
# AVIATION SAFETY INVESTIGATION REPORT 200402747

**Boeing Co**
**B737**

**24 July 2004**

Australian Government

Australian Transport Safety Bureau

**MEDIA RELEASE** **May 2005**

# Final ATSB report into the 24 July 2004 Boeing 737 ground proximity caution near Canberra

The ATSB's final report into the terrain proximity caution incident to the south-south-east of Canberra at 0544 am on 24 July 2004 has found that the flight crew of the Boeing 737 were affected by fatigue and they misinterpreted the instrument approach chart and entered incorrect data into the flight management computer.

The aircraft was being operated on an overnight service from Perth to Canberra, when it proceeded beyond the limits of the Church Creek Holding pattern, 10.9 NM south of Canberra. In doing so the crew manoeuvred the aircraft closer to terrain than intended. As a consequence the aircraft received a 'Caution Terrain' message from the aircraft's enhanced ground proximity warning system.

The crew had commenced a right turn back to the north towards Canberra shortly before the 'Caution Terrain' message. They then climbed the aircraft to a higher altitude.

The flight crew's fatigue was partly the result of an airconditioning fault that led to hot cockpit conditions from Perth to Canberra. Normal air traffic assistance was unavailable in Canberra until 40 minutes after the scheduled 0530 am opening time.

The aircraft operator has amended its procedures to require a higher altitude for aircraft holding to the south of Canberra and the chart publisher is amending charts to reduce the likelihood of misinterpretation.

The ATSB initiated a category 3 investigation, which was subsequently noted on the ATSB website in early August. The Bureau released a preliminary report on this occurrence on 22 September 2004.

The final ATSB investigation report is available on the website www.atsb.gov.au.

**Media Contact:**George Nadal business hours & after hours duty officer 1800 020 616

15 Mort Street, Canberra City ACT 2601 • PO Box 967, Civic Square ACT 2608 Australia
Telephone: 02 6274 6411 • Facsimile: 02 6247 3117
24 hours: 1800 621 372 • www.atsb.gov.au
ABN 86 267 354 017

# EXECUTIVE SUMMARY

On 24 July 2004, the flight crew of a Boeing 737-838 aircraft, registered VH-VXF, received a terrain proximity caution from the aircraft's enhanced ground proximity warning system (EGPWS) while descending to the south-south-east of Canberra Airport. The aircraft was being operated on a scheduled fare-paying passenger service from Perth to Canberra with two pilots, five cabin crew and 80 passengers on board.

Due to staff shortages on the morning of the occurrence, the approach control services normally provided by the Canberra Terminal Control Unit did not become available until approximately 40 minutes after the scheduled unit opening time. This meant that the aircraft's descent below 9,000 ft was conducted without air traffic control radar assistance.

The aircraft departed Perth at 0211 Eastern Standard Time (EST) and the occurrence was at 0544 EST. The flight deck during the flight was abnormally hot because of a pre-existing air conditioning problem.

As the aircraft approached Canberra, the crew elected to track to Church Creek[1] (CCK), to enter the holding pattern at that position and descended to 5,000 ft to intercept the instrument landing system (ILS) approach in accordance with Airservices Australia and Jeppesen published procedures for the approach for runway 35.

The published CCK holding pattern requires that aircraft holding at 5,000 ft observe a maximum indicated airspeed (IAS) of 170 kts and limit time outbound to either 1 minute or a distance measuring equipment (DME) limit of 14 NM from Canberra, whichever is reached first.

As the aircraft approached CCK, the copilot, under the direction of the pilot in command, entered the holding pattern details into the Flight Management Computer (FMC). In doing so, an erroneous entry was made, which resulted in the FMC computing a holding pattern with a leg length of 14 NM, instead of 1 minute or a maximum distance from Canberra of 14 NM.

By entering a leg distance of 14 NM, the crew inadvertently commanded the FMC to establish the aircraft in a holding pattern that would take the aircraft about 11 NM beyond the published holding pattern limit. The crew initiated descent to 5,000 ft after passing overhead CCK. As it descended, the aircraft proceeded outside the airspace specified for holding. Consequently, the aircraft was operated closer to the surrounding terrain than would normally occur.

The aircraft was fitted with an EGPWS, which detected the aircraft's proximity to the terrain and provided the crew with a 'CAUTION TERRAIN' message to which the

[1] Church Creek is an instrument approach fix (locator) 10.9 NM from Canberra Airport.

crew responded by climbing the aircraft to 6,500 ft. Sixteen seconds before the message, the crew had commenced a right turn to intercept the inbound track to CCK. At the time of the message, the aircraft's height above terrain was 2,502 ft (radio altimeter indication).

During the turn, the aircraft passed 0.6 NM (1.11 km) north abeam and 810 ft higher than the closest terrain that had a spot height of 4,920 ft above mean sea level. It also passed 2.7 NM (5 km) north abeam Tinderry Peak. The aircraft climbed to 6,500 ft and subsequently joined the runway 35 localiser.

This occurrence was not simply a case of incorrect data entry, but was influenced by a number of events occurring prior to, and during the flight that affected the crew, the aircraft and the air traffic control system. Evidence suggests that the flight crew's operational performance was affected at a critical stage of the flight by fatigue, the late advice of the status of air traffic services and the crew's misinterpretation of the CCK locator holding pattern data on the runway 35 ILS approach chart.

The crew's ineffective contingency planning for a descent to Canberra without air traffic control support and the erroneous data entry in the aircraft's flight management computer (FMC) suggest that the crew was not functioning at an appropriate level of alertness.

It is likely that both the pilot in command and the copilot were experiencing fatigue due to the cumulative effects of ineffective sleep in the period preceding the Perth to Canberra night sector and the ongoing period of wakefulness during the flight. Additionally, as they approached Canberra, the crew was working at a low point in their circadian rhythms[2]. It is therefore likely that they were experiencing a decreased level of alertness. The application of the minimum equipment list on the flight deck air conditioning system allowed continued flight operation despite abnormally hot conditions, about 10 degrees Celsius above normal. While this may have had less impact on crew performance during a short daylight flight, it was of greater significance during a night flight of more than three hours. In combination, those conditions probably interacted to reduce the level of crew alertness, performance and attention. The crew's lack of recognition of the inaccurate entry in the FMC is consistent with the effects of fatigue, and it is likely that those effects were exacerbated by the excessive flight deck temperatures.

As a result of this occurrence, the aircraft operator has taken action to ensure earliest rectification of flight deck or passenger cabin temperature control problems and increased the minimum holding pattern altitude at Church Creek. Airservices Australia has issued a temporary local instruction detailing how the Canberra Terminal Control Unit staff shortage contingency plan should be activated. Additionally, Jeppesen Sanderson Inc. has advised the ATSB that they intend to include the DME identifier in the holding pattern limit notes on relevant charts.

[2] Circadian rhythms refer to body functions (i.e. sleep/wakefulness, motor activity, hormonal processes, body temperature, and performance) that are controlled by internal biological clocks and that vary over a 24 hour cycle. As a result, levels of human performance also vary significantly during the 24 hour period.

# 1 FACTUAL INFORMATION

## 1.1 Sequence of events

On 24 July 2004 at 0105[3] the crew of a Boeing Company 737-838 (737), registered VH-VXF, signed on for duty at Perth, WA. During the pre-flight briefing, the crew obtained the weather forecast and flight plan for the flight to Canberra, ACT. The crew also became aware that the Flight Deck Temperature Control System of the aircraft's air conditioning system was malfunctioning and was the subject of a minimum equipment list (MEL) limitation[4].

