



**Australian Government**

**Australian Transport Safety Bureau**



**ATSB TRANSPORT SAFETY REPORT**  
Aviation Occurrence Investigation  
AO-2008-080  
Final

**Operational event**  
**Darwin Aerodrome, NT**  
**17 December 2008**  
**PK-GZJ, Boeing B737-4MO**





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# CONTENTS

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<b>THE AUSTRALIAN TRANSPORT SAFETY BUREAU .....</b>	<b>vi</b>
<b>TERMINOLOGY USED IN THIS REPORT .....</b>	<b>vii</b>
<b>FACTUAL INFORMATION .....</b>	<b>1</b>
Sequence of events.....	1
Personnel information.....	3
Aircraft pilots.....	3
Air traffic controllers.....	4
Aircraft information .....	4
Flight data recorder and cockpit voice recorder .....	4
Aircraft navigation systems.....	4
Meteorological information .....	5
Forecast weather.....	5
Observed weather .....	5
Summary .....	5
Communications .....	6
Organisational and management information.....	6
Operator's procedures .....	6
Requirements for the conduct of instrument approaches .....	7
Radiotelephony readback requirements.....	7
Additional information.....	7
The inertial reference system.....	7
En route naviads .....	8
<b>ANALYSIS.....</b>	<b>9</b>
Introduction.....	9
Darwin runway 11 very high frequency omnidirectional radio range approach .....	9
Positioning for the approach.....	9
Conduct of the approach.....	9
Radiotelephony and ATC instructions .....	10
Accuracy of the inertial reference system position.....	11
Monitoring of raw data .....	11

<b>FINDINGS.....</b>	<b>13</b>
Contributing safety factors.....	13
<b>APPENDIX A: DARWIN RUNWAY 11 VOR APPROACH CHART .....</b>	<b>17</b>
<b>APPENDIX B: REQUIREMENTS FOR THE CONDUCT OF     INSTRUMENT APPROACHES.....</b>	<b>19</b>
<b>APPENDIX C: RADIOTELEPHONY READBACK     REQUIREMENTS.....</b>	<b>21</b>
<b>APPENDIX D: SOURCES AND SUBMISSIONS.....</b>	<b>23</b>

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### **Abstract**

On 17 December 2008, a Boeing Company 737-4MO aircraft, registered PK-GZJ, made a significant diversion around weather at night while en route to Darwin, Northern Territory from Denpasar, Indonesia. The aircraft was cleared to conduct the runway 11 very high frequency omnidirectional radio range (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 105 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 105 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 105 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° tolerance either side of the 105 radial. From then on, the aircraft was no longer 'established' on the 105 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.

The investigation did not identify any organisational or systemic issues that might adversely affect the future safety of aviation operations. However, in response to the occurrence, the aircraft operator developed a corrective action plan that addressed a number of crew resource management and non-precision approach training aspects to the event.

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# THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to 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 identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

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

## **Developing safety action**

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

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## TERMINOLOGY USED IN THIS REPORT

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**Occurrence:** accident or incident.

**Safety factor:** an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

**Contributing safety factor:** a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

**Other safety factor:** a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

**Other key finding:** any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

**Safety issue:** a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

**Risk level:** The ATSB’s assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

**Safety action:** the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.



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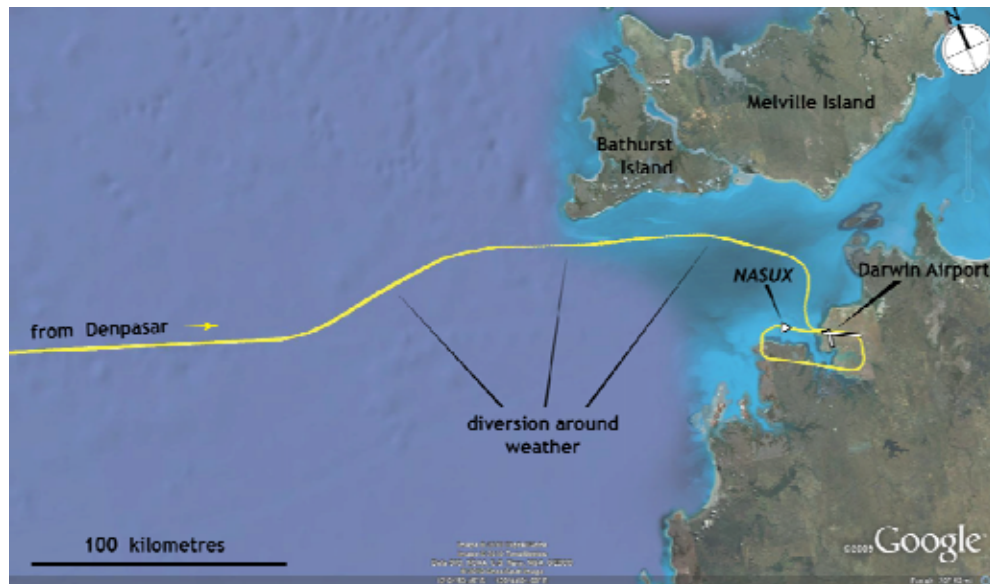
# FACTUAL INFORMATION

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## Sequence of events

On 17 December 2008, a Boeing 737-4MO, registered PK-GZJ, was being operated on a scheduled passenger service from Denpasar, Indonesia to Darwin, Northern Territory with an arrival time in Darwin of about 0500 Central Standard Time<sup>1</sup>. The aircraft's planned track from Denpasar approached Darwin from the north-west but the flight crew were forced to divert up to 40 km left of track to avoid weather (Figure 1).

