground proximity warning system (EGPWS) annunciated 'caution terrain' for 4 seconds and the terrain display and terrain caution message appeared on the navigation displays on the forward instrument panel for 15 seconds. At 1309:18, a second EGPWS 'caution terrain' was annunciated for 4 seconds.

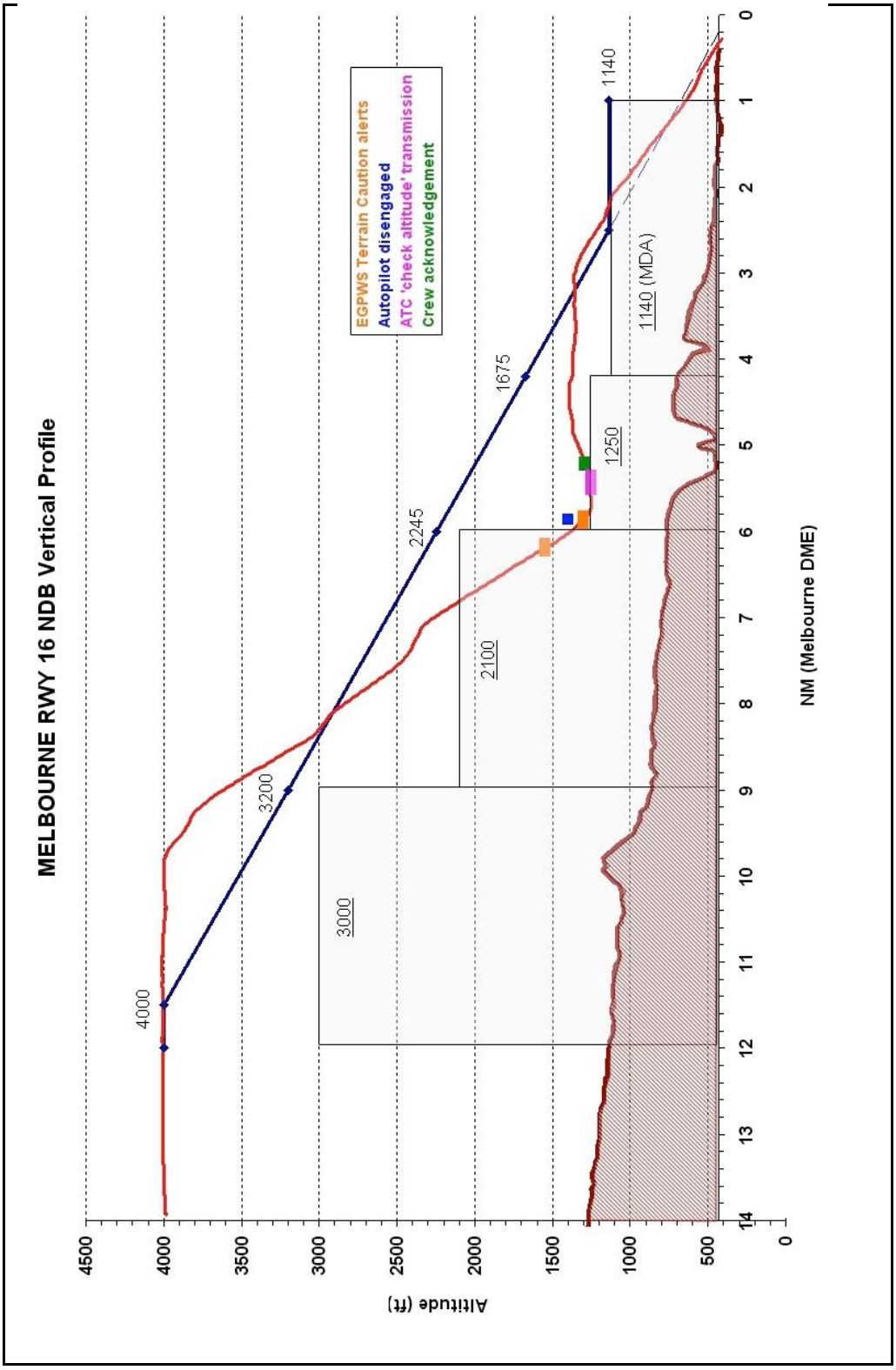
The pilot in command reported that he sighted the terrain under the aircraft and the runway when he heard the EGPWS. The FDR indicated that 2 seconds after the second EGPWS annunciation at 1309:20, the copilot disengaged the autopilot and initiated a pitch-up manoeuvre. The lowest altitude recorded during this manoeuvre was 1,247 ft, which was 513 ft above ground level.

About this time, the aerodrome controller in the Melbourne Airport air traffic control tower saw lights below the cloud base that appeared to be unusually low for an aircraft. After confirming the aircraft's position on the air situation display, at 1309:30, the aerodrome controller transmitted 'low altitude alert, check your altitude immediately' to the crew. The copilot reported that after this transmission he first made visual contact with the runway and the precision approach path indicator (PAPI) .[11] The pilot in command replied to ATC 'okay, we have the runway in sight now'.