The crew noted that due to a forecast tailwind, the expected arrival time in Canberra was before the scheduled opening of the Rescue and Fire Fighting Services (RFFS)[5] and the aerodrome and approach control services[6]. Consequently they reduced the target cruise speed in the flight management computer (FMC) to ensure that the arrival into Canberra would be after the tower and approach control services commenced scheduled operation.

At 0211, the aircraft departed Perth for Canberra, with two pilots, five cabin crew and 80 passengers on board. During the flight, the pilots endured air temperatures on the flight deck that were hotter than normal[7] and spent much of the available time referring to the aircraft's flight operation's manual in an attempt to troubleshoot the faulty air conditioning system.

At 0515, the aircraft passed over Griffith (167 NM from Canberra) at flight level (FL) 390 (39,000 ft). The copilot asked the Melbourne Centre air traffic controller which runway was in use at Canberra and was told 'next sector will advise'.

At 0519, the crew requested descent clearance and the controller responded 'standby'.

At 0520, the aircraft was 122 NM to the west of Canberra when it passed the FMC programmed top of descent point. The crew advised the controller that they 'required descent' and were cleared to descend to FL 210.

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[3] Eastern Standard Time (adjusted to the nearest minute; seconds displayed where relevant) is used throughout the report.

[4] Minimum Equipment List – details those components or systems which may remain inoperative for further flight until spares and time are available for their rectification (operator's definition). The MEL is approved by the Civil Aviation Safety Authority (CASA).

[5] RFFS scheduled commencement time 0535.

[6] Aerodrome and approach control services scheduled commencement time 0530.

[7] See 1.5.3.1 below.

At 0522, the copilot again asked the controller which runway was in use in Canberra and was told that both the Canberra Tower and Approach air traffic control services were closed.

At 0525, the aircraft was about 70 NM to the west of Canberra when the controller cleared the crew to descend to FL 150. When the aircraft was about 45 NM to the west of Canberra, the Melbourne Centre controller advised the crew that Canberra Approach Control would not be available 'due to staff shortages'. The controller also asked the crew if they wanted to hold or to accept radar vectors. The crew advised that they would accept radar vectors for a runway 35 ILS[8] approach, and the controller instructed them to take up a heading of 170° M to position the aircraft for the ILS.

At 0530, both the Canberra Tower and Approach Control services were scheduled to commence operations.

At 0532, the Melbourne Centre controller advised the crew 'we're still waiting for the approach controller'. The crew responded that they were happy to continue outside controlled airspace under mandatory broadcast zone[9] (MBZ) procedures.

In response to their requests, the controller advised the crew that the minimum vector altitude[10] he could assign was 9,000 ft, and that they were cleared to track direct to the Church Creek Locator (CCK), then to Canberra, with a descent clearance to 9,000 ft.

At 0535, the crew commenced the turn to CCK. After completing the turn, the aircraft tracked direct to CCK with a groundspeed of 320 kts.

At 0540, the aircraft passed over CCK at 9,000 ft as it entered the holding pattern.

At 0541, the aircraft passed 8,500 ft and turned to the right to join the outbound leg of the holding pattern.

At 0544, the aircraft passed 6,200 ft at 21.1 NM from Canberra DME[11] when the crew commenced the right turn to intercept the track to CCK.

At 0544:24, the crew received a 'CAUTION TERRAIN'[12] message from the Enhanced Ground Proximity Warning System (EGPWS). At the time of the

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[8] Instrument Landing System: standard ground aid to landing which comprised two radio guidance beams localiser for direction in horizontal plane and glideslope for vertical plane with usual inclination of 3 degrees and two markers for linear guidance.

[9] Mandatory broadcast zone: pilots operating within the zone are responsible for separation from other aircraft and terrain.

[10] Manual of Air Traffic Services states: 'The lowest altitude a radar controller may assign to a pilot in accordance with a radar terrain clearance chart.'

[11] Distance Measuring Equipment: airborne secondary radar sending out paired pulses (interrogation) received at a ground transponder. The time for a round trip of a pulse is translated into distance.

caution, the aircraft's position was 35° 38′ 10.36″ S and 149° 17′ 29.40″ E; at a DME distance from Canberra of 21.7 NM. The aircraft was turning right to intercept the inbound track to CCK and its altitude at the time of the caution was 5,850 ft and the radio altitude indication was 2,502 ft AGL[13].

At 0544:27, the crew initiated a recovery manoeuvre in response to the 'CAUTION TERRAIN' message.

At 0544:30, the minimum altitude recorded during the event was 5,730 ft.[14]

At 0545:30, the aircraft reached 6,500 ft.

At 0548:52, the aircraft intercepted the runway 35 localiser and tracked to runway 35.

At 0554, the crew landed the aircraft on runway 35 at Canberra.

## 1.2 Injuries to persons

| *Injuries* | *Crew* | *Passengers* | *Others* | *Total* |
|---|---|---|---|---|
| *Fatal* | - | - | - | - |
| *Serious* | - | - | - | - |
| *Minor* | - | - | - | - |
| *None* | *7* | *80* | - | *87* |

## 1.3 Damage to aircraft

The aircraft was not damaged.

## 1.4 Other damage

Nil.

[12] The 'CAUTION TERRAIN, CAUTION TERRAIN' message is given typically 60 seconds ahead of the predicted terrain/obstacle conflict and is repeated every seven seconds as long as the conflict remains within the caution area. The crew reported that they only received the first half of a single 'CAUTION TERRAIN, CAUTION TERRAIN' message.

[13] Above ground level.

[14] The crew placed the aircraft into a climb attitude at 0544:27. However, as the aircraft had been descending, it continued to descend a further 120 ft.

## 1.5 Personnel information

### 1.5.1 Pilot in command

| | |
|---|---|
| Type of licence | Air transport pilot (aeroplane) licence |
| Medical certificate | Class 1 |
| Total flight time | 15,984 hours |
| Flight time on 737 | 1,109 hours |
| Flight time on 737-838 | 207 hours |
| Flight time last 90 days | 186 hours |
| Flight time last 30 days | 81 hours |
| Last flight | 23 July 2004 |
| Last check | 21 June 2004 |

### 1.5.2 Copilot

| | |
|---|---|
| Type of licence | Commercial pilot (aeroplane) licence |
| Medical certificate | Class 1 |
| Total flight time | 1,992 hours |
| Flight time on 737 | 530 hours |
| Flight time on 737-838 | 127 hours |
| Flight time last 90 days | 185 hours |
| Flight time last 30 days | 58 hours |
| Last flight | 23 July 2004 |
| Last check | 29 April 2004 |

The crew reported no medical condition that was likely to have impaired their performance and, although they had both reported poor sleep during the rest period prior to the flight, they felt they were adequately rested and medically fit when they reported for duty.

Both the pilot in command and the copilot were operating the same two-day flight duty schedule, which commenced on 22 July 2004.

The following provides details about the work and rest patterns of the flight crew during this schedule:

- The crew spent about 23 hours free of duty prior to the commencement of the Perth to Canberra sector
- The crew signed on in Perth at 0105 and landed the aircraft at Canberra at 0554
- On the previous day, both crew members had operated a 3-sector day, which ended in Perth at 0209.

### 1.5.3 Human performance issues

#### 1.5.3.1 Flight deck temperature and heat stress

Both pilots reported that conditions on the flight deck were very abnormally hot throughout the duration of the flight. The copilot reported that the flight deck supply duct temperature gauge 'was showing 50 degrees [Celsius] most of the time and at times was up to 60 degrees'. When the cabin temperature is comfortable at approximately 22 to 24 degrees Celsius (C), the flight deck supply duct temperature gauge normally indicates around 40° C.