**Figure 1: Track to Darwin**



When the aircraft was about 130 km north-west of Darwin and descending through 25,000 ft above mean sea level (AMSL), the approach controller advised the flight crew that, once clear of the weather, they could expect to track direct to NASUX, which was the initial approach fix<sup>2</sup> for the runway 11 very high frequency (VHF) omnidirectional radio range (VOR)<sup>3</sup> approach. The aircraft cleared the weather at a position north of Darwin and to the east of NASUX.

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<sup>1</sup> The 24-hour clock is used in this report to describe the local time of day, Central Standard Time (CST), as particular events occurred. Central Standard Time was Coordinated Universal Time (UTC) + 9.5 hours.

<sup>2</sup> A point in space, defined by both a specified height AMSL and a specified distance from a ground-based navigation aid, at which the initial approach segment of an instrument approach begins.

<sup>3</sup> VOR. A ground-based navigation aid comprising a beacon emitting a fixed horizontal circular radiation pattern at 108 to 118 MHz, on which is superimposed a rotating directional pattern at 30 Hz. A receiver in an aircraft displays the bearing (called a 'radial') of the aircraft to/from the beacon.

Once the aircraft was within 55 km of the Darwin Aerodrome distance measuring equipment (DME)<sup>4</sup>, or about 60 track km from the runway 11 threshold, the approach controller cleared<sup>5</sup> the flight crew to descend to 3,000 ft (the commencement height for the runway 11 VOR approach via NASUX).

Shortly after, the approach controller asked the flight crew if they could accept a clearance to track to NASUX to position the aircraft for the runway 11 VOR approach (Appendix A). The flight crew's response did not mention NASUX but instead indicated that they could intercept the final approach radial of 105°<sup>6</sup> at 9 DME (17 km).<sup>7</sup> That was, at a position to the east of NASUX and about 12 km from the runway 11 threshold. The flight crew were flying the aircraft using the autopilot in HDG SEL<sup>8</sup> mode to intercept the 105 radial about 8 km from the runway threshold and for the subsequent approach. The pilot in command reported that his electronic flight information system (EFIS) display showed the VOR raw data during the approach, but that he did not correct for the wind, which blew the aircraft right of track.

The approach controller then instructed the flight crew to manoeuvre west of NASUX as required to track direct to NASUX for a straight-in approach to runway 11 via the runway 11 VOR approach, and to contact the tower when established on final. In response, the flight crew correctly read back the tower frequency and included the phrase 'straight-in approach runway 11' in their transmission. The flight crew's readback did not include the approach controller's instruction to track via NASUX for the runway 11 VOR.

The approach controller repeated that the clearance was for the runway 11 VOR approach via NASUX, again using the term '[for a] straight-in approach'. Again, the flight crew's response did not include the term 'VOR' and indicated they understood they were cleared for a 'straight-in approach'. The aircraft then left 3,000 ft on further descent, although it had not been cleared to descend below 3,000 ft. Shortly after, radar indicated that the aircraft was descending and about to pass through 2,000 ft. The approach controller confirmed with the flight crew that the starting height for the runway 11 VOR approach was 3,000 ft. The flight crew responded that they were at 2,000 ft to 'intercept ... runway course'.

At a position 17 km north-west of the Darwin DME and 12 track km from the runway 11 threshold, the flight crew requested descent to 1,500 ft and the approach controller cleared them to descend to the radar lowest safe altitude (and minimum sector altitude (MSA)) of 1,600 ft. The aircraft levelled at 1,600 ft and then turned left to track 105° inbound to the aerodrome, rolling out of the turn 8 km from the

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<sup>4</sup> Airborne secondary radar equipment that sends out paired pulses that interrogate a DME ground station before returning to the airborne equipment. The time from transmission to receipt back at the aircraft of the transmission is translated into distance.

<sup>5</sup> A clearance is an authorisation by air traffic control for an aircraft to proceed under specified conditions within controlled airspace.