After the copilot disengaged the autopilot, he climbed the aircraft to about 1,400 ft. He then manually flew the aircraft in level flight until he could see by reference to the PAPI that he could conduct a visual approach to runway 16. The crew reported that the approach was stabilised by 500 ft above the runway, and the approach and landing continued without further incident.

11 The precision approach path indicator (PAPI) is a ground based light system which provides visual approach slope guidance to the crew during an approach.

Figure 2: **Approach profile (in red) derived from FDR data, published constant angle descent path (in blue), segment minimum altitude limiting steps (in grey) and terrain profile (in brown).**



Personnel information

Flight crew

The pilot in command held an airline transport pilot licence, was type rated on the 777 aircraft, held a current medical certificate, and had 23,707 hours total flight experience. The pilot in command's flight time included 9,149 hours on the 777 aircraft. He reported that he had last flown into Melbourne 15 days prior to the incident.

The copilot held an airline transport pilot licence, was type rated on the 777 aircraft, held a current medical certificate, and had 6,282 hours total flight experience with 4,389 hours on the 777 aircraft. The copilot reported that he had last flown into Melbourne during the previous month prior to the incident.

The relief copilot held a commercial pilot licence, was type rated on the 777 aircraft, held a current medical certificate, and had 1,914 hours total flight experience with 1,320 hours on the 777 aircraft. The relief copilot reported that he had last flown into Melbourne about 2 months prior to the incident.

Air traffic controllers

Airservices Australia reported that all air traffic controllers involved in the control of the aircraft as it approached Melbourne Airport were licensed, rated and current for the relevant controller positions.

Aircraft information

Aircraft data

Aircraft model	Boeing 777-2D7
Serial number	34591
Date of manufacture	11 October 2007
Certificate of Registration	Valid, issued 29 October 2007
Certificate of Airworthiness	Valid, issued 29 October 2007
Total airframe hours and cycles	51 hours, 5 cycles

Automatic flight control system

The 777 automatic flight control system consisted of the autopilot flight director system (AFDS) and the auto-throttle system. Both the AFDS and the auto-throttle were controlled using the mode control panel (MCP) and the two flight management computers (FMCs). The crew used the MCP to select and activate AFDS modes, and to select altitudes, speeds and climb/descent profiles (Figure 3).

Figure 3: Mode control panel

Crew selection of the lateral navigation (LNAV) mode and/or vertical navigation (VNAV) mode would result in the FMCs calculating the optimum lateral and/or vertical navigation flight path. This flight path would be calculated using information obtained from the FMC databases, flight plan information entered by the crew, and other aircraft systems.

Alternatively, the aircraft's vertical flight path could also be controlled by other AFDS modes, such as flight level change. These other vertical modes did not interface with the FMCs and relied solely on MCP selections by the crew. As a result, any speed restrictions and altitude constraints entered by the crew into the FMCs did not alter the aircraft's flight path in these other modes.

The other AFDS vertical modes included:

- flight level change (FLCH) mode which controlled the aircraft's speed during the descent by varying the aircraft's pitch attitude to maintain the speed selected on the MCP with engine thrust being held at a pre-determined value;
- vertical speed (V/S) mode which controlled the aircraft's vertical speed during a descent by varying the aircraft's pitch attitude to maintain the vertical speed selected on the MCP; and
- flight path angle (FPA) mode which controlled the aircraft's flight path during a descent by varying the aircraft's pitch attitude to maintain the angle selected on the MCP.

When reaching the altitude selected on the MCP, while descending in these modes with the autopilot engaged, the altitude hold mode would automatically level the aircraft at that altitude. Altitude hold mode could also be selected at any altitude by pushing the altitude hold switch on the MCP and the aircraft would maintain the altitude existing when the switch was pushed.

Enhanced ground proximity warning system

The aircraft was fitted with an enhanced ground proximity warning system (EGPWS), also known as a terrain awareness and warning system (TAWS). Compared with the conventional ground proximity warning system, EGPWS was capable of providing an increased warning time to pilots about potential terrain conflicts by incorporating two additional functions: a forward looking terrain avoidance function, and a premature descent alert function. EGPWS also enhanced pilot situational awareness by providing coloured terrain information on the navigation displays on the forward instrument panels.

The forward looking terrain avoidance function compared the aircraft's present position and flight path, using data from the aircraft's global positioning system receiver, with a terrain database to compute if there were any potential conflicts with the terrain. The premature descent alert function compared the aircraft's

current position and flight path with an aerodrome database to determine if the aircraft was hazardously below the normal approach path for the nearest runway.

The EGPWS coloured terrain display provided the pilots with a graphical presentation of terrain information. The continuous terrain display also provided various visual indications of imminent contact with the ground, including excessive rates of descent and excessive closure rate to terrain.