Although the investigation was unable to determine the actual flight deck temperature, it is likely that the faulty air conditioning system provided abnormally hot air to the flight deck. (For more detail on the faulty air conditioning system, refer to section 1.6).

Research indicates that heat can have a marked effect on human performance.[15] The human body is most comfortable in a temperature range of about 20° to 30° C, with a relative humidity of about 50%.[16] When the body temperature rises above this range it can become susceptible to heat stress.

Heat stress can have a number of adverse effects, including an increase in perspiration rate, heart rate and blood pressure. Other effects include fatigue, dehydration, headache, nausea, loss of concentration, and disorientation. In turn, the physiological effects of heat stress can lead to work incapacity and inefficiency.[17]

Heat stress can have a significant effect on the performance of flight crew. Key findings from the literature indicate that:

[15] Hygge S. (1992). Heat and performance. In D.M. Jones and A.P. Smith (Eds.), *Handbook of human performance, Volume 1, The physical environment*. London, UK: Academic Press.
[16] Transport Canada. (1996). *Human factors for aviation: Basic handbook*. Ontario: Author.
[17] Nunneley S.A. (1996). Thermal stress. In R.L. DeHart (Ed.), *Fundamentals of aerospace medicine*, 2nd edition. Baltimore, MD: Kluwer

- The main symptom to be exhibited by pilots is a sharp degradation in mental performance
- Attention becomes narrowed and restricted and decision-making becomes impaired
- The effects are often insidious, such that pilots may be unaware of degrading performance
- The effects can go unnoticed by an entire crew, if all members are operating in the same environment.

#### 1.5.3.2 Sleep loss and fatigue

There are a number of factors that may have contributed to ineffective sleep as reported by the pilots. These include:

- Late sign-off time associated with the previous day's duty
- Time since awake. The flight crew was awake for several hours before reporting for the night flight. If the period of wakefulness is long and coincides with the circadian low, there is a very sharp drop in alertness, a strong tendency to sleep, and a significant drop in performance[18]
- Disturbed circadian rhythms. Due to the late sign-off time and the upcoming night duty, both crew members were attempting to sleep at a time when their body was most alert (i.e. during the day). Circadian physiology is discussed in more detail below.

Circadian rhythms refer to body functions (i.e. sleep/wakefulness, motor activity, hormonal processes, body temperature, and performance) that are controlled by internal biological clocks and that vary over a 24 hour cycle. As a result, levels of human performance also vary significantly during the 24 hour period. For example, people are least alert during the circadian low between the hours of 0300 to 0500, and many functions demonstrate reduced levels from 0000 to 0600[19].

Research indicates that when work hours coincide with the circadian low, humans experience an increased tendency to sleep, reduced motor activity, decreased performance, and worsened mood. Within the operating environment, many studies have demonstrated decreased performance and increased errors and accidents associated with night work and the circadian low.

Cumulative sleep loss and circadian disruption can lead to decreased waking alertness, loss of concentration, diminished decision-making abilities, impaired co-ordination of control skills, and extended reaction times.

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[18] Perelli (1990, December). *Fatigue Stressors in Simulated Long Duration Flight: Effects on Performance, Information Processing, Subjective Fatigue and Physiological Costs.* School of Aerospace Medicine, Brooks Air Force Base. Report No. SAM-TR-80-49.

[19] Rosekind, M. R., Neri, D. F., & Dinges, D. F. (1997). *From laboratory to flightdeck: Promoting operational alertness*. *In Fatigue and Duty Limitations – An International Review*. The Royal Aeronautical Society (pp.7.1-7.14). London: The Royal Aeronautical Society.

#### 1.5.3.3 Crew actions

The crew reported that they conducted a briefing for the descent and approach to runway 17 before commencing descent. When the briefing was conducted they were under the impression that Canberra Approach would be available to assist with the descent and approach. It was only after they were established in the descent that the crew became aware that runway 35 had been allocated for the arrival and that the descent and approach would be conducted without assistance from the radar controller.

Because the controller was not available, the crew needed to implement a change of plan and made preparations for the holding at CCK. The crew was still completing the descent approach checklist while tracking outbound in the holding pattern. It was only after the crew completed the checklist that they sensed that the holding pattern 'did not seem right'. At that time, the pilot in command selected 'Terrain'[20] mode on the navigation display and the copilot monitored the DME distance. Shortly after, the pilot in command initiated the inbound turn. This was just prior to the caution message from the EGPWS, see paragraph 1.6.3.2.

## 1.6 Aircraft information

The aircraft's maintenance release was valid for the flight.

### 1.6.1 Aircraft systems

#### Air conditioning system - Flight Deck Temperature Control

The 737 air conditioning system mixes hot engine bleed air and cooler air that has passed through a heat exchanger and an air cycle machine. To obtain a warmer temperature, the system increases the amount of bleed air feeding into the system. When a lower temperature is required, the flow of bleed air is reduced. In this way, a comfortable cabin and flight deck temperature is achieved.

Control of the air conditioning system is largely automated and requires the crew to select the desired temperature. A temperature selector is provided for each of the three zones; flight deck (CONT CAB), forward cabin (FWD CAB), and aft cabin (AFT CAB) (see figure 1).

[20] This feature, when selected by the crew, provides an image of the surrounding terrain represented in various colours and intensities.

**Figure 1: Boeing 737-800 series aircraft air conditioning control panel showing the three zone temperature selectors and supply duct temperature gauge.[21]**


The 737 crew experienced difficulty maintaining the temperature on the flight deck at an acceptable level. The air conditioning system continued to supply excessively warm air to the flight deck zone even though the crew had adjusted the CONT CAB zone temperature selector to schedule a cooler temperature.

### 1.6.2 Aircraft technical log

The aircraft's technical log is used to keep the operator, the pilot in command and the Licensed Aircraft Maintenance Engineer (LAME) informed about the serviceability of the aircraft and its systems.

Prior to departure from Perth, the aircraft's technical log included reference to a problem with the aircraft's air conditioning system that was the subject of an MEL limitation. The nature of the problem was such that the crew could expect difficulty controlling the flight deck temperature during flight. According to the copilot, the flight deck supply duct temperature indicator was showing 50° C and at times reached 60° C.

The problem of excessive flight deck heat was not new, having been first reported on 21 July 2004. The aircraft was dispatched in accordance with an approved Minimum Equipment List (MEL). The application of the MEL allowed for continued operation with the defect for up to 10 days, during which time the rectification action could be completed. The flight crew had been informed of the problem prior to departure from Perth.

[21] Temperature gauge shows temperature in the airconditioning supply duct, the passenger cabin or airconditioning pack depending on selection made by the crew.

Between 21 July and the time of the aircraft's departure from Perth, 3 days, the air conditioning defect had been reported in the aircraft's technical log on six separate occasions. Various maintenance actions were taken to rectify the defect and on 23 July the temperature control system was listed in the technical log as being inoperative and the MEL was reapplied.

The pilot in command reported that the checks required in accordance with the MEL procedure were completed before departing Perth for Canberra.

Subsequently, the aircraft was flown to Sydney where maintenance engineers again were unable to rectify the defect. The engineers therefore made an entry in the aircraft's technical log advising crews to 'keep the trim air pressure regulating and shutoff valve in the closed position'. That would have the effect of isolating the section of the air conditioning system associated with the faulty temperature controller, thereby preventing the entry of hot air to the flight deck.