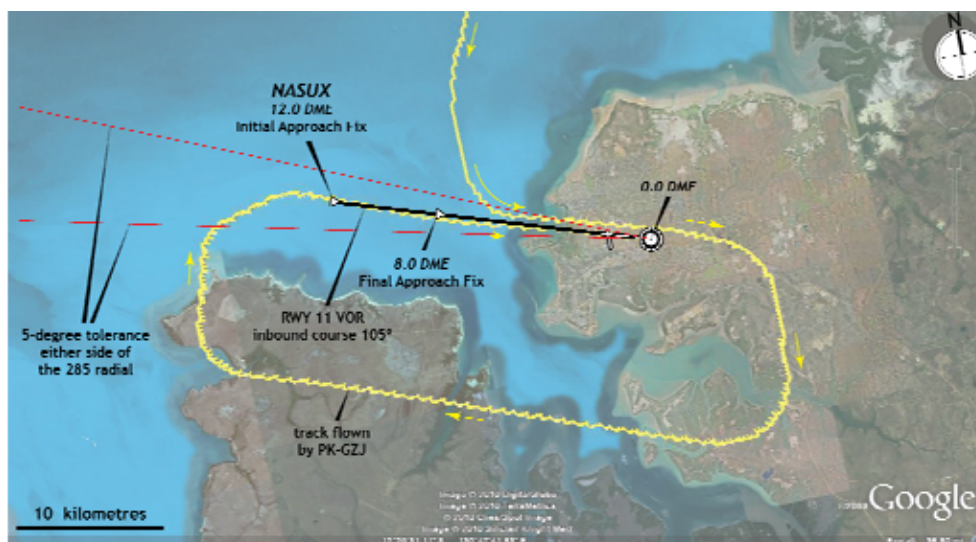
<sup>6</sup> At the time of the incident, the final approach radial for the RWY 11 VOR approach was 105. At the time of writing this report, the final approach radial for the RWY 11 VOR approach was 106.

<sup>7</sup> Runway 11 is aligned on 106° magnetic.

<sup>8</sup> HDG SEL (heading select) is an autopilot mode in which the aircraft can be steered by adjusting the heading bug on the HSI (horizontal situation indicator).

threshold. It did not intercept the 105 radial inbound to the VOR.<sup>9</sup> Instead, the aircraft flew a track parallel to, and 600 m north of, the 105 radial (Figure 2) while continuing its descent towards the minimum descent altitude for the runway 11 VOR approach of 500 ft.

**Figure 2: Aircraft track superimposed on elements of the runway 11 VOR approach<sup>10</sup>**



The approach controller transferred the aircraft to the aerodrome controller (ADC) when it was about 5 km from the runway threshold. The aircraft became visible to the ADC when it broke through the cloud at about 700 ft. Realising the aircraft was not lined up with the runway, the ADC instructed the flight crew to make a missed approach. The aircraft descended to 513 ft after it passed abeam the threshold. During the missed approach, the flight crew switched the autopilot's lateral guidance mode to VOR.

About 17 minutes later, the aircraft landed after conducting a runway 11 VOR approach via NASUX.

## Personnel information

### Aircraft pilots

The pilot in command, who was the pilot flying (PF) at the time of the occurrence, had about 3,000 hours flying experience on Boeing 737 aircraft. He had flown about 70 hours in the preceding 30 days.

<sup>9</sup> An aircraft track is its path over the ground from takeoff to touchdown, in this case oriented on 105°. A radial is a magnetic bearing extending from a point-source navigation aid.

<sup>10</sup> Derived from latitude and longitude information that was supplied by the aircraft's inertial reference units (IRUs) and recorded at 1-second intervals by the aircraft's flight data recorder (FDR). The serrated appearance of the aircraft's track was a result of the limited resolution of the recorded latitude and longitude data.

The copilot, who was the non-flying pilot at the time of the occurrence, had about 4,000 hours flying experience on Boeing 737 aircraft. He had flown about 70 hours in the preceding 30 days.

Both pilots were well rested and the flight from Denpasar to Darwin was their first flight of the day.

### **Air traffic controllers**

The approach controller graduated from military air traffic control (ATC) training in 2006 and was rated as a tower controller in December 2006 and an approach controller in November 2008 (1 month before the occurrence).

The ADC had been at Darwin since January 2007 and obtained a tower rating in May 2007.

The ATC night shift of 16/17 December 2008 was from 2145 until 0600, with the next shift beginning at 0545. The staffing that night was normal, comprising the two controllers and no supervisor. In consequence, the approach controller and planner roles were combined, as were the ADC and surface movement controller roles.

### **Aircraft information**

The aircraft, a Boeing Company 737-4MO, serial number 29205, was manufactured in the United States (US) in 1998. It was first registered in Indonesia in 2004 and had been operated by the same operator since that time.

### **Flight data recorder and cockpit voice recorder**

The aircraft was fitted with a flight data recorder (FDR) and cockpit voice recorder (CVR). On 17 December 2008, the Australian Transport Safety Bureau (ATSB) requested the Indonesian National Transportation Safety Committee (NTSC) to facilitate the download of the FDR by the operator and to arrange for the downloaded data to be sent to the ATSB recorder facilities in Canberra.

The relevant parameters were summarised by ATSB recorder technicians in tabular form and graphically for the ATSB investigation and provided to the NTSC.

### **Aircraft navigation systems**

The aircraft was fitted with two Litton inertial reference units (IRUs). Those units used a magnetic variation model that was based on US National Oceanic and Atmospheric Administration geomagnetic survey data from 1990 and extrapolated to 1995.

The aircraft's enhanced ground proximity warning system<sup>11</sup> incorporated a Global Positioning System (GPS)<sup>12</sup> input and there were two GPS receivers integrated into the aircraft's flight management system (FMS).

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<sup>11</sup> An enhanced ground proximity warning system uses aircraft flight data to calculate an envelope around the projected flightpath and compares this with an internal database of the terrain. Potential conflicts result in an aural/visual warning to the flight crew.

