Australian Government

Australian Transport Safety Bureau

AVIATION SAFETY INVESTIGATION REPORT
200202710

Runway overrun at Darwin International Airport

Boeing 737-800, VH-VOE

11 June 2002

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ISBN 1 877071 57 9 March 2004

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CONTENTS

INTRODUCTION

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

In terms of aviation, the ATSB is responsible for investigating accidents, serious incidents, incidents and safety deficiencies involving civil aircraft operations in Australia, as well as participating in overseas investigations of accidents and serious incidents involving Australian registered aircraft. The ATSB also conducts investigations and studies of the aviation system to identify underlying factors and trends that have the potential to adversely affect safety. A primary concern is the safety of commercial air transport, with particular regard to fare-paying passenger operations.

The ATSB performs its aviation functions in accordance with the provisions of the *Air Navigation Act 1920*, Part 2A. Section 19CA of the Act states that the object of an investigation is to determine the circumstances surrounding any accident, serious incident, incident or safety deficiency to prevent the occurrence of other similar events. The results of these determinations form the basis for safety recommendations and advisory notices, statistical analyses, research, safety studies and ultimately accident prevention programmes. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment, with the need to properly explain what happened, and why, in a fair and unbiased manner.

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) + 9½ hours. Times are accurate to within 30 seconds of the reported event.

EXECUTIVE SUMMARY

A Boeing 737-800, registered VH-VOE, was being operated on a scheduled flight between Brisbane and Darwin. The crew conducted a VOR/DME arrival to Runway 29 at Darwin International Airport. The runway had a temporarily displaced threshold. The aircraft touched down an estimated 1016 m from the departure end of the runway, at about 23:35 Central Standard Time. During the landing roll, the aircraft overran the runway and came to a stop approximately 44 m into the 90 m runway end safety area. There were no injuries, and the aircraft was not damaged. Air Traffic Control was not aware that the aircraft had overrun the runway. Consequently, emergency response services were not contacted.

Runway overruns feature prominently in accidents involving western-built transport category jet aircraft. Long and/or fast landings were factors in these occurrences. In this occurrence, a high approach speed led to a long landing and overrun situation. The pilot in command continued with an unstabilised approach and did not go around as required by company standard operating procedures. The copilot did not announce that the approach was unstable and instruct the pilot in command to go around. Throughout the approach, there were various cues available to both crewmembers to indicate that the approach was unstable and that a go-around was required.

Overall, there were a number of safety issues identified during the course of the investigation. Those issues included: a non-precision approach at night that was conducive to illusions; a displaced threshold that limited the landing distance available; crew resource management problems; aircraft handling difficulties; an underdeveloped landing approach risk assessment by the crew and a safety management system that had yet to incorporate the flight data monitoring programmes advocated by the International Civil Aviation Organization and industry associations. As part of the relatively new operator's maturation process, the operator has developed a number of measures that are being implemented over the short, medium and longer terms to improve the training of crews, and the capability of the operator's safety management system.

1. FACTUAL INFORMATION

1.1 History of the flight

On 11 June 2002, a Boeing 737-86Q (737-800), registered VH-VOE, was being operated on a scheduled public transport service between Brisbane, Qld, and Darwin, NT. The inbound track during the descent to Darwin facilitated a straight-in approach to runway 29. The pilot in command was the handling pilot for the sector and clearances given by Air Traffic control (ATC) allowed a continuous descent from cruise level until landing. There were no ATC speed restrictions.

Due to works-in-progress on the eastern end of the runway, the landing threshold was temporarily displaced 1,173 m beyond the permanent threshold, resulting in a reduced Landing Distance Available[1] (LDA) of 2,181 m. The temporary threshold was equipped with threshold lights and approach slope guidance was provided by a portable Precision Approach Path Indicator (PAPI). Because of the presence of the temporarily displaced threshold, ATC cleared the aircraft for an ILS approach to the circling minima, by which time it was expected that the crew would visually acquire the displaced threshold and complete the approach with the aid of the temporary PAPI. The pilot in command elected to conduct a VOR/DME approach to runway 29, depicted at figure 1.

Data from the aircraft's Flight Data Recorder (FDR) indicated that the descent from flight level (FL) 300 commenced at 99 NM from Darwin, by distance measuring equipment (DME). The aircraft's Flight Management System was engaged in Lateral Navigation (LNAV) and Vertical Navigation - Path (VNAV PTH)[2]. Recorded information indicated that the descent profile from the top of descent until approximately 2,000 ft above aerodrome level (aal) was maintained close to the standard 3.0 degrees.

During the descent from FL300 the engine power was set at, or close to, flight idle. Recorded information indicated that the wind at cruise level was from the west, resulting in a small headwind component. During the descent, the wind affecting the aircraft varied east to southeast between 5 and 20 kts, which was stronger than forecast. The wind speed was generally greatest during the final 5,000 ft of the descent, resulting in a tailwind component between 10 and 20 kts until 1,000 ft aal when the tailwind component reduced to less than 10 kts. The investigation calculated that the landing was conducted with a tailwind component of 6 kts.

The operator's 737 Flight Crew Training Manual (FCTM) was based on the Boeing version of the same document. The FCTM gave guidance for descent planning, stating:

> A good crosscheck is to be at 10,000 feet, 30 miles from the airport, at 250 kts.

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[1] Landing Distance Available is the declared distance available for the landing manoeuvre, commencing at the landing threshold and finishing at the far end of the runway. No stopway or overrun is included in the LDA.

[2] VNAV PTH controls aircraft descent to fly a vertical path that complies with altitude and speed restrictions in the flight plan. The path reflects descent wind values entered on the DESCENT FORECAST page of the Flight Management System (FMS) and the forecast use of anti-ice. During a VNAV PTH descent, the Autopilot Flight Director System (AFDS) tracks Flight Management Computer (FMC) descent path.

When the FMS optimum path is not constrained by crossing restrictions and appropriate wind entries have been made, the aircraft will descend at the desired speed with the thrust levers at idle. When the path is constrained or wind entries are sufficiently inaccurate, speed must be maintained using thrust levers (for underspeed) and airbrakes (for overspeed).