### 1.6.3 Enhanced Ground Proximity Warning System

The aircraft was equipped with a Honeywell EGPWS.

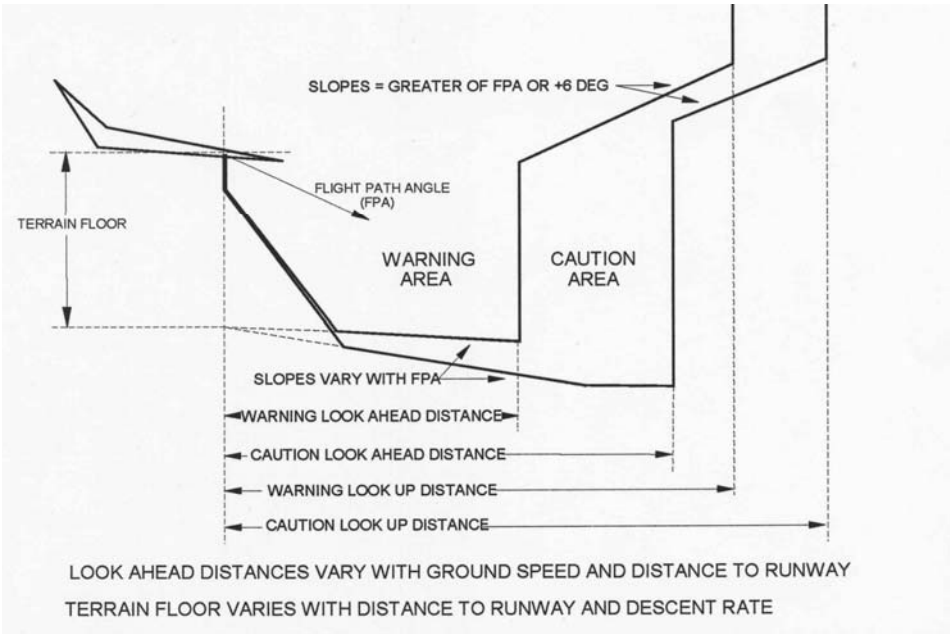
The EGPWS provides aural and visual cautions or warnings to the flight crew of conditions which have the potential to adversely impact on the safety of flight. Depending on how the system is configured, the crew may receive warnings of excessive glideslope deviation; flying too low with flaps or gear not in the landing configuration; excessive bank angle and windshear. An additional feature is the ability of the system to warn the crew that they are approaching terrain.

The EGPWS computer has built-in terrain, obstacle and airport databases. When inputs from aircraft's systems that ascertain: geographic position; altitude; attitude; airspeed and glideslope deviation are combined, the system can predict potential conflict between the aircraft's flight path and terrain.

The EGPWS computer continuously computes terrain clearance envelopes ahead of the aircraft. If the boundaries of these envelopes conflict with the terrain elevation data stored in the terrain database, messages are issued to the crew. Two terrain proximity envelopes are computed. One corresponds to a caution alert level and the other to a warning alert level.

The caution look-ahead distance (see figure 2) is computed from the aircraft's groundspeed and turn rate, to provide an advanced warning with adequate time for the crew to react safely. Depending on the particular aircraft system inputs, this time corresponds to between 60 and 40 seconds of advanced alerting.

**Figure 2: Terrain caution warning envelope diagram**[22]



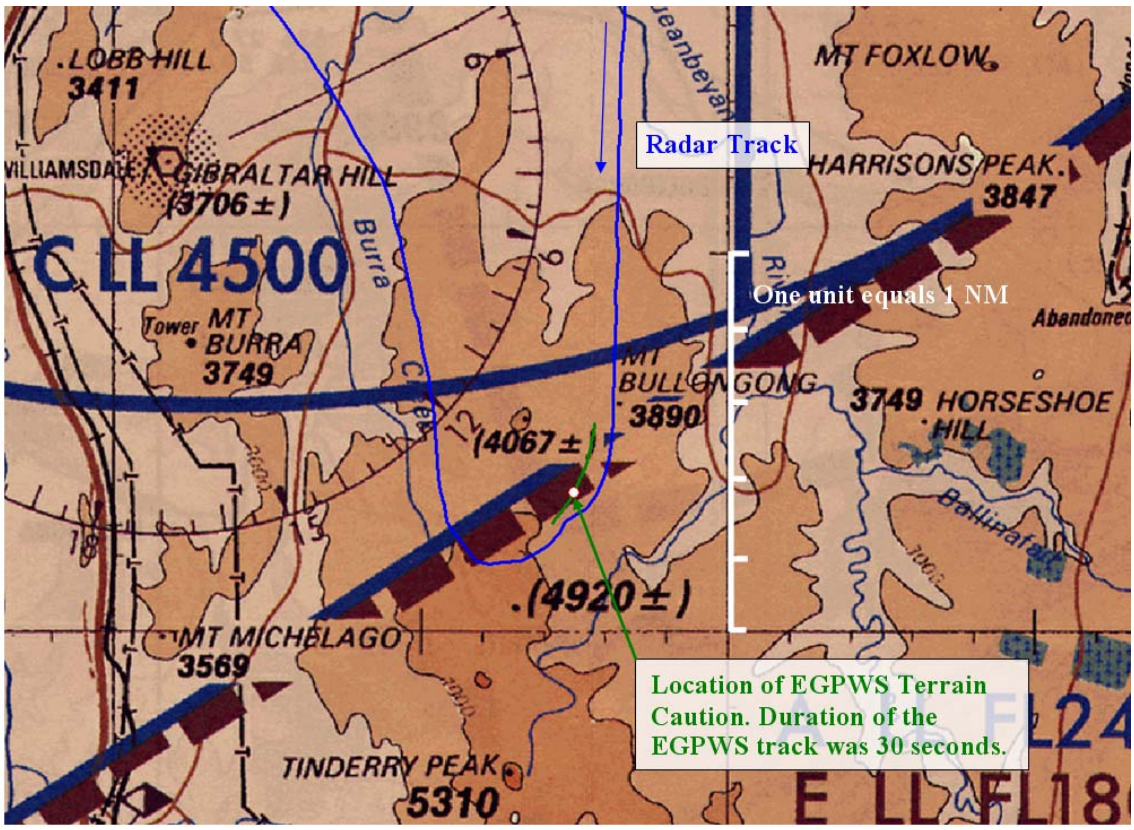

If the aircraft penetrates the caution envelope boundary (corresponding to approximately 60 seconds advanced alerting), the crew receive an aural 'CAUTION TERRAIN, CAUTION TERRAIN' and visual annunciations. If the aircraft penetrates the warning envelope boundary (corresponding to approximately 40 seconds advanced warning), the crew receive an aural 'TERRAIN, TERRAIN, PULL UP' as well as visual annunciations.

### 1.6.3.1 Crew reaction to EGPWS caution message

The crew reported receiving a single 'CAUTION TERRAIN' aural message. The operator's *737 Operations Manual* – Non Normal Checklist requires that the crew, on receiving such a warning, should 'Correct the flight path or the airplane configuration'. The crew had already commenced the inbound turn and reacted to the caution by climbing the aircraft to 6,500 ft. The aircraft was already turning away from the area of conflicting terrain when the caution terrain envelope was momentarily penetrated, causing the abbreviated caution message to be generated by the EGPWS.