The flight crew flew the first approach with the autopilot in HDG SEL (heading select) mode and the EFIS in MAP mode<sup>13</sup>. In this configuration, they could change the aircraft's heading by manually adjusting the heading bug on the autopilot mode selector panel on the glareshield, and they had a visual representation of the aircraft, the VOR, and the 105 radial on the EFIS MAP display.

## **Meteorological information**

### **Forecast weather**

The Bureau of Meteorology reported that the aircraft was likely to have encountered cloud at a number of levels between 25,000 ft and 500 ft on its approach and descent into Darwin. Radar data indicated that there were widespread areas of rain in the region surrounding Darwin Aerodrome, that they were especially prevalent within 100 to 150 km to the south-west and north-west, and that there were areas of moderate to heavy rain to the west and north within about 50 km of the aerodrome.

### **Observed weather**

The flight crew reported that, during their approach from the north, there was weather about 20 km to the north-west of the runway.

The air traffic controllers reported that, during their shift, the cloud had been 'at its worst' when the occurrence aircraft reached Darwin and that the cloud base was about 700 ft.

Surface weather observations indicated broken<sup>14</sup> low cloud with a base at 600 ft, and a reduction in horizontal surface visibility to 4,000 m in moderate rain at the aerodrome at the time of the incident.

## **Summary**

The weather forecasts, reports and observations were consistent with the aircraft approaching Darwin Aerodrome in instrument meteorological conditions, with a cloud base at the aerodrome of between about 500 ft and 700 ft.

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<sup>12</sup> GPS. A worldwide system in which users derive their position by interrogating a net of 24 satellites.

<sup>13</sup> MAP was an EHSI (electronic horizontal situation indicator) display mode that showed aircraft position relative to the route of flight on a moving map background. It had the advantage that the pilot could turn the aircraft to position the track line over a desired waypoint or symbol, and the aircraft would then fly accurately to that point, regardless of wind effect.

<sup>14</sup> 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. Few = 1 to 2 oktas, scattered = 3 to 4 oktas, broken = 5 to 7 oktas and overcast = 8 oktas.

## Communications

Over a series of four transmissions, the approach controller:

- advised the flight crew to expect tracking to NASUX once clear of weather
- asked the flight crew if they could accept a clearance for the runway 11 VOR approach via NASUX
- cleared the flight crew to conduct the runway 11 VOR approach via NASUX.

Two of those transmissions included the phrase 'straight-in approach', which has specific meaning depending on the flight rules under which an aircraft is being operated. Under the instrument flight rules, the term straight-in approach refers to an instrument approach where the final approach is made without a prior procedure turn. Under the visual flight rules, it refers to an approaching aircraft lining up on the intended landing runway's extended centreline without executing any other part of the circuit pattern.

The flight crew did not respond to any of those transmissions to indicate either that they understood the approach controller's intention that they should fly the runway 11 VOR approach via NASUX, or that they were going to comply with the clearance to do so. Instead, their responses indicated either that they had only understood the part of the instructions that included the words 'straight-in approach', or that they intended to make a straight-in approach from a pilot intercept of the 105 radial.

Although the approach controller used the term 'VOR' four times in separate transmissions, the flight crew did not say 'VOR' until after they had turned onto final approach about 8 km from the runway threshold.

## Organisational and management information

### Operator's procedures

There was no requirement in either the manufacturer's recommended standard operating procedures (SOPs), or in the operator's SOPs for the flight crew to check the accuracy of the aircraft's IRS position against externally-derived position information, such as from ground-based nav aids.

The operator's procedures stated the following:

#### Approach and landing

##### Use of FMC during approach

In principle, the use of FMCS [flight management computer system] (LNAV mode) below 5,000 feet or Minimum Sector Altitude<sup>[15]</sup>, whichever is higher, during descent and approach is strictly prohibited. It should only be used as

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<sup>15</sup> The lowest altitude that provides 1,000 ft clearance above all objects within a circle of 25 NM (46 km) or 10 NM (19 km) radius centred on either a radio navaid or the Aerodrome Reference Point.

additional information, both VHF-NAV receivers<sup>16]</sup> must be manually set to enable continuous monitoring of the FMC position (on aircraft without scanning DME, leave one set in auto tune, if possible, to enable correct radio update).

If the FMC position is found to be incorrect, discontinue the use of it.

[.....]

During ILS [instrument landing system] or VOR approach, PF must have RAW DATA<sup>17]</sup> display on his/her EHSI not later than Initial Approach Fix (IAF).

The RAW DATA that was required to be monitored by the PF during the approach into Darwin was the VOR information that was displayed on the EHSI. That would have shown that the aircraft was not tracking the 105 VOR radial inbound, and would have indicated when the aircraft was no longer established on the 105 radial.

## **Requirements for the conduct of instrument approaches**

The Australian Aeronautical Information Publication (AIP) contained guidance on the conduct of instrument approaches in Australia. That guidance specified that an aircraft must be established on the correct instrument approach track before descending below the specified altitude. The full AIP requirements are at Appendix B.

## **Radiotelephony readback requirements**

The AIP and Manual of Air Traffic Services (MATS) contained the required radiotelephony readbacks for application by pilots, and explained the need for those readbacks to air traffic controllers respectively. That included ensuring that a pilot understood and complied with air traffic control clearances and instructions. The relevant AIP and the MATS requirements are at Appendix C.