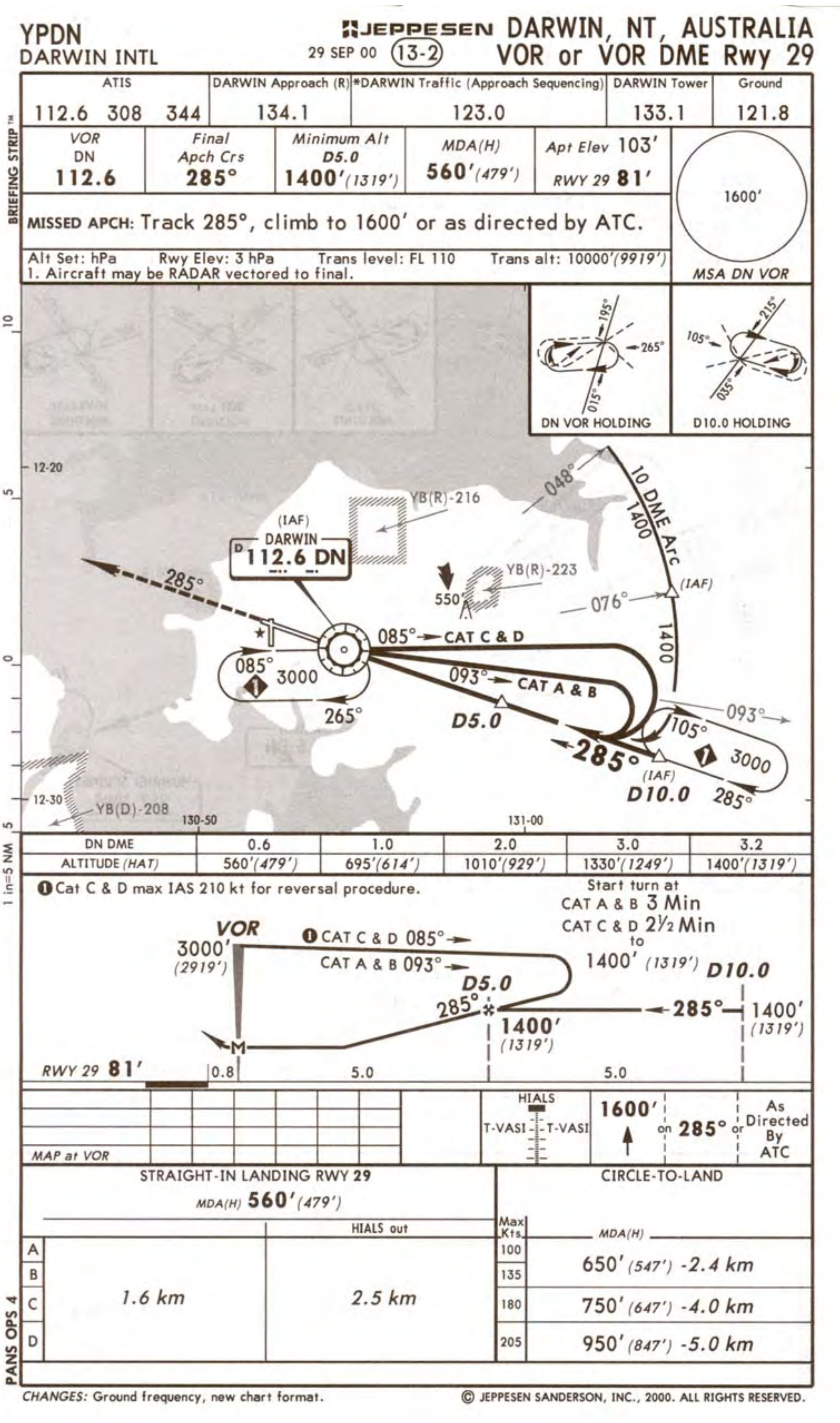

Figure 1. Darwin, NT (YPDN) Runway 29 VOR or VOR/DME Approach[3].

[3] Chart valid at the time of the occurrence.

Recorded information indicated that at 2327:05 CST, the aircraft was passing 10,000 ft at 35 DME, with an airspeed of 309 kts and a ground speed of 373 kts. As the aircraft approached 5,200 ft and 13 DME, a reduction in airspeed commenced, decreasing to 225 kts by 4,170 ft. The descent mode was changed from VNAV PTH to Level Change (LVL CHG) at that altitude, and a Mode Control Panel (MCP) speed of 225 kts was selected.

The FCTM continued:

> Plan to arrive at the traffic pattern altitude at flaps up manoeuvring speed approximately 12 miles from the runway when proceeding strait-in.

At 2331:44 the aircraft was passing 3,470 ft at an airspeed of 222 kts, which was 11 kts above the flaps up manoeuvring speed. The groundspeed was 256 kts. At that stage, the total distance to run was approximately 12 NM. Although the aircraft was approximately 400 ft low on a standard 3.0 degree approach profile, the high groundspeed made it necessary for the crew to configure[4] flaps and landing gear in order to conform with the standard instrument approach profile documented in the operator's FCTM. The descent was continued in the clean[5] configuration at approximately 1,000 ft/min. Early configuration of an aircraft during an approach produces an increase in drag and improves the likelihood of achieving a stable approach.

At 3,000 ft the aircraft was on slope, in the clean configuration, with an airspeed of 204 kts, and with approximately 9.5 NM to touchdown. The descent rate of 1,000 ft/min was continued to 2,400 ft, when FLAP 1 was selected at an airspeed of 203 kts and with 6.6 NM to run. The rate of descent then gradually decreased to 640 ft/min over the following 30 seconds during which time FLAP 5 was selected (at 2,200 ft) and the aircraft gradually deviated above the correct approach angle that would have been indicated by the temporary PAPI. At that time, to maintain the on-slope PAPI indication at the recorded groundspeed of 235 kts, would have required a rate of descent of 1180 ft/min.

At 2,000 ft and an airspeed of 189 kts, with 4.4 NM to touchdown, the autopilot was disengaged, the gear was selected down and the rate of descent was increased markedly by the pilot in command in an attempt to regain the PAPI glide path. FLAP 15 was selected at 1,546 ft altitude and an airspeed of 185 kts. FLAP 25 was selected 20 seconds later at 1,043 ft altitude at an airspeed of 185 kts. FLAP 30 was selected at 721 ft altitude or 618 ft aal but the airspeed of 185 kts was 10 kts above the flap load relief[6] limiting speed of 175 kts, resulting in FLAP 30 not being set until 219 ft altitude (116 ft aal).

Recorded information indicated that, during the approach and landing phases, the engine thrust was not increased above the APPROACH IDLE setting[7]. Preferred

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[4] Aerodynamic shape of the aircraft variable by pilot in command, eg position of landing gear, flaps, leading/trailing-edge devices and external stores.

[5] Landing gear, flaps and/or high-lift systems retracted.

[6] The flaps load relief system protects the flaps from excessive air loads, see section 1.6.1

[7] The engine acceleration characteristics of a high by-pass ratio engine are such that when there is a requirement to increase the thrust from idle, there is an engine response lag of 3 or 4 seconds before the thrust increases very rapidly to its maximum.

practice was reflected in the operator's standard procedure that required the engines to be spooled up by at least 500 ft aal.

The peak rate of descent recorded during the final part of the approach was 1,900 ft/min, occurring at 454 ft aal. When the aircraft was approximately 450 ft aal, the aircraft's Ground Proximity Warning System (GPWS)[8] alerted the crew to an excessive descent rate. The alert takes the form of an aural "sink rate" and a visual PULL UP on both attitude indicators. The copilot recalled hearing the GPWS aural "sink rate" alert at around 300 ft. The "sink rate" alert was another indication that the criteria for a stable approach had been exceeded and that the situation required a go-around.

The rate of descent remained above 1,000 ft/min until 300 ft aal. That high rate of descent enabled the aircraft to come close to regaining the correct profile, crossing the threshold approximately 20 ft above the correct height. However, the attempt at regaining the correct profile came at the expense of an excessive airspeed. FDR analysis revealed that the airspeed at 500 ft aal was 183 kts. The planned landing configuration was FLAP 40, with a reference landing speed (V_{ref}) of 137 kts[9] entered in the flight management computer. The recommended approach or target speed for the final approach was 142 kts (V_{ref} plus 5). However, the final target speed setting selected by the crew was 147 kts. At 100 ft above the runway surface the airspeed was V_{ref} + 29.