Meteorological information

Aerodrome forecasts

The Bureau of Meteorology (BoM) issued a terminal aerodrome forecast for Melbourne Airport at 2138 on 3 November 2007 with a local time validity period from 2300 on 3 November to 2300 on 4 November. The forecast was issued about seven hours prior to the aircraft's departure from Bangkok and the validity encompassed the aircraft's planned arrival time at Melbourne. From 1100 the forecast wind was from 170 degrees true at 23 kts gusting to 35 kts; visibility 9 km; rain; and cloud, 5 to 7 oktas[12] with a cloud base of 1,000 ft above the aerodrome elevation.

The BoM issued an amended terminal aerodrome forecast for Melbourne at 0341, with a validity period that extended beyond the aircraft's planned arrival time at Melbourne. The main difference was that from 1100 the cloud was forecast to be 3 to 4 oktas at 1,000 ft and 5 to 7 oktas at 3,000 ft. A further amended terminal aerodrome forecast was issued at 0930 with the main difference being that the cloud was forecast to be 3 to 4 oktas at 1,000 ft and 5 to 7 oktas at 1,400 ft during the period of the aircraft's arrival.

Actual weather information

The Melbourne special aerodrome weather report (SPECI) issued at 1230 indicated that the wind was from 150 degrees true at 25 kts, gusting to 32 kts, visibility was 9 km, rain showers, with 3 oktas of cloud at 1,300 ft and 6 oktas of cloud at 1,600 ft above the aerodrome level (AAL).

The Melbourne trend type forecast (TTF) appended to the 1230 SPECI indicated that, at the aircraft's estimated time of arrival (ETA), the visibility would be 3,000 m in rain with 5 to 7 oktas of cloud at 800 ft AAL for periods of 30 minutes or more, but less than one hour.

The Melbourne SPECI issued at 1300 local time indicated that the wind was from 150 degrees true at 21 kts, gusting to 26 kts, visibility was 9 km, rain showers, with 1 okta of cloud at 1,100 ft AAL and 7 oktas of cloud at 1,500 ft AAL. The TTF appended to the 1300 SPECI did not vary from the 1230 TTF.

12 Cloud amounts are reported in oktas. An okta is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon.

Provision of weather information to the flight crew

At 1256:40, ATC broadcast to pilots of aircraft on frequency that the Melbourne Airport automatic terminal information service (ATIS) had changed, with the current ATIS being identified as 'X-RAY'. This broadcast occurred while the aircraft was descending through FL 130 about 48 NM to the north-west of the airport.

These changes to the ATIS included the wind being 140 degrees magnetic at 15 to 30 kts, and the cloud being scattered (3 to 4 oktas) at 1,200 ft AAL and broken (5 to 7 oktas) at 1,800 ft AAL and the QNH being 1010 hPa[13]. At 1300:05, the crew contacted ATC on a different radio frequency and they reported that they had received ATIS 'X-RAY'. The FDR indicated that the pilot in command and copilot altimeters were set to 1010 hPa during the descent.

At 1307:54, ATC cleared the crew to land on runway 16. During that transmission the controller advised the crew that the wind was 140 degrees at 25 kts.

Aids to navigation

Ground-based navigation aids

There were two instrument approach procedures published for runway 16; an ILS precision approach procedure; and a runway-aligned NDB non-precision approach procedure, utilising the Bolinda and Rockdale NDBs and the Melbourne DME (Figure 1).

Unavailability of runway 16 instrument landing system

In September 2007, work commenced on the Melbourne runway 16 ILS to permit the installation of new equipment. This work was part of a navigation aid replacement program that Airservices Australia had announced to the aviation industry in October 2005.

A Notice to Airmen (NOTAM) was issued by the Australian NOTAM Office on 4 October 2007 to inform appropriate personnel of the planned unavailability of the runway 16 ILS. The NOTAM advised that the ILS would be unavailable from 0900 local time on 8 October to 1700 on 22 November 2007.

Communications

The transmissions between the air traffic controllers and the crew during the aircraft's descent and approach to Melbourne Airport were recorded by ground-based automatic voice-recording equipment. The quality of those recorded transmissions was good.

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

Aerodrome information

Melbourne Airport is located about 20 km north-west of the Melbourne central business district at an elevation of 434 ft above mean sea level. The airport has two runways: runway 16/34, aligned 160/340 degrees magnetic, which is 3,557 metres long and 60 m wide and runway 09/27, aligned 083/263 degrees magnetic, which is 2,286 m long and 45 m wide.

Runway 16 is equipped with a PAPI which is calibrated for a 3 degree visual glide path angle. The touchdown elevation of runway 16 is 432 ft and the runway slopes down to 330 ft at the departure end.

Recorded information

The operator forwarded the digital flight data recorder (FDR) to the Australian Transport Safety Bureau (ATSB) and the data was downloaded. The operator also forwarded the data from the quick access recorder (QAR) to the ATSB. Data from the cockpit voice recorder for the incident flight had been over-written and therefore was not available to the investigation.

Further investigation

The investigation is continuing and will include an examination of operating procedures, training and regulatory requirements.