## **Additional information**

### **The inertial reference system**

An aircraft's IRS is centred on its inertial reference units (IRUs). Each IRU has three sets of laser gyros and accelerometers that enable it to sense a change in the aircraft's position. The IRS calculates the aircraft's path by adding the change in position sensed during flight to the position when the IRS was 'initialized' on the ground before the flight began. During flight, the IRS-calculated position becomes less and less accurate because of small internal errors in the IRUs. The accumulated error or 'drift' as a result of this process may be up to 3.7 km/hr (2 NM/hr).

To correct accumulated internal IRS errors, an aircraft's FMS can update the aircraft's position during flight using ground-based navigation aids (navaids). As the aircraft flies over ground-based navaids such as DMEs, VORs, and localisers

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<sup>16]</sup> Radio receivers in an aircraft that pick up the signal from VOR stations.

<sup>17]</sup> Data that has not been subjected to processing or any other manipulation.

(LOCs)<sup>18</sup>, the FMS determines the aircraft's current position by summing the position determined by the IRS with the position determined on the basis of those ground-based navaids. This refines the position calculated on the basis of the IRS alone and corrects for IRS drift.

Such refinement is not possible during oceanic and remote area operations, where there are no ground-based navaids. Under those circumstances, the position calculated by the FMC cannot be more accurate than the IRS position with its accumulated error or drift.

Correction to the IRS position occurs continuously, either automatically or manually, if signals from the following navaids (listed by decreasing priority) are available:

- two or more DME stations
- one VOR with a co-located DME
- one LOC with a co-located DME
- one LOC.

The correction with two or more DMEs is the most accurate. The VOR/DME correction is less accurate, due to inherent VOR bearing errors, and the VOR/DME correction can occur only if the aircraft is within 46 km (25 NM) of the beacon. When updating occurs on the basis of one VOR/DME, the position accuracy is 0.3 to 0.6 NM (0.56 to 1.1 km). The LOC correction is only possible in the aerodrome terminal area if accompanied by manual adjustment of the relevant ILS frequency.

## **En route navigation aids**

The route from Denpasar to Darwin was almost entirely over water and there were no ground-based navaids between Denpasar and Darwin from which the aircraft's FMS could have updated the IRS-generated position. The route did pass abeam the Kupang VOR/DME at the south-western end of the island of Timor, but not close enough (within 46 km) for position updating to occur.

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<sup>18</sup> Part of the instrument landing system that provides directional guidance to pilots through an aircraft's cockpit instrumentation.

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# ANALYSIS

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## Introduction

There was no evidence to indicate that the aircraft or its systems were a factor in the occurrence. The crew was appropriately qualified for the flight and, although an in-flight diversion was necessary to avoid weather to the north of Darwin, the ambient conditions affecting the approach were not a factor. There was no evidence that language proficiency or comprehension of spoken English were a factor in the incident.

The following analysis will examine a number of operational interactions between the flight crew and air traffic control officers that contributed to the development of the occurrence. In addition, the flight crew's aircraft systems management during the approach will be reviewed.

## Darwin runway 11 very high frequency omnidirectional radio range approach

### Positioning for the approach

The diversion around weather meant that, by the time the aircraft was clear of the weather, it was at a position north of Darwin and to the east of the initial approach fix 'NASUX' for the Darwin runway 11 very high frequency omnidirectional radio range (VOR) approach. That made it less convenient for the flight crew to track via NASUX, because they would have had to fly west again, lengthening their track to Darwin.

The flight crew reported difficulty hearing a number of the approach controller's transmissions as they flew through heavy rain. However, there was no evidence that they did not understand the key elements of the controller's request of whether they could accept tracking via NASUX for the runway 11 VOR approach, or the controller's subsequent instruction to track via NASUX for that approach.

The incomplete readbacks to the approach controller's transmissions by the flight crew should have prompted the controller to seek the correct readbacks. To do so would have confirmed (or otherwise) the flight crew's understanding of the controller's instructions, and may have prevented the occurrence. To have not done so likely confirmed for the flight crew that their erroneous interpretation of the controller's instructions was, in fact, the controller's intent. That may explain why the flight crew continued to fly south until they could turn left about 8 km from the threshold to intercept the 105 'radial' inbound to the runway, rather than tracking via NASUX and maintaining 3,000 ft until established on the 105 radial inbound as instructed.

### Conduct of the approach

During the ensuing period of misunderstanding, the flight crew left 3,000 ft above mean sea level (AMSL) on descent to an uncleared and unauthorised altitude of 1,500 ft. In contrast, descent to 1,500 ft was only permitted for an aircraft joining

the runway 11 VOR approach via the 12 NM (22 km) distance measuring equipment (DME) arc, once it had crossed the 320 radial (Appendix A).

The aircraft was not on the 12 DME arc at the commencement of the descent, and did not track that arc to intercept the 105 radial as required by the runway 11 VOR approach. The action by the approach controller to query the flight crew's descent and then initially limit the descent to the radar lowest safe altitude of 1,600 ft ensured terrain clearance until the aircraft turned to intercept what the controller would have anticipated to be the 105 radial.