FLAP 40 was selected at an altitude of 194 ft aal and an airspeed of 175 kts, but due to the flap load relief system did not commence running until the aircraft was 10 ft above the runway and was not set until 3.5 seconds before touchdown.

The typical pitch attitude for a 737-800 crossing the threshold at V_{ref} + 5 is in the region of 1.4 degrees for a FLAP 40 landing. During the incident, the aircraft crossed the temporary threshold at a pitch angle of – 0.5 degrees, at which time the pilot in command manoeuvred the aircraft to a pitch angle of + 2.5 degrees by 10 ft above the runway. The aircraft then floated at a more or less constant height of about 10 ft above the runway for a further 8 seconds before the main wheels touched down. That required a reduction in aircraft pitch angle by the pilot in command. Recorded data indicated that the aircraft's main gear touched down at a speed of 140 kts. The nose gear touched down 2 seconds after the main gear.

The speed brakes, which were armed prior to landing, operated correctly, deploying immediately on touchdown. Recorded data indicated that the autobrake was applied one second after touchdown, and was disarmed 6 seconds later by the application of manual braking. Engine thrust reversers were operated within 3 seconds of main gear touchdown. A reverse thrust setting of 80% N1 was selected and maintained until the aircraft had decelerated to an airspeed speed of 60 kts.

As the aircraft approached the end of the runway, it commenced to veer to the left of the centreline, crossing the end of the runway at a groundspeed between 35 and 40 kts, and travelling a distance of 44 m into the Runway End Safety Area (RESA)[10]. Heavy manual braking continued to be applied until the groundspeed had reduced to

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[8] GPWS monitors the aircraft's height above ground from signals received by its radio altimeter. GPWS provides alerts for potentially hazardous flight conditions involving imminent impact with the ground.

[9] Based on the aircraft landing weight, the reference landing speed (V_{ref}) was 138 kt for a flap 40 landing. The surface wind was reported as light and variable as the aircraft approached and landed, so there were no wind correction factors to add to the V_{ref}. The recommended approach or target speed in those circumstances was V_{ref}+5.

[10] The Runway End Safety Area is an area primarily intended to reduce the risk of damage to an aeroplane undershooting or overrunning the runway.

approximately 10 kts. The aircraft was then turned through 180 degrees and taxied to the airport terminal. ATC was unaware of the overrun until a safety officer, carrying out a runway inspection 3 hours later, noticed wheel tracks in the RESA.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	7	92	-	99

1.3 Damage to aircraft

Nil.

1.4 Other damage

Nil.

1.5 Personnel information

1.5.1 Pilot in command

Type of licence	Air Transport Pilot (Aeroplanes) Licence
Medical certificate	Class 1, valid to 23 June 2002
Medical restriction	Vision correction required (glasses were worn)
Flying experience (total hours)	12,580 hours
Flight time on 737	3,688 hours
Flight time in the last 24 hours	4 hours
Flight time in the last 30 days	60 hours
Flight time in the last 90 days	127 hours
Last line check 737-400	05 December 2001
Last simulator check 737-300	12/13 November 2001
CRM training	20 October 2001

During the 12 months preceding the incident, the pilot in command accrued a total of 772 flying hours, of which 266 hours were on the 737-300/400, 320 hours on the 737-700, and 186 hours on the 737-800.

The pilot in command reported that he had commenced duty about 5 hours before the occurrence and had slept for 8 hours during the preceding night. He had been awake for 16 hours prior to the occurrence. The pilot in command had 123 hours free of duty prior to the work period. He reported no physiological or medical condition that was likely to have impaired his performance, and that he was adequately rested and medically fit for the flight.

The most recent recorded training or checking was a flight proficiency line check completed on 5 December 2001. The pilot in command's last line check indicated a good standard. His most recent flight into Darwin Airport was 2 months earlier than the occurrence flight.

1.5.2 Copilot

Type of licence	Air Transport Pilot (Aeroplanes) Licence
Medical certificate	Class 1, valid to 30 March, 2003
Medical restriction	No restrictions
Flying experience (total hours)	5,812 hours
Flight time on 737	720 hours
Flight time in the last 24 hours	4 hours
Flight time in the last 30 days	71 hours
Flight time in the last 90 days	186 hours
Last simulator check 737-300	11 April 2002
CRM training	21 April 2002

During the 12 months preceding the incident, the copilot accrued a total of 716 flying hours of which 441 hours were on the 737-300/400, 132 hours on the 737-700, and 142 hours on the 737-800.

The copilot reported that he had commenced duty about 5 hours before the occurrence, and had slept for 10 hours during the preceding night. He had been awake for 13 hours prior to the occurrence. The copilot had 107 hours free of duty prior to the work period. He reported no physiological or medical condition that was likely to have impaired his performance, and that he was adequately rested and medically fit for the flight.

The most recent recorded training or checking was a flight proficiency check completed on 11 April 2002. That check satisfied the requirement for an instrument rating renewal. The occurrence flight was his first flight into Darwin Airport. The copilot's last line check indicated a good standard.

1.6 Aircraft information

The airline operated a mixed fleet of 'classic' (-300 and -400 series) and 'new generation' (-700 and -800 series) 737 aircraft. The occurrence aircraft, a 737-800, was heavier and more aerodynamically efficient than the 'classic' variants.

The estimated landing weight of the aircraft was 62,142 kg. That weight included an estimated 9,725 kg of fuel. The aircraft was "tankering" fuel. Tankering extra fuel involves uplifting more fuel at the departure aerodrome than is required for a given flight. That practice is an accepted procedure because of fuel price differences between airports.

Manufacturer	Boeing
Model	737-86Q
Serial number	30272
Registration	VH-VOE
Year of manufacture	2001
Engine type (number of)	CFM56-7B26 (2)
Maximum allowable take-off weight	78,390 kg
Maximum allowable landing weight	66,360 kg

1.6.1 Flap load relief system

The flaps/slat electronics unit provided a trailing edge flaps load relief function that protected the flaps from excessive air loads. That function was operative at the FLAP 30 and FLAP 40 positions only. The flap lever did not move, but the flap position indicator displayed flap retraction and re-extension.

When the flaps were set at FLAP 30, the trailing edge flaps:

- retracted to FLAP 25 if the airspeed exceeded 176 kts
- re-extended when the airspeed was reduced below 171 kts

When the flaps were set to FLAP 40, the trailing edge flaps:

- retracted to 30 if the airspeed exceeded 163 kts
- re-extended when the airspeed was reduced below 158 kts

1.6.2 Spoiler panels

The 737-800 has 12 spoiler panels (6 on each wing), consisting of flight spoilers and ground spoilers. The flight spoilers are used for maintaining lateral control and reducing airspeed in flight. The flight and ground spoilers can be armed before landing to enable their automatic deployment at touchdown. Their purpose is to reduce the aircraft landing roll by increasing aerodynamic drag and reducing the lift created by the wings.