[22] Diagram courtesy Honeywell

**Figure 3: Position of aircraft at the time of terrain caution, shown on visual terminal chart dated 27 November 2003.**




### 1.6.3.2 Recovered data

The following information was derived from EGPWS equipment on board the aircraft and the Airservices Australia (Airservices) radar data. Flight data recorder (FDR), cockpit voice recorder (CVR) and quick access recorder (QAR) data were unavailable, see section 1.11.

When an EGPWS message is generated, the EGPWS computer records certain data relating to the event in non-volatile memory. Recorded data covers a duration of 30 seconds; 20 seconds before an event and 10 seconds after.

At the request of the ATSB, information stored in the non-volatile memory of the EGPWS computer was downloaded by the system manufacturer and the recovered data forwarded to the ATSB for analysis.

The EGPWS receives inputs from the same aircraft sensors that are used by the crew or autopilot to navigate the aircraft. The accuracy of the GPS latitude and longitude recorded by the EGPWS was ± 100 metres. The accuracy of the altitude recorded by the EGPWS was ± 10 ft.

The data was analysed and a terrain caution message was found to have been recorded during flight leg 1364. This was the only terrain caution message that had been recorded by the EGPWS computer since installation. The flight leg data from the status file showed that it had occurred on a Perth to Canberra flight.

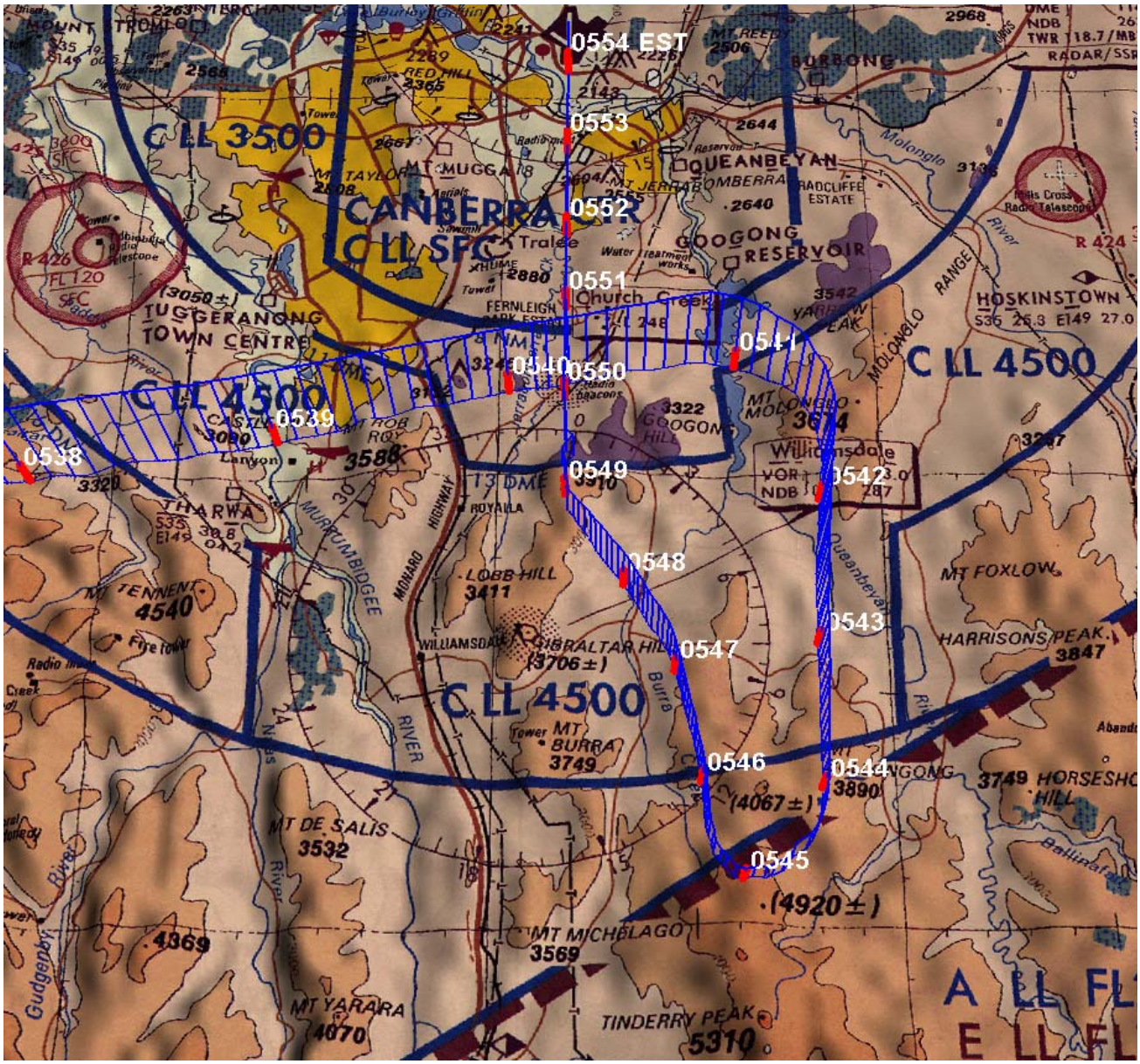
Latitude and longitude recorded at the time of the terrain caution message correlated with radar position data. The recorded terrain caution message was positively identified as the reported event.

Recorded radar data for the aircraft's flight was obtained from Airservices and data for the period between 0500 and 0555 was examined. The data showed that the aircraft overflew CCK in an easterly direction at 9,000 ft at 0540:13.

At 0540:53 the aircraft commenced a right turn and at the completion of the turn tracked due south. At 0544:08 it was on descent, passing 6,200 ft when it commenced a right turn to intercept the inbound track to CCK.

At the time of the 'CAUTION TERRAIN' message the aircraft was 2,502 ft above terrain. During the turn, it passed 0.6 NM (1.11 km) north abeam and 810 ft higher than the closest terrain that had a spot height of 4,920 ft above mean sea level. It also passed 2.7 NM (5 km) north abeam Tinderry Peak. The aircraft climbed to 6,500 ft and subsequently joined the runway 35 localiser.

**Figure 3: 3D representation of radar track**




### 1.6.4 Flight Instruments

The aircraft was equipped with an electronic flight instrumentation system, which comprised two electronic attitude director indicators (EADIs) and two electronic horizontal situation indicators (EHSIs). The EHSIs provided the crew with a pictorial display of the aircraft's track, and could be selected to a variety of modes to provide optimum information relating to a particular phase of flight. Supplementary information from the aircraft's weather radar or the EGPWS may also be displayed when selected by the crew member.