The use by the flight crew of the autopilot HDG SEL (heading select) mode and of the electronic flight information system (EFIS) in MAP display mode as the primary means of reference meant that the flight management system (FMS) was navigating the aircraft on the basis of position information from the aircraft's inertial reference system (IRS), not on the basis of information from the VOR. The aircraft therefore intercepted and flew along what the FMS calculated to be the 105 'radial', instead of tracking the actual 105 radial referenced to the VOR. However, because the IRS had drifted during the flight from Denpasar, the IRS-derived position did not correspond to the aircraft's actual position. As a result, the aircraft tracked 105° magnetic parallel to the 105 VOR radial, instead of along it and the extended runway centreline. A track flown with reference to a signal from the VOR would be expected to converge on the VOR instead of running parallel to a radial.

Although initially within the permitted 5° tolerance either side of the actual 105 radial, and therefore technically 'established' on that radial, by tracking parallel to the 105 radial instead of along it, the aircraft eventually left the tolerance splay (see Figure 2). This occurred about 2 km from the runway threshold, and explained the misalignment with the runway when the aircraft broke through cloud at about 700 ft. In consequence, the aircraft was below the minimum sector altitude in instrument meteorological conditions without being on an instrument approach, increasing the risk of collision with terrain.

## **Radiotelephony and ATC instructions**

The approach controller's clearance to the crew to conduct a straight-in approach via NASUX was intended to indicate the requirement to track the 105 VOR radial straight in from NASUX and to descend in accordance with the published runway 11 VOR approach procedure. However, the repeated use of the term 'straight-in approach' after the flight crew advised that they could intercept the 105 radial 9 NM (17 km) from the Darwin VOR may have combined with their previously unchallenged and incomplete readbacks to reinforce the flight crew's understanding that they were cleared to fly south to intercept the 105 radial, instead of conducting a straight-in runway 11 VOR approach via NASUX.

More effective action by the approach controller to query the flight crew's intent once it became clear that they were not tracking via NASUX, could have recovered flight crew compliance with the intended clearance. Alternately, the approach controller had the opportunity to issue an updated clearance that supported the flight crew's intentions, but maintained normal separation and instrument approach criteria. The lack of any follow-up by the controller would have acted to confirm the flight crew's incorrect understanding that they were acting in accordance with (their interpretation of) the clearance.

## **Accuracy of the inertial reference system position**

The IRS drift during the flight, and lack of an appropriate ground station to update the system prior to the aircraft's approach at Darwin, meant that the position error at that time could have been as great as 7.5 km. Once the aircraft came within 46 km of the Darwin VOR/DME, the flight management computer would have commenced updating the aircraft's IRS-generated position. The displacement of the aircraft 600 m from the 105 radial during the approach was consistent with an IRS position update via the Darwin VOR/DME.

The inclusion of a requirement in the operator's procedures for crews to check the accuracy of the aircraft's IRS position before using it to fly an approach in MAP mode would have alerted the crew to the size of the error in the IRS position before attempting to use it as their primary means of navigation to intercept the 105 radial. However, had the flight crew complied with the operator's existing requirement for its crews to monitor the raw VOR data during an approach, they would have been alerted to the IRS positional error. In that case, it could be expected that the crew might have reverted to using the VOR.

## **Monitoring of raw data**

If the flight crew had monitored the raw VOR data on the aircraft's electronic horizontal situation indicator during the approach as required by the operator's procedures, they would have identified that the aircraft was not tracking the 105 radial, and that they were outside the tolerance for being established on that radial. In that case, it could have been expected that the crew would have conducted a missed approach to re-establish safe flight.



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## FINDINGS

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From the evidence available, the following findings are made with respect to the operational event at Darwin Aerodrome, Northern Territory on 17 December 2008 involving a Boeing Company B737-4MO aircraft, registered PK-GZJ. They should not be read as apportioning blame or liability to any organisation or individual.

### **Contributing safety factors**

- The approach controller did not obtain a sufficiently detailed readback that clearly indicated the flight crew had understood and would comply with all air traffic control clearances and instructions.
- The flight crew erroneously interpreted the approach controller's transmissions to mean that they could make a pilot intercept of the 105 radial instead of tracking via NASUX.
- The flight crew did not monitor the very high frequency omnidirectional radio range raw data while flying the approach, using the HDG SEL and MAP display autopilot modes instead.
- The flight crew attempted a pilot intercept of the 105 radial using the autopilot HDG SEL and MAP display modes as their primary means of navigation but the flight management computer-generated position was not sufficiently accurate to allow them to track the 105 radial in that manner.

### **Other safety factors**

- The flight crew left 3,000 ft on descent without a clearance.
- The approach controller did not issue an updated clearance after it became apparent the flight crew were not tracking via NASUX.



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## **SAFETY ACTION**

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The investigation did not identify any organisational or systemic issues (safety issues) that might adversely affect the future safety of aviation operations. In such a case, however, relevant organisations may proactively initiate safety action in order to further reduce their safety risk.

All of the relevant organisations identified during this investigation were given a draft report and invited to provide submissions. The following proactive safety action was submitted by one of those organisations.