1.6.3 Brake system

Each main gear wheel has a multi-disc hydraulic-powered brake. The brake pedals provide the pilot with independent manual control of the left and right brakes. The 737-800 is fitted with an autobrake system, the purpose of which is to optimise braking performance and reduce tyre wear. The autobrake system provides braking at any one of four preselected deceleration rates for landing. In order to maintain the selected landing deceleration rate, autobrake pressure is reduced as other controls, such as thrust reversers and spoilers contribute to total deceleration. On dry runways, the maximum autobrake deceleration rate is less than that produced by full pedal braking. The application of manual brakes will automatically disarm the autobrake system.

1.6.4 Thrust reverser

Each engine is equipped with a hydraulically operated thrust reverser. Those thrust reversers are used after touchdown to slow the aircraft, reducing stopping distance and brake wear. Movement of the reverse thrust levers to the number-1 detent provides reverse idle thrust. When raised to the number-2 detent, adequate reverse thrust for normal operations is provided. The normal procedure is for reverse thrust to be maintained until the airspeed approaches 60 kts, and then reduced at a rate commensurate with the deceleration rate of the aircraft. However, when necessary, the reverse thrust lever can be moved beyond the number-2 detent, providing maximum reverse thrust. In an emergency, maximum reverse thrust may be used on the ground at any aircraft speed commensurate with the emergency.

1.7 Meteorological information

The meteorological conditions at the time of the approach were reported on the Aerodrome Terminal Information System (ATIS), designated information Bravo.

ATIS information Bravo was as follows:

Runway 29, displaced threshold

Wind light and variable

CAVOK

QNH 1012

Temperature 23° Celsius

The airport's Low Level Windshear Alerting System (LLWAS) incorporated runway threshold anemometers that recorded the local surface wind at 10-second intervals. LLWAS data indicated that, at the time of landing, the surface wind was generally from the south at a maximum of 7 kts.

When issuing the landing clearance, the air traffic controller indicated to the crew that a tailwind component of up to 4 kts could be expected.

1.8 Aids to navigation

Runway 29 at Darwin was equipped with an instrument landing system (ILS) that incorporated a 3 degree glideslope and a localiser course of 285 degrees M. A co-located VOR/DME was situated on the extended centreline of the runway, 1,338 m (0.72 NM) prior to the runway 29 permanent threshold. All aids were serviceable at the time of the occurrence.

1.9 Communications

All communications between Air Traffic Services (ATS) and the crew were normal and not considered to be a factor in the occurrence.

1.10 Aerodrome information

Runway 29, the active runway on the evening of the occurrence, was 3,354 m long and 60 m wide. The standard runway width at major Australian airports was 45 m. The runway had omni-directional medium intensity runway edge lighting but no centreline lighting. The runway edge lights were white, except the final 600 m of the runway, which were yellow. Uni-directional red lights marked the runway end.

At the western end of runway 29, there was a 90 m Runway End Safety Area (RESA) consisting of three-quarter-strength pavement. Beyond the RESA was a smooth grassed area. Due to runway works-in-progress at the eastern end of the runway, the landing threshold was temporarily displaced 1,173 m (0.63 NM) beyond the permanent threshold, resulting in a reduced Landing Distance Available (LDA) of 2,181 m. There were several gradient changes along the length of the runway, including a hump between where the aircraft touched down and the runway end.

The temporary threshold was equipped with threshold lights. Approach slope guidance was provided by a portable PAPI that was set at 2.85 degrees and giving an eye height over the threshold of 60 ft. The crew was aware of that information, which had been promulgated by NOTAM. The temporary runway 29 infrastructure was designed to accommodate the largest aircraft expected to use the runway, a 767. The threshold lights and the PAPI were installed by an appropriately qualified surveyor assisted by trained airfield lighting technicians and had not been flight tested[11].

The runway 29 works-in-progress involved re-surfacing the runway with a bitulastic compound. Significant curing times were required before the treated section of the runway was suitable for operational use. Consequently, the full length of the runway could not be opened at short notice, except in an emergency. To avoid severely curtailing movements during the works-in-progress, the work was scheduled to take place away from peak traffic times.

1.11 Flight recorders

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR). The ATSB requested and obtained access to the FDR data only.

The recorded FDR data applicable to the incident was imported into the Bureau’s Hewlett Packard C3000 computer for readout. That readout utilised Recovery, Analysis and Presentation System (RAPS) software. The raw FDR data was converted to engineering units using scaling information provided by Boeing Commercial Airline Company (Boeing Standard 737-3B data frame format).

Engineering parameters were prepared to assist in the analysis of the incident. Copies of selected plots are included in Appendix 1.

1.12 Wreckage information

Not applicable

[11] NOTAM C0223/02, issued 9 June 2002, alerted flight crews to the temporary installation of threshold lights and PAPI that had not been calibrated through flight testing.

1.13 Medical information

Not applicable

1.14 Fire

Not applicable

1.15 Survival aspects

Not applicable

1.16 Tests and research

Not applicable

1.17 Organisational information

1.17.1 Operator

1.17.1.1 Operations manual

The operator provided the flight crew with an Operations Manual to provide the necessary limitations, procedures, performance and systems information to safely operate the 737 aircraft.

The manual consisted of several parts and included:

- Boeing 737 Operations Manual Volume 1, which consisted of bulletins, limitations and procedures
- Boeing 737 Operations Manual Volume 2, which contained systems information, including the function of the flap load relief system as described in section 1.6.1
- Boeing 737 Quick Reference Handbook (QRH), which was designed primarily as a cockpit aid, and contained normal and non-normal checklists and abbreviated performance data. Advisory information on autobrake landing distances was included in the QRH
- Boeing 737 Flight Crew Training Manual (FCTM), which outlined certain operational information and recommendations on manoeuvres and techniques. The Holding, Approach, and Landing chapter provided information on holding, instrument and visual approaches and landings.

1.17.1.2 Stabilised approach requirements

The following FCTM extract described the Stabilised Approach requirements:

> Maintaining a stable speed, descent rate and vertical/lateral flight path in landing configuration is commonly referred to as the stabilised approach concept. Any significant deviation from planned flight path, airspeed or descent rate should be announced. The decision to execute a go-around is no indication of poor performance.

Note: Do not attempt to land from an unstable approach.

All approaches should be stabilised by 1,000 feet above airport elevation in IMC and by 500 feet above airport elevation in VMC. An approach is considered stabilised when all of the following criteria are met:

- The aircraft is on the correct flight path
- Only small changes in heading/pitch are required to maintain the correct flight path
- The aircraft speed is not more than V_{ref} + 20 kts indicated airspeed and not less than V_{ref}
- The aircraft is in the correct landing configuration
- Sink rate is no greater than 1,000 fpm
- Power setting is appropriate for the aircraft configuration
- All briefings and checklists have been conducted

Note: An approach that becomes unstabilised below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around. These conditions should be maintained throughout the rest of the approach for it to be considered a stabilised approach. If the above criteria cannot be established and maintained at and below 500 feet AFE, initiate a go-around.

As the aircraft crosses the runway threshold it should be:

- Stabilised on target airspeed to within +10 kts until arresting descent rate at flare
- On a stabilised flight path using normal manoeuvring
- Positioned to make a normal landing in the touchdown zone (ie, first 3,000 feet or first third of the runway, whichever is less).