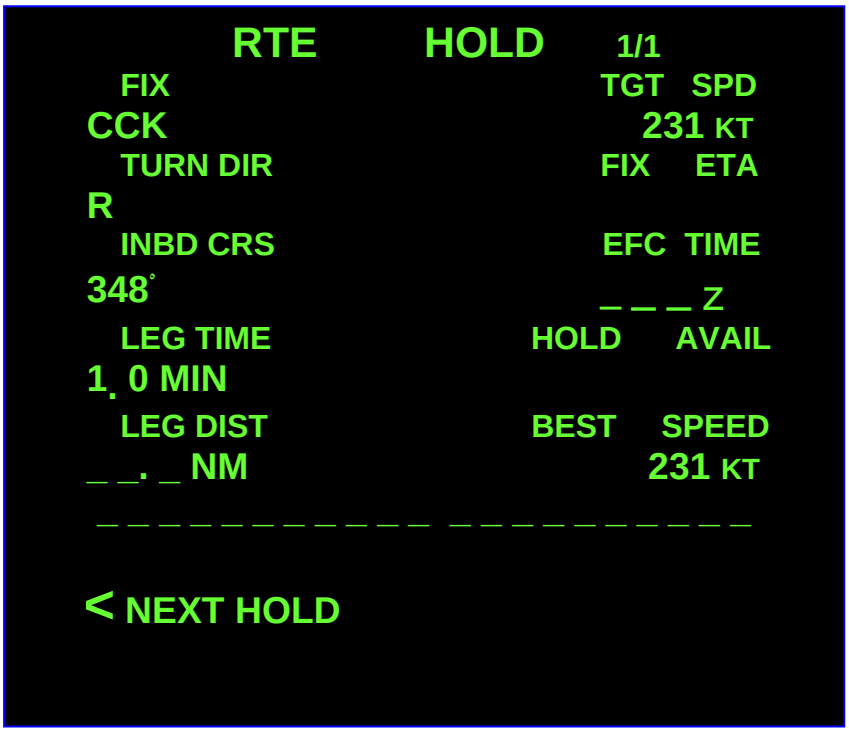
### 1.6.5 Flight Management Computer system

The flight management computer (FMC) system fitted to the 737 provided performance and flight path guidance to the crew. The FMC can also provide control and guidance to the autopilot.

The FMC combines data from navigation and performance databases as well as aircraft systems data and crew entered flight plan information to determine the aircraft's track and flight path.

The crew was able to enter data into the FMC via one of two control display units (CDU), which were mounted on the forward electronic panel located on the flight deck. The CDU allowed the crew to select the appropriate flight plan from the navigation database and to activate the route selected. The crew was able to modify the route (including entering data for a holding pattern) in a number of ways.

**Figure 5: FMC CDU display showing hold page before leg distance had been entered.**




In order to enter the holding pattern, the copilot selected the Route Hold (RTE HOLD) page on the CDU and entered the holding fix of CCK. The FMC HOLD page provided fields that prompted the copilot to input or modify the inbound course (INBD/CRS); leg time (LEG TIME), and leg distance (LEG DIST), as well as speed and target altitude (SPD/TGT ALT).

The FMC has no facility to enter a holding pattern DME limit (as is necessary when holding at CCK at 5,000 ft). The DME limit is based on the Canberra DME, which is located at Canberra airport. The CCK locator is positioned approximately 10.9 NM from the Canberra DME.

The copilot, under the direction of the pilot in command, entered a LEG DIST of 14 NM on the previously selected FMC HOLD page for CCK.

Entry of a LEG DIST on the FMC CDU HOLD page causes the previous displayed LEG TIME to be deleted.

**Figure 6: FMC CDU display showing hold page after leg distance had been entered.**


## 1.6.6 Performance

The normal descent profile of the Boeing 737 aircraft is typical of many modern turbofan aircraft, covering approximately 3 NM per 1,000 ft of descent. This profile may be altered to some extent by changing speed or altering the aircraft configuration. However, it was not possible for the crew to increase the descent gradient sufficiently to effect a straight in approach to runway 35, because the terrain in the area surrounding Canberra rises rapidly from 1,886 ft at the aerodrome to 6,273 ft at 30 NM south-west of the aerodrome. The crew decided that they would enter a holding pattern at CCK at 9,000 ft and descend to 5,000 ft to join the ILS for runway 35.

## 1.7 Meteorological information

The weather in the Canberra area was not considered to have been significant with respect to the occurrence.

First light at Canberra on 24 July 2004 was 0637.

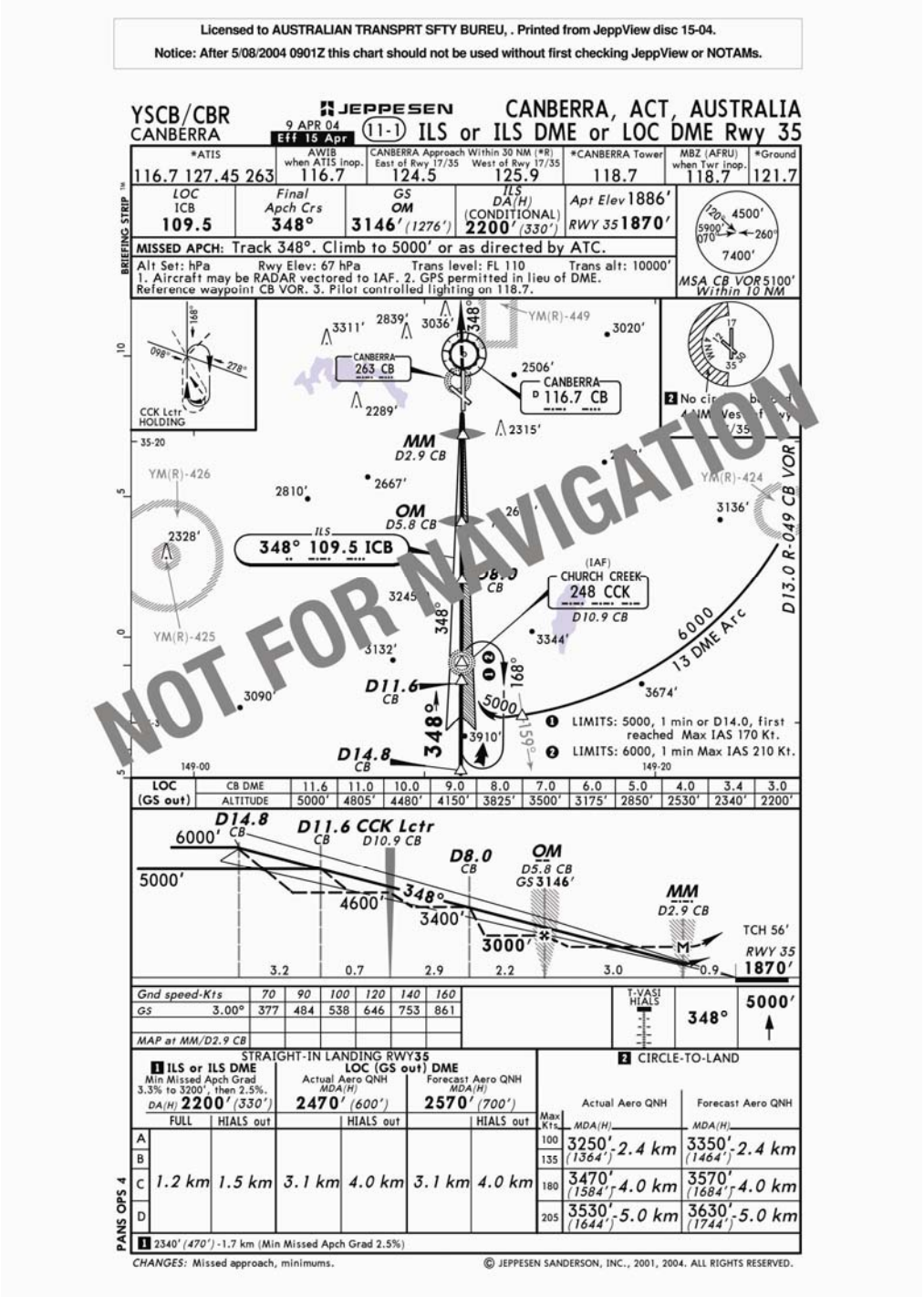
## 1.8 Aids to navigation

The runway 35 ILS at Canberra was functioning normally at the time of the occurrence.