### **Aircraft operator**

#### **Corrective action plan**

As a result of this occurrence, the aircraft operator conducted a formal safety meeting to analyse the incident and identify appropriate corrective actions. As a result of that consideration, a corrective action plan was produced that would:

1. Brief and train the respective crew in the simulator with the following:

a) CRM aspects which include, but are not limited to:

TEM [threat and error management]

Situational awareness

Communication

PACE.

b) Non-precision approaches with strong emphasis on:

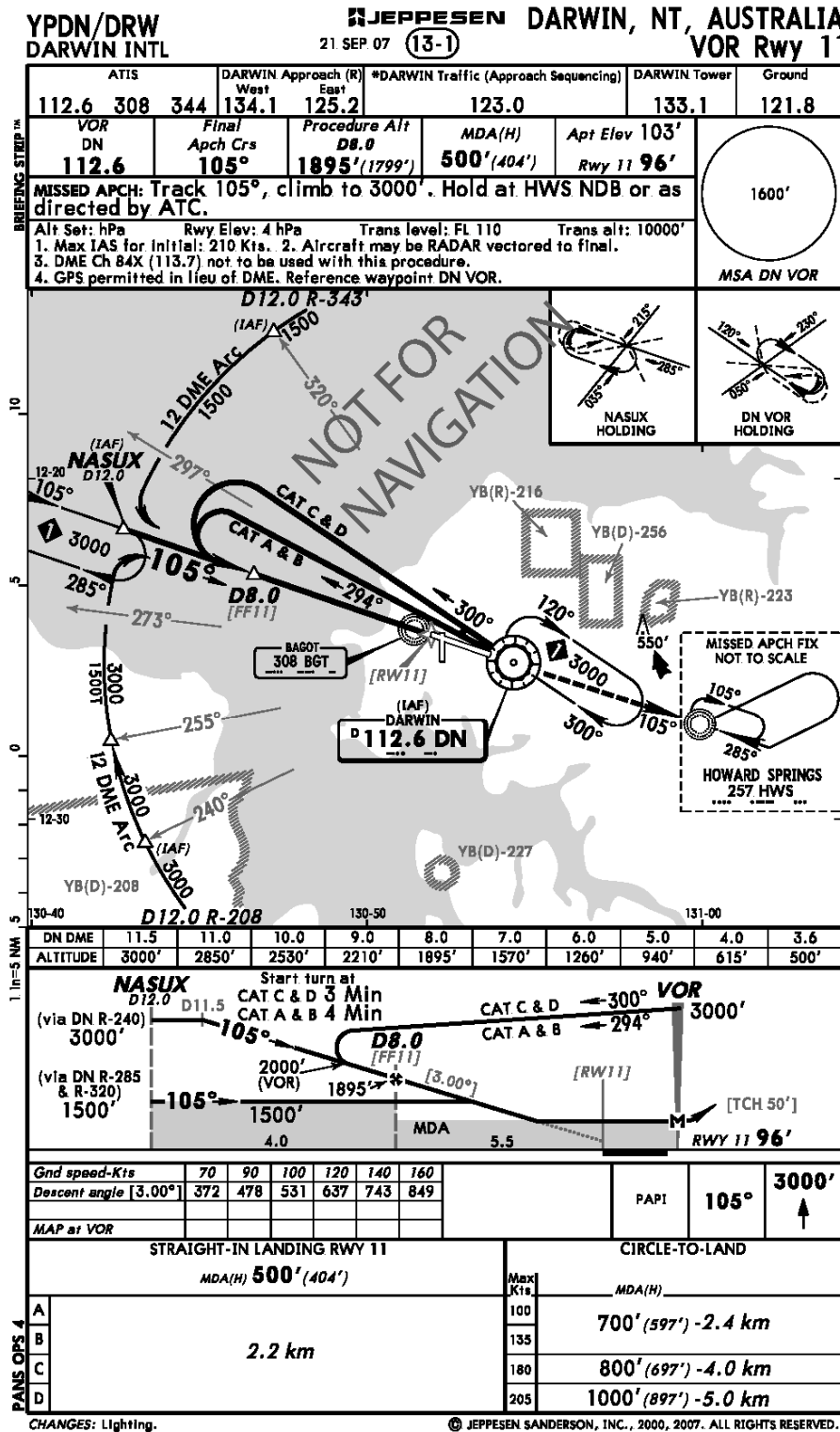
Accurate planning

Proper automation

Proper crew coordination.



# APPENDIX A: DARWIN RUNWAY 11 VOR APPROACH CHART<sup>19</sup>



<sup>19</sup> Current at the time of the occurrence. At the time of writing this report, the runway 11 very high frequency omnidirectional radio range (VOR) final approach radial was the 106 radial.



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## APPENDIX B: REQUIREMENTS FOR THE CONDUCT OF INSTRUMENT APPROACHES

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The Australian Aeronautical Information Publication (AIP) contained the following guidance for flying instrument approach procedures:

*AIP ENR 1.1, paragraph 11.5.1*

ATC Authorisation: Unless authorised to make a visual approach, an IFR flight must conform to the published instrument approach procedure nominated by ATC.