Initiate a go-around if the above criteria cannot be maintained.

1.17.1.3 Instrument approach profiles

The operator incorporated a section within the FCTM that detailed company variations to the manufacturer's standard operating procedures. On the issue of standard instrument approach profiles, the manual stated:

The standard runway approach, ILS, LLZ, VOR or Twin Locator is based upon a normal ILS profile with the Final Approach Point (FAP) being at 10 miles:

- Approaching 10 miles to touchdown, establish the aircraft at 3,000 feet with flap 1 selected
- One dot below glideslope, select flap 5 and reduce speed towards flap 5 manoeuvring
- At 2,000 feet (~7 miles), select landing gear down, flap 15 and reduce speed towards flap 15 manoeuvring
- At 1,500 feet IMC (5 miles) or 1,000 feet VMC, select landing flap and reduce towards V_{ref} plus additives

1.17.1.4 Standard callouts

The FCTM described Standard Callouts to be made by the crew. It stated that, during

the approach phase below 500 ft aal, the pilot not flying (non-handling pilot) was to "call out any significant deviations from programmed airspeed, descent and instrument indications".

1.17.1.5 Crew resource management training

Crew Resource Management (CRM) is generally defined as "the effective use of all available resources, that is equipment, procedures and people, to achieve safe and efficient operations"[12]. It is associated with principles such as communication skills, interpersonal skills, stress management, workload management, leadership and team problem solving. These principles have been taught in major airlines since the late 1970s.

CRM training programmes generally consist of initial awareness training, recurrent awareness training, knowledge acquisition, skill acquisition, practical training exercises, and the incorporation of CRM elements in normal check and training activities[13]. These courses are predominantly awareness based rather than skill acquisition courses.

The operator's CRM course was a one-day joint flight crew and cabin crew awareness-based course. The CRM course generally reflected current developments in CRM. The operator's CRM course addressed issues such as decision-making, situation awareness, leadership, error management, and flight crew and cabin crew attitudes. The course also included various video presentations and discussion sessions as well as a case study on a runway overrun occurrence. During the runway overrun case study, particular mention was made of unstabilised approaches and the relevant standard operating procedures. During the presentation on Controlled Flight Into Terrain (CFIT), particular mention was made of the risks associated with non-precision approaches, unstable approaches, the crew ignoring GPWS warnings, the higher risk of a CFIT event when the pilot in command was flying, and the potential difficulty for a copilot to instruct a go-around when the aircraft was in an unstable condition.

The first phase of the CRM training programme was designed as an annual refresher course for both flight crew and cabin crew. The primary objective of the course was to ensure that participants developed an awareness of how CRM concepts were related to the safety of flight.

All company cabin crew completed the CRM course as part of their induction training. However, newly appointed flight crew did not complete a CRM course as part of their induction. Rather, the new flight crew completed a CRM course during their first year of employment, and every 12 months thereafter. The rationale behind that decision was that most flight crews had completed some form of CRM training during previous employment with a major or regional airline.

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[12] International Civil Aviation Organization. (1992). *Flight crew training: Cockpit resource management (CRM) and Line-oriented flight training (LOFT)* (Circular 217-AN/132, Human Factors Digest No. 2). Montreal, Canada: ICAO.

[13] Wiener, E. L., Kanki, B. G., & Helmreich, R. L. (Eds.) (1993). *Cockpit resource management*. San Diego, CA: Academic Press.

At the time of the occurrence, the operator was in the process of revising the CRM course to include a greater focus on the specific challenges confronting company operations. The operator was also developing a command CRM course designed for senior copilots upgrading to captaincy, newly promoted captains, and direct entry captains.

Both occurrence crewmembers had completed company CRM training at the time of the occurrence.

1.17.1.6 Line oriented flight training

The airline environment has recently incorporated a specific skills-based component to CRM training in the form of Line-Oriented Flight Training (LOFT) and/or Line-Oriented Simulation (LOS). These programmes supplement the standard approach to CRM training by facilitating the development of attitudes and skills necessary for successful flight deck management through the use of simulators[14]. During LOFT sessions, flight crews practice CRM principles in the simulator under the observation of an appropriately trained instructor pilot. These sessions are often videotaped and the crews responses to the various situations that are encountered during the LOFT are discussed and analysed during a de-brief that is facilitated by the instructor pilot.

One of the advantages of LOFT is that it is 'situated' training. That is, by personally applying the principles of CRM in a high fidelity simulated environment, the acquisition and application of cognitive skills, such as decision-making, situation awareness, team coordination and communication may be more successful[15, 16]. When cognition is situated within a given context, it is possible that the associations that are formed between specific situations or experiences and system behaviour help facilitate the development of appropriate domain specific mental models[17]. This is an important concept because the declarative knowledge and awareness that may be acquired during a traditional CRM course may not translate into the deployment of desirable cognitive skills in the operational environment.

The operator conducted line-oriented flight training (LOFT). Captains were generally the handling pilots and copilots were the support pilots during LOFT training. During each LOFT evaluation, a pilot's performance was rated against 5 parameters on a scale of 1 (poor performance significantly below the requirement) to 5 (high standard well above average). The LOFT assessment markers included: Briefings (conduct, content, relevance, effectiveness); Crew Relationship (cooperative, constructive, participative, supportive, communicative, mutual respect, objective crew self-critique, conflict resolution); Flight Management (preparation, workload distribution, anticipation, situational awareness, systems management, correct procedures); Leadership/Followership (decisiveness, balance delegation, perception, vigilance, appropriate assertiveness, initiative, enquiry); and Overall Crew Effectiveness.

The operator's LOFT sessions were not videotaped. In addition, the LOFT evaluators, who were also check and training captains, did not receive any formal de-briefing

[14] Helmreich, R. L., Merritt, A. C., & Wilhelm, J. A. (1998). The evolution of crew resource management training in commercial aviation. *The International Journal of Aviation Psychology, 8*, 285-297.

[15] O'Neil, Jr, H. F., & Andrews, D. H. (Eds.). *Aircrew training and assessment*. Mahwah, NJ: Lawrence Erlbaum.

[16] Lintern, G. (1995). Flight instruction: The challenge from situated cognition. *The International Journal of Aviation Psychology, 5*, 327-350.

[17] Ibid.

training. The operator's LOFT evaluation methods and forms did not fully reflect the more recent developments in the measurement of 'safety behaviours', including but not limited to behavioural markers.

The last of the pilots' line checks indicated a good standard. There were no reports that the flight crew had any difficulties demonstrating sound CRM principles.

1.17.1.7 Company CRM training tempo

The CRM training co-ordinator commented that the operator was experiencing substantial growth. Consequently, the promotion rate of copilots was high. At the time of the occurrence, there were about six copilots being promoted to captain each month. There was also a backlog of new captains who had not completed a command CRM course, and there was a need to put 10 pilots (6 copilots and 4 new captains) through a command CRM course each month. However, there was no indication that the training tempo impacted adversely upon the quality of crew training.