The CCK locator forms part of the runway 35 ILS, and the associated holding pattern can be utilised to manage traffic flow, to delay arrival due to weather conditions, or to safely facilitate an aircraft's descent from the minimum safe altitude to a lower altitude from which interception of the ILS profile is feasible. The locator was functioning normally at the time of the occurrence.

The purpose of an instrument approach chart is to display the data necessary for the safe execution of the appropriate procedure. The Canberra runway 35 ILS approach chart depicted in figure 7, which was used by the 737 crew, included information denoting limits for aircraft holding at CCK. Although the DME limit associated with the CCK holding position utilised the Canberra DME, this was not detailed on the holding pattern limits on the chart. There was no DME located at CCK. The 737 crew involved in this occurrence were prompted by the FMC to enter a LEG DIST for the holding pattern at CCK, however, the chart did not provide the crew with that specific information.

**Figure 7: Canberra runway 35 ILS approach chart valid at the time of the occurrence.**

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## 1.9 Communications

All communications between ATS and the crew were recorded by ground based automatic recording equipment. The quality of recorded transmissions was good.

## 1.10 Aerodrome information

Canberra Aerodrome is located in the Australian Capital Territory (ACT) and has two intersecting runways, 35/17 and 30/12. Only runway 35 is equipped with an ILS. At the time of the occurrence the aerodrome and approach air traffic services were normally available from 0530 to 2200. Outside those hours the aerodrome reverted to a non-controlled mandatory broadcast zone, requiring that pilots provide their own separation from other aircraft and from terrain. The minimum sector altitude[23] within 10 NM of the Canberra VOR[24] navigation aid was 5,100 ft, but due to mountainous terrain, particularly south of Canberra, was 7,400 ft within 25 NM from the VOR[25], between the 080º radial and the 250º radial.

## 1.11 Flight recorders

The aircraft was fitted with a digital flight data recorder and a cockpit voice recorder. However, no information relating to the occurrence flight was available from these recorders because the occurrence flight data had been overwritten. The aircraft's quick access recorder was found to be unserviceable and had not recorded the occurrence flight and the previous sector.

## 1.12 Wreckage and impact information

Not applicable.

## 1.13 Medical and pathological information

Not applicable.

## 1.14 Fire

Not applicable.

[23] The minimum sector altitude is the published altitude that provides a 1,000 ft obstacle clearance within a 25 NM radius from the navigation facility upon which the MSA is predicated.
[24] VHF omni-directional radio range.

## 1.15 Survival aspects

Not applicable.

## 1.16 Tests and research

Not applicable.

## 1.17 Organisational and management information

### 1.17.1 Airservices Australia

Airservices was responsible for performing the following functions, relating to the safety, regularity and efficiency of air navigation[26]:

- air traffic services
- an aeronautical information service
- rescue and fire fighting services
- an aeronautical radio navigation service
- an aeronautical telecommunications service.

#### 1.17.1.1 Aeronautical information service

One of the many functions of Airservices is to develop and produce instrument approach charts for aeronautical use. Although the chart used by the crew was produced by Jeppesen Sanderson Inc., it was developed from data published by Airservices.

#### 1.17.1.2 Canberra Terminal Control Unit

The Canberra Approach control function was performed by the Canberra Terminal Control Unit (TCU)[27], which was remotely located at the Melbourne Air Traffic Control Centre at Tullamarine Airport.

On the day of the occurrence, the rostered air traffic controller did not report for duty at 0515 as assigned. Consequently, the Canberra Approach Control service was not available until approximately 40 minutes after the scheduled TCU opening time of 0530.

[26] Air Services Act 1995 – Sect 8

[27] Terminal Control Unit (TCU) – A unit providing air traffic services generally within a control area established at the confluence of ATS routes in the vicinity of one or more major aerodromes in which air traffic services are provided by Approach and Departures Control.

### 1.17.1.3 Temporary Local Instruction

Airservices had previously identified a need to formalise procedures to be followed in the event that the Canberra Tower or TCU services could not be provided. The contingency planning was to cover eventualities such as staff shortages, TCU evacuation and operating from temporary facilities. Three days prior to the occurrence flight, the contingency plan was promulgated as a temporary local instruction (TLI) - TLI/MC/04/157. It applied immediately.

Some of the features of the contingency plan that would have applied to an aircraft arriving in Canberra from Perth are as follows:

- Canberra control zone and TCU Class C airspace within 30 NM of Canberra from 3,500 ft up to 10,000 ft shall be declared a temporary restricted area
- Canberra Tower would continue to provide an Aerodrome Control Service
- Arriving IFR[28] aircraft shall remain on the enroute frequency until 15NM from Canberra then contact Canberra Tower
- Canberra Tower would record Automatic Terminal Information Service (ATIS) information for contingency procedures and update operational information as usual. The ATIS must include the following:
  CANBERRA APPROACH CONTROL SERVICE NOT AVAILABLE. CANBERRA CONTROL ZONE AND CLASS C AIRSPACE WITHIN 30 NM CANBERRA BETWEEN 3,500 ft AND 10,000 ft DECLARED AS RESTRICTED AREA
- The Canberra/Central group (enroute) controller must notify relevant aircraft of the airspace status and contingency procedures.

### 1.17.1.4 Air traffic control staffing issues

The controller rostered for duty on the morning of the occurrence was expected to report for duty at the Melbourne Air Traffic Control Centre at 0515. This was to allow time for preparation prior to the TCU opening time of 0530. When the controller did not report for duty, attempts were made to contact the controller, but without success. An off duty controller was contacted, who proceeded to the Centre to perform the duties of the absent rostered controller.

The contingency plan contained in the TLI was not implemented on the morning of the occurrence. Airservices stated that the reason the contingency plan was not followed was ‘because the duty supervisor believed he was doing the right thing by leaving the airspace as MBZ, as he considered that a replacement whom had been contacted and who resides

[28] Instrument flight rules.

close to Tullamarine Airport would arrive in a short time, and there may have been confusion and promulgation issues'.

#### 1.17.1.5 Qualifications of Controllers

Before being able to fulfil the role of approach controller at the Canberra TCU, a controller must undergo simulator training, as well as a period of on the job training under the supervision of a Canberra TCU qualified instructor.

In addition, a controller must satisfy recency requirements associated with the Canberra TCU as follows:

> To satisfy the Recency requirement for an operating position or discrete function, a licence-holder must have performed the duties of that endorsement for at least **five hours** in the previous **21 days.**

Although the Melbourne TCU had other controllers present when the rostered controller did not report for duty, no controller was available to open the Canberra TCU. Those present were either not Canberra TCU qualified, were not recent, or were performing other duties in the Melbourne TCU.

## 1.18 Other information

The ATSB database had no record of similar holding pattern excursions in the vicinity of Canberra.

## 1.19 Useful or effective investigation techniques

Access to the data stored in the EGPWS computer non-volatile memory assisted the investigation significantly. The accessibility of non-volatile memory data has provided another tool for the investigation of incidents and accidents.

# 2 ANALYSIS

This occurrence is characterised by the influence of events occurring prior to, and during the flight that affected the crew, the aircraft and the air traffic control system. Evidence suggests that the flight crew's operational performance was affected at a critical stage of the flight by fatigue, the late advice of the status of air traffic services and the crew's misinterpretation of the Church Creek (CCK) locator holding pattern data on the instrument approach chart.

The crew's ineffective contingency planning for a descent to Canberra without air traffic control support and the erroneous data entry in the aircraft's flight management computer (FMC) suggest that the crew was not functioning at an appropriate level of alertness.