An aircraft must be 'established' before it descends below the specified altitude. In the case of very high frequency omnidirectional radio range (VOR) approaches, this means that the deflection of the course deviation indicator from the centred position must not be more than half full scale. The following section of the AIP refers:

*AIP ENR 1.5, paragraph 1.20.1*

### 1.20 Descent

1.20.1. For a straight approach (no reversal procedure), the aircraft must:

- a. for a radio navaid-based approach, cross the fix or facility, or
- b. for an RNAV-based approach, pass the way-point, and when established on the specified track, descend to not below the specified altitude.

Note: "Established" means being within half full scale deflection for the ILS, VOR and GPS, within  $\pm 5$  degrees of the required bearing for the NDB, or within  $\pm 2$ NM of the DME arc.<sup>[20]</sup>

The 'specified altitude' for the Darwin runway 11 VOR approach via NASUX was 3,000 ft. Once the aircraft was cleared by the controller to the radar lowest safe altitude of 1,600 ft, which was the 'specified altitude' below which further descent should not have been made until the aircraft was established on the 105 radial. Any deviation from clearance must be addressed as follows:

*AIP ENR 1.1 paragraph 18.6.1 and 18.6.2*

18.6.1 In controlled airspace, separation standards are based on the pilot maintaining track as closely as possible at all times. Corrective action must be taken to regain track as soon as any deviation is observed.

18.6.2 Additionally, the pilot must immediately notify ATC if the aircraft is found to be off-track by any of the deviations described below: where track guidance is provided by a localiser or VOR, half-scale deflection or more of the Course Deviation Indicator (CDI).

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<sup>20</sup> In the case of a finals bearing or radial, any tolerance in azimuth, while constant in terms of degrees either side of the finals bearing or radial, diminishes in terms of its lateral distance until approaching zero at the ground-based navigation aid itself (see Figure 2 in the body of this report).

An aircraft must make a missed approach if, during the final segment of an instrument approach, the aircraft is not maintained within the applicable navigation tolerance for the nav aid in use.<sup>21</sup>

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<sup>21</sup> AIP ENR 1.5, section 1.10 *Missed Approach – Standard procedures*, paragraph 1.10.1 refers.

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## APPENDIX C: RADIOTELEPHONY READBACK REQUIREMENTS

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The AIP stated the following with respect to pilot readback requirements:

*AIP GEN 4. RADIOTELEPHONY PROCEDURES*

4.4 Read-Back requirements

4.4.1 Pilots must transmit a correct read-back of ATC clearances, instructions and information which are transmitted by voice. For other than item a., only key elements of the following clearances, instructions, or information must be read back ensuring sufficient detail is included to indicate compliance:

- a. an ATC route clearance in its entirety, and any amendments;
- b. en route holding instructions;
- c. any route and holding point specified in a taxi clearance;
- d. any clearances or instructions to hold short of, enter, land on, conditional line-up on, wait, take-off from, cross, taxi or backtrack on, any runway;
- e. any approach clearance;
- f. assigned runway, altimeter settings directed to specific aircraft, radio and radio navigation aid frequency instructions;

*Note: An 'expectation' of the runway to be used is not to be read back.*

- g. SSR<sup>22</sup> codes, data link logon codes;
- h. level instructions, direction of turn, heading and speed instructions.

The Manual of Air Traffic Services stated the following with respect to ATC readback requirements:

*MATS paragraph 9-15-410*

Obtain a readback in sufficient detail that clearly indicates pilot's understanding of and compliance with all ATC clearances, instructions and information which are transmitted by voice.

*MATS paragraph 9-15-420*

ATC route clearance - Obtain a readback of an ATC route clearance in its entirety, as well as any amendments.

*MATS paragraph 9-15-430*

Obtain a readback of the key elements of the following ATC clearances, instructions and information:

- a. en route holding instructions
- b. any route and holding point specified in a taxi clearance
- c. any clearances or instructions to hold short of, enter, land on, conditional line up on, wait, take-off from, cross, taxi or backtrack on, any runway
- d. any approach clearance

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<sup>22</sup> SSR = Secondary surveillance radar.

- e. assigned runway, altimeter settings directed to specific aircraft, radio and radio navigation aid frequency instructions
- f. SSR codes, data link logon codes and
- g. level instructions, direction of turn, heading and speed instructions.

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## APPENDIX D: SOURCES AND SUBMISSIONS

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### Sources of Information

The sources of information during the investigation included:

- Royal Australian Air Force, 44 Wing Detachment, Darwin
- the operating crew of PK-GZJ (GZJ)
- National Transport Safety Committee (NTSC), Indonesia
- the Civil Aviation Safety Authority (CASA)
- the Bureau of Meteorology
- a B737-400 technical specialist
- Jeppesen Sanderson Inc
- Google Earth.

### Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the following.

- the Directorate of Defence Aviation and Air Force Safety
- Royal Australian Air Force, 44 Wing Detachment, Darwin
- National Transport Safety Committee (NTSC), Indonesia
- the operator of GZJ
- the operating crew of GZJ
- CASA
- a B737-400 technical specialist.

Submissions were received from the aircraft operator, CASA and the B737-400 technical specialist. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Operational event - Darwin Aerodrome, NT, 17 December 2008,  
PK-GZJ, Boeing B737-4MO