1.17.2 Operator's safety management and intelligence system

1.17.2.1 Safety management systems

A safety management system can be defined as "an integrated set of work practices, beliefs and procedures for monitoring and improving the safety and health of all aspects of [an] operation" [18]. Safety management processes are generally deliberate activities of an organisation to develop, maintain or otherwise ensure the adequacy of specific safety defences. Defences are the measures put in place by an organisation to facilitate and assure safe performance of the operational components of the system[19]. Within the aviation industry, some airlines regularly assess the current state of their safety health along a number of situational and organisational dimensions.

In terms of safety, a transport activity needs to be managed through the use of appropriate defences and safety management processes so that the risk associated with the transport activity is minimised or reduced to an acceptable level[20]. A comprehensive safety management and intelligence system is required to ensure that the organisation has sufficient data to understand the safety health of its operations and that informed data driven strategies are developed to address any shortcomings. The operator had a safety management system in place at the time of the occurrence.

1.17.2.2 Safety intelligence systems

In order to develop countermeasures to human error, it is essential to expand the field of observation, and access human factors data from normal operations[21]. Examples of

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[18] Civil Aviation Safety Authority (2002). *Safety management systems: What's in it for you* (p. 8). Canberra, ACT: Author.

[19] Reason, J. T. (1997). *Managing the risks of organisational accidents*. Aldershot, UK: Ashgate.

[20] Ibid.

[21] Shappell, S. A., & Wiegmann, D. A. (2000a). *The human factors analysis and classification system (HFACS)* (Federal Aviation Administration, Office of Aviation Medicine Report No. DOT/FAA/AM-00/7). Washington, DC: Office of Aviation Medicine.

aviation industry attempts to capture such data are self-reporting schemes, such as the Aviation Safety Action Programme (ASAP), and flight data acquisition and analysis programmes, known as Flight Data Monitoring (FDM)[22] or Flight Operations Quality Assurance programmes (FOQA)[23].

There are various other sources of safety data, albeit incomplete, that are available to an organisation to assess the safety of its operations. Apart from checks of the technical competence of crew in simulators, other sources of safety intelligence include accident and incident investigations and reports.

These sources of data are now considered standard sources of safety intelligence within the airline industry[24]. However, each of these sources has their limitations. For example, one of the problems associated with accident data is that accidents are relatively rare and do not readily avail themselves to statistically founded conclusions regarding system weaknesses[25]. Moreover, many accident and incident reporting systems and databases have not employed well-defined human performance methodologies, terms and variables. This has made the identification of appropriate intervention strategies difficult and prone to error[26]. Furthermore, self-reporting schemes often do not capture all events, and the actual baseline for events is unknown. Despite efforts to assure pilots and other aviation personnel of the non-punitive nature of reports, the programmes do not elicit complete reporting[27]. Finally, recorded flight data from line operations provides information on deviations from organisational procedures and expectations; however, it does not provide insights into why the deviations or flight parameter exceedences occurred.

At the time of the occurrence, the operator did not have a comprehensive safety intelligence system that was consistent with industry best practice. The operator relied primarily upon reports submitted by crews to determine the safety of their operation.

1.17.2.2.1 Flight data monitoring programmes

Flight Data Monitoring (FDM) programmes utilise Quick Access Recorders (QAR) to record flight parameters that are later analysed by the operator to help identify, quantify, assess, and address operational risks that are present in normal operations[28]. FDM has been in use since the early 1970s, when one operator, realising the potential benefits that recorded data routinely collected could be put to, instigated the first known FDM programme.

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[22] Flight data monitoring (FDM) programmes are sometimes referred to as Flight Operations Quality Assurance (FOQA) programmes or Flight Data Analysis Programmes (FDAP). For consistency, the report uses the common acronym FDM to refer to such programmes.

[23] U.S. General Accounting Office. (1998). Aviation safety: U.S. efforts to implement flight operational quality assurance programs. *Flight Safety Digest, 17,* 1-36.

[24] International Civil Aviation Organization. (2002). *Proceedings of the Third LOSA Week.* Dubai, UAE: Author.

[25] Wickens, C. D. (2001). Attention to safety and the psychology of surprise. In R. S. Jensen (Ed.), *Proceedings of the 11th International Symposium on Aviation Psychology* (pp. 1-11). Columbus, OH: Ohio State University Press.

[26] Shappell, S. A., & Wiegmann, D. A. (2000a). *The human factors analysis and classification system (HFACS)* (Federal Aviation Administration, Office of Aviation Medicine Report No. DOT/FAA/AM-00/7). Washington, DC: Office of Aviation Medicine.

[27] Federal Aviation Administration. (2000). *Aviation safety action programs* (Advisory Circular 120-66A). Washington, DC: FAA.

[28] Enders, J. H. (1998). FSF study report urges application of flight operational quality assurance methods in U.S. air carrier operations. *Flight Safety Digest, 17,* 37-46.

The objective of FDM programmes is to enable proactive safety intervention based on the analysis of exceedences and trends in flight data obtained on a routine basis from line operations. FDM programmes are owned and managed by the operators. The programmes improve safety by continuously monitoring operations, detecting adverse trends in operational behaviour, and highlighting undesirable operational issues that can foreshadow accidents and incidents. Within a non-punitive framework, the analysis and assessment of these issues can facilitate improvements in operational procedures and flight crew training. Appropriate data analysis also helps to identify operational and engineering efficiency improvements[29].

International Civil Aviation Organization (ICAO) Annex 6 – Operation of Aircraft includes the following relevant standards and recommended practices in relation to FDM programmes:

Recommendation

3.2.2 Recommendation - From 1 January 2002, an operator of an aeroplane of a certificated take-off mass in excess of 20 000 kg *should* establish and maintain a flight data analysis programme as part of its accident prevention and flight safety programme.

Standard

3.2.3 From 1 January 2005, an operator of an aeroplane of a maximum certificated take-off mass in excess of 27 000 kg *shall* establish and maintain a flight data analysis programme as part of its accident prevention and flight safety programme.

3.2.4 A flight data analysis programme shall be non-punitive and contain adequate safeguards to protect the source(s) of the data.

The UK Civil Aviation Authority response to the amendment of the Annex 6 guidelines on FDM programmes agreed with the recommendations of the Accident Investigation and Prevention (AIG) divisional meeting 1999 for amendment of Annex 6 – Operation of Aircraft. In response to ICAO, the UK CAA stated:

> It is believed that whilst safety proactive operators will implement such programmes without a standard those likely to benefit most will not. However, once a recommended practice, any operator not having a fully functional programme in place could be seen as not making “best endeavours” and hence culpable after an incident.

Another major Australian operator has had an FDM programme in place since 1989. Even though an FDM programme is currently not a regulatory requirement for Australian operators of large transport category jet aircraft, FDM programmes are considered by ICAO, industry associations, and other major airlines as one of the more effective safety tools for identifying and managing operational risks.

At the time of the occurrence, the operator did not have an FDM programme in place in accordance with industry best practice. Consequently, the operator did not have the capability to objectively determine the reason(s) for, and the rate of, unstable approaches in their operation.

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[29] Flight Safety Foundation, Pinet, J., & Enders, H. (1998). Flight safety foundation Icarus committee cites advantages of FOQA for trend analysis, knowledge building and decision making. *Flight Safety Digest, 17*, 47-54.