It is likely that both the pilot in command and the copilot were experiencing fatigue due to the cumulative effects of ineffective sleep in the period preceding the Perth to Canberra night sector and the ongoing period of wakefulness during the flight. Additionally, as they approached Canberra, the crew was working at a low point in their circadian rhythms. It is therefore likely that they were experiencing a decreased level of alertness.

The application of the minimum equipment list (MEL) on the flight deck air conditioning system allowed continued flight operation despite abnormally hot conditions. In combination, those conditions probably interacted to reduce the level of crew alertness, performance and attention. The crew's lack of recognition of the inaccurate entry in the FMC is consistent with the effects of fatigue, and it is likely that those effects were exacerbated by the warmer flight deck temperatures.

The crew had appropriately planned their departure from Perth in accordance with the operator's arrival time requirements. Consequently, throughout the flight they expected that normal air traffic services would be available and placed a heavy reliance on the availability of radar services to safely facilitate descent. Their lack of effective contingency planning to cover the absence of the controller contributed to the occurrence and was also an indicator of possible crew fatigue.

As the aircraft's arrival at Canberra was during the period of pre-dawn darkness, the crew would normally have accepted directions from air traffic control radar services for terrain avoidance during descent to the aerodrome. However, by the time the crew realised that an air traffic controller would not be available for their approach, they had limited time available to interpret the CCK holding pattern data from the instrument approach chart and correctly enter and verify the required data entry in the FMC.

The holding pattern Distance Measuring Equipment (DME) limit distance on the referenced instrument approach chart was misinterpreted by the crew. The crew did not detect that the DME distance referenced on the chart was based on the Canberra DME. The instrument approach chart did not contain the specific Canberra DME identifier in the CCK holding pattern limits.

The activation of the contingency plans for staff shortages in the Canberra Terminal Control Unit (TCU) is unlikely to have changed the circumstances of the occurrence, other than the classification of the airspace in which the aircraft was operating. However, by not resolving the uncertainty regarding the availability of the TCU, air traffic services contributed to the 737 crew's lack of preparedness for a descent to Canberra without radar services.

The effect on the 737 crew of inadequate preparation, rushed procedures and inadequate verification of entered data resulted in the aircraft flying a holding pattern with a leg length of 14 NM, taking the aircraft outside the designed protected area of the CCK holding pattern.

This occurrence emphasises the need for flight crews to plan ahead and develop timely and effective contingency plans to allow for non-normal operational circumstances. The ability of the crew to develop such a plan was made more difficult by the effects of fatigue and heat stress and the absence of timely advice regarding the status of air traffic services.

# 3 CONCLUSIONS

## 3.1 Findings

### 3.1.1 Aircraft

1. There were no aircraft, engine or system malfunctions that contributed to the aircraft proceeding beyond the published limits of the holding pattern.

2. The aircraft carried a minimum equipment list (MEL) requirement relating to the air conditioning system malfunction.

3. The faulty air conditioning system provided abnormally hot air to the flight deck for the duration of the flight.

4. The Enhanced Ground Proximity Warning System (EGPWS) detected proximate terrain and provided the crew with a single CAUTION TERRAIN message.

### 3.1.2 Flight Crew

1. The flight crew was appropriately licensed, trained and medically fit to conduct the flight.

2. The flight crew departed Perth aware that the air conditioning system was affected by an MEL.

3. The flight crew departed Perth with the expectation that Approach and Tower services would be available for their arrival in Canberra.

4. The flight crew commenced the descent expecting that Canberra Approach and Tower services would be available.

5. The flight crew's initial descent briefing did not include discussion of the CCK holding pattern.

6. The flight crew misinterpreted the holding pattern limit from the runway 35 ILS approach chart.

7. The flight crew did not monitor the Canberra DME to check distance on the holding pattern outbound leg until they had proceeded beyond the holding pattern limit.

8. The pilot in command reacted to the EGPWS CAUTION TERRAIN message by climbing to 6,500 ft.

### 3.1.3 Air Traffic Services

1. The air traffic controller rostered to open the Canberra Approach position did not report for duty at the rostered time on the day of the occurrence.

2. Airservices issued temporary local instructions (TLI) covering contingency planning in the event of staff shortages at the Canberra TCU, three days prior to the occurrence, effective immediately.

3. The contingency plan promulgated by Airservices was not implemented on the morning of the occurrence.

4. Three days after the occurrence Airservices issued a new TLI that implemented clearer instructions regarding the implementation of the contingency plan.

5. The holding pattern limits published for CCK, did not contain the referenced DME identifier (Canberra) in the limit notes.

## 3.2 Significant Factors

1. The MEL applied to the aircraft allowed continued operation when elevated temperatures caused the environmental conditions on the flight deck to become abnormally hot, contributing to pilot fatigue during a long flight sector.

2. The assistance of air traffic control radar services, which is normally provided, was not available to the crew.

3. The holding pattern limits published for CCK, did not contain the referenced DME identifier (Canberra) in the limit notes.

4. The copilot, under the direction of the pilot in command, entered incorrect data in the FMC.

5. The pilot in command did not detect the incorrect entry in the FMC.

6. The flight crew did not employ effective means to verify the navigational performance of the FMC.

7. The flight crew did not comply with the published CCK holding pattern limit of 14 NM by DME from Canberra.

8. The flight crew was suffering from fatigue due to exposure to heat, circadian disruption and sleep loss.

# 4. SAFETY ACTION

## 4.1 Aircraft operator's safety action

On 29 July 2004, the operator issued the following flight standing order to 737 flight crews.

**B737**
**FMC HOLD PAGE**

A recent incident has indicated that there may be some confusion relating to the function of the Leg Distance (LEG DIST) prompt of the B737 FMC Hold page.

The Leg Distance prompt allows entry of the actual length of the inbound Leg of a holding pattern in nautical miles. It does not refer to a DME limit as depicted on a charted holding pattern.

Additionally, beware that a Leg Distance entry will override a Leg Time value.

The operator issued the following INTAM [Internal (Company) Notice to Airmen] to its crews on 4 August 2004:

**HOLDING – YSCB**

Holding at Church Creek Locator below 6000 ft not permitted
UFN [until further notice]

The operator also advised that it had published an article in its Flight Operations Newsletter (Safety Section), December 2004 edition, drawing the attention of crews to the requirements and guidelines concerning the submission of Air Safety Incident Reports, which are detailed in Chapter 3 of the its Flight Administration Manual (FAM).

The operator also advised that it has amended its procedures to require the removal from service of both the FDR and the QAR when it is believed that there will be a need for data in an event of 'potential importance'.

The operator instructed maintenance personnel to rectify, at the soonest opportunity, any flight deck or passenger cabin temperature control problems that are entered in the aircraft technical or maintenance logs.

## 4.2 Airservices Australia safety action

On 27 July 2004, Airservices Australia issued Temporary Local Instruction (TLI), (TLI/MC/04/160) that detailed how the Canberra TCU staff shortage contingency plan should be activated.

The TLI states in part:

> If the ATC (air traffic controller) does not present for work by 0530 the Systems Supervisor is to advise the Canberra Tower and activate the Canberra TCU Contingency Plans with an effective time of not later than 0545. This should occur regardless of the advised time of arrival of the duty ATC – NOTAMS[29] etc can be cancelled if required.

## 4.3 Approach chart publishers safety action

The publishers of the approach charts used by the 737 crew, Jeppesen Sanderson Inc., have advised the ATSB that they intend to include the DME identifier in the holding pattern limit note of the Canberra ILS chart and on other charts similarly affected.

[29] Notice to Airmen