1.17.2.2.2 Proposed Australian Civil Aviation Safety Regulation (CASR) - Part 119

In order to reduce the safety risks associated with aircraft flight and associated ground operations, the Civil Aviation Safety Authority (CASA) is presently introducing a Safety Management Systems (SMS) approach for passenger carrying operations. That approach will be formalised under the proposed CASR Part 119 regulatory requirements, and will affect air transport operators who engage in operations under the following proposed CASRs:

- Part 121A; or
- Parts 121B or 133, when operations under these Parts are undertaken:
  - wholly within Australia and, at any time, involve the operation of four or more aircraft under the operator's AOC; or
  - not wholly within Australia.

The proposed Part 119 regulations are estimated by CASA to commence having effect in the second quarter of 2005 [30], and will mandate the implementation of an SMS by affected AOC holders. Documented processes for risk management within an operator's organisation are also mandated under the Part 119 proposal.

CASA proposes to meet the ICAO Annex 6 requirement for large commercial air transport operators to establish an accident prevention and flight safety programme, through the implementation of an appropriate safety management system. In particular, the proposed CASR 119.300 'Safety management system improvement and preventive action' states in part that:

> (1) An operator must plan and manage the process necessary for the continuous improvement of the safety management system.
>
> (2) The continuous improvement process must include the following:
>
> (d) the analysis of data (including the analysis of quick-access flight data recorder information, where available).

1.17.2.2.3 Line operations safety audits

In 1999, the ICAO endorsed Line Operations Safety Audits (LOSA) as the primary tool to develop countermeasures to human error in aviation operations[31]. LOSA is considered an addition to the suite of safety intelligence systems, because it records successful human performance or mitigated operational errors, and leads to a more comprehensive picture of crew behaviour and error management on the flight deck.

LOSA is an organisational tool that is designed to identify threats to safety, to minimise the risks such threats may generate, and to implement measures to manage human error in operational contexts. LOSA allows airlines to diagnose their levels of resilience to systemic threats, operational risks and front-line personnel errors, thus providing a principled, data driven approach to prioritising and implementing actions to enhance safety[32].

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[30] CASA Directive 3/2004 of 3 February 2004 delayed further development of CASR Part 119 until 30 June 2004.
[31] International Civil Aviation Organization. (2002). *Proceedings of the Third LOSA Week.* Dubai, UAE: Author.
[32] Ibid.

LOSA employs trained observers to collect data about flight crew behaviour and situational factors on normal flights. The audits are conducted under non-jeopardy conditions. Therefore, flight crews are not at risk of being punished for observed actions and errors. The observers record and code potential observed threats to safety and how the threats are addressed during the flight. Observers also record and code specific behaviours that have been known to be associated with accidents and incidents.

FDM and LOSA are linked to CRM training. Since CRM training forms part of error management training for operational personnel, data from FDM and LOSA forms a basis for the design and delivery of contemporary CRM training programmes. One of the strengths of LOSA is that it identifies examples of preferred performance that can be modelled and positively reinforced during training.

FDM and LOSA data analysis is a proactive form of safety intervention that can facilitate the prevention of adverse events. LOSA is a mature concept, but its implementation is in a developing stage. The methodology is not limited to flight crew, but may also be useful for maintenance personnel, air traffic controllers, cabin crew and dispatch personnel.

At the time of the occurrence, the operator did not have a LOSA programme in place.

1.17.2.2.4 Operator’s safety management system

Interviews with personnel from the Safety and Flight Operations Departments indicated that the operator’s safety management system had not detected any major areas of pilot concern with 737 aircraft operations. In particular, the operator’s safety management system had not identified unstable approaches as a problem. The LOSA audit, which was conducted after the occurrence, also did not identify unstable approaches as an area of concern. Senior company personnel conceded that an FDM programme would be necessary to reliably detect any adverse trends in operational events across the fleet.

The operator’s safety philosophy, policies, procedures and practices were maturing at the time of the occurrence. Senior management responsibilities for safety were identified and defined. Senior management was also committed to providing company personnel with the tools to help manage their performance and to ensure the safety of operations. Regular safety meetings were held for senior managers and company crews to discuss the operator’s occurrence data, ongoing safety actions, and any other concerns with line operations as identified by the occurrence database or crew discussions.

The operator advised that the reporting culture within the airline was very good, however, senior company personnel commented that they were unable to determine if they were capturing the most important information.

In summary, the operator’s safety management system was still in a developmental stage when the runway overrun occurred. As part of a young airline’s maturation and expansion process, it needs to be acknowledged that the operator has continued to develop its safety management system in accordance with sound industry practice. For example, since the occurrence, the operator has conducted a LOSA and is planning to implement an FDM programme by the end of 2004. The operator also sought and received an independent audit from Boeing. In addition, the safety department is continuing to expand and has been re-structured to better meet the needs of the company.

1.18 Additional information

1.18.1 Prevalence of runway overruns and approach and landing accidents

Worldwide aviation occurrence data has highlighted that runway overruns are a relatively common event. Between 1970 and 1998 there were 33 runway overrun accidents involving 'western-built jet airline aircraft' in which the landing was long and/or fast on a dry runway[33]. The Flight Safety Foundation's study on approach and landing accidents (ALAs) worldwide between 1980 and 1996 indicated that the risk of an ALA increased in accordance with a number of dimensions[34]. Those dimensions included but were not limited to:

- A disproportionate number of accidents occurred at night. The accident rate at night was estimated to be three times that for day

- 75% of ALAs occurred when a precision approach aid was not available or was not used

- The most frequent circumstantial factors were nonfitment of presently available safety equipment (generally ground-proximity warning system) and failure in crew resource management. Lack of ground aids was cited in at least 25% of ALAs for all classes of aircraft

Some of the conclusions and recommendations arising from the study included but were not limited to:

- Establishing and adhering to adequate standard operating procedures (SOPs) and CRM processes improves approach and landing safety

- Unstabilised and rushed approaches contribute to ALAs. Operators should define in their flight operations manuals the parameters of a stabilised approach. Corporate policy should state that a go-around is required if the aircraft becomes unstabilised during the approach. Training should reinforce this policy

- Before descent, a checklist-triggered risk assessment by the crew for the upcoming approach should be company SOP. Prior to commencement of the approach, the crew should perform the risk assessment

- The implementation of and crew training for constant-angle and rate-of-descent procedures for non-precision approaches should be expedited globally

- Failure to recognise the need for and to execute a missed approach when appropriate is a major cause of ALAs

- The risk of ALAs is higher in operations conducted during conditions involving:

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[33] Australian Transport Safety Bureau. (2001). *Boeing 747-438, VH-OJH Bangkok, Thailand 23 September 1999* (Investigation Report 199904538). Canberra, ACT: Author.

[34] Flight Safety Foundation. (1998). A study of fatal approach-and-landing accidents worldwide, 1980-1996. *Flight Safety Digest, 17,* 1-41.

- low light
- poor visibility
- the likelihood of optical illusions
- wet or otherwise contaminated runways

- When the pilot in command is the handling pilot, and the operational environment is complex, the task profile and workload reduce handling pilot flight management efficiency and decision-making capability in approach and landing operations

- In-flight monitoring of crew/aircraft parameters (via FDM or similar programme) identifies performance trends that operators can use to improve the quality of approach and landing operations. Performance improvement will result only if these data are managed sensitively and de-identified.

The occurrence flight crew was exposed to some of these risks and the operator had processes in place to address some of these risks. However, the operator conceded that the crew’s approach briefing could have considered the following aspects in more detail: the autobrake setting; the likelihood of a constant tailwind during the descent; the PAPI crossing height and glideslope giving an aim point further down the runway; any alternatives to a straight-in runway 29 approach; and a discussion of the difference in visual cues of the flare for landing on a 60 m wide runway at night over a displaced threshold.

1.18.2 Certified landing field length

The performance limitations applicable to large aircraft operations in Australia originate in Section 20.7.1B of the Civil Aviation Orders (CAO) which specifies the landing distance required. That distance is measured from a point where the aircraft first reaches a height of 50 feet above the landing surface at the minimum approach speed (1.3 times the stall speed). The landing distance is predicated on the aircraft stopping with spoilers extended and maximum wheel braking, but without the use of reverse thrust. It is not reasonable to expect an aircraft in routine service to match the landing distances demonstrated by the manufacturer at the time of certification. Therefore, the flight test demonstrated landing distance is increased by 67% to allow for operational variables. In operational terms, the factors used to derive the landing distance limit provide approximately twice as much runway in which to stop an aircraft than is actually required.

The landing field length limit graph for the 737-800 indicated that, at the time of the incident, the landing distance required was 1,690 m.

1.18.3 Factors affecting landing distance

1.18.3.1 The temporary PAPI

1.18.3.1.1 Threshold crossing height

Height over the threshold is a function of glide path angle and the planned landing gear touchdown target (typically a 1,000 ft aim point for a 737). During a typical 3.0 degree visual approach, the main landing gear of a 737-800 will cross the threshold at approximately 35 ft with an eye height of 50 ft. In contrast, for the landing gear of a 767 to cross the threshold at 30 ft, the eye height is 59 ft.

The temporary PAPI was adjusted to give an eye height over the threshold of 60 ft in order to take account of the largest aircraft expected to use the runway during the period of operations, in this case, a 767. That extra 10 ft of height on crossing the threshold increased the landing distance of the 737-800 by 61 m.

The PAPI system does not indicate small deviations from the approach slope and, for that reason, it is used for guidance only. PAPI use below 300 ft aal is secondary to a visual judgement of the approach path down to the touchdown point.

1.18.3.1.2 Approach angle

A glide path shallower than the normal 3 degrees increases the distance to touchdown. In this occurrence, the PAPI was set at 2.85 degrees, resulting in a 15 m increase in the landing distance.

1.18.3.2 Effect of tailwind

ATSB calculations determined that, during the approach there was a tailwind component of 19 kts at 2,000 ft, 10 kts at 1,000 ft and 6 kts during the flare. When an approach is made with a tailwind an increased rate of descent is required to maintain the glideslope relative to the ground. Consequently, it becomes more difficult to reduce speed and configure the aircraft for landing while maintaining that constant glideslope. A tailwind will increase the overall landing distance due to the associated increase in ground speed. In addition, as the aircraft approaches the runway surface, the decrease in the tailwind associated with frictional retardation[35] results in an increase in true airspeed (due to inertia). That makes it more difficult to place the aircraft on the ground and consequently amplifies the tendency of the aircraft to float[36].

1.18.3.3 Runway slope

The gradient for runway 11/29, was described in the En-route Supplement Australia (ERSA). That gradient was 0.2% down to the southeast. However, that was an average figure for the whole length of the runway. Examination of runway engineering diagrams indicated that the slope of the runway varied from positive to negative several times along its length. In the region where the aircraft commenced its float, the runway sloped downward 0.43% to the west, but then sloped upward in a similar fashion to a crest 540 m before the runway end. Precise data for this effect is not known but the effect on the landing run of the aircraft would have been marginal. The visual limitations presented to the pilot of a landing aircraft by the change in gradient are discussed in section 1.18.5.2.

1.18.4 Pilot technique

1.18.4.1 Approach speed

[35] Friction effects the surface wind by reducing its speed. The degree of reduction in wind speed will depend on the roughness of the terrain. Friction effect decreases with height.

[36] Van Es., G. W. H., & Karwal, A. K. (2001). *Safety aspects of tailwind operations* (NLR-TP-2001-003). The Netherlands: National Aerospace Laboratory.

Excess approach speed increases the tendency of an aircraft to float during the flare and increases the stopping distance required once on the runway. Floating above the runway before touchdown must be avoided because it uses a large portion of the available runway. Advisory information available to the pilots in the QRH indicated that, for every 10 kts of approach speed above V_{ref}, the total landing distance would increase by approximately 175 m.

Once an aircraft has landed and is in the stopping mode, the increase in distance resulting from excess touchdown speed is small when compared to the effect of an extended flare. Decelerating the aircraft once on the ground, using spoilers, reversers and brakes, is at least three times more effective than decelerating in an extended flare.

Recorded data indicated that the aircraft floated just above the runway surface for approximately 650 m before the main gear touched down at an airspeed of 140 kts, 1,165 m from the displaced threshold.

1.18.4.2 Approach path

Height of the aircraft over the runway threshold has a significant effect on the total landing distance due to the length of runway used up before an aircraft actually touches down. It was calculated that the aircraft crossed the threshold at an eye height of 83 ft. That extra 23 ft of height above the 60 ft threshold crossing height guidance of the temporary PAPI increased the distance before touchdown by 159 m.

1.18.4.3 Rollout

Once the aircraft has touched down, the forces available to stop the aircraft are aerodynamic drag, reverse thrust and wheel braking. Wheel braking is the most effective method of stopping the aircraft and it is important to commence braking as soon as possible[37]. The effectiveness of the brakes is dependent on tyre to ground friction. For this reason, lowering the nosewheel and deploying ground spoilers should be accomplished promptly to ensure the transfer of aircraft weight on to the wheels. Advisory information contained in the 737-800 QRH indicates that there is a considerable difference between the landing distance using autobrake and that using maximum manual braking. Table 1 shows unfactored FLAP 40 landing distances based on a V_{ref} 40 approach speed, at a landing weight of 60,000 Kg. Prescribed conditions are nil wind, nil runway slope and 2 engines detent reverse thrust.

The pilot in command stated that he selected AUTOBRAKE 2 during the pre-landing preparations. The AUTOBRAKE 2 setting gives a deceleration rate of 5 ft/sec^2. Recorded data indicated that the autobrake was applied one second after touchdown and was disarmed 6 seconds later by the application of manual braking. During the period of autobrake application, the aircraft travelled 390 m. The deceleration rate for full manual braking is approximately 14 ft/sec^2.

[37] Boeing publication, *Landing on slippery runways* (February 1977).

Table 1:
Comparison of Boeing 737-800 braking performance and landing distances.

Braking configuration	Landing distance (metres)
Max manual braking	855
Autobrake setting 2	1875
Autobrake setting 3	1485
Max autobrake setting	1060

Aerodynamic drag and reverse thrust are most effective at high speed. As the aircraft's speed reduces during the landing roll, aerodynamic drag and reverse thrust become less effective. Deployment of ground spoilers and the initiation of reverse thrust should occur as soon as possible after main gear touchdown. At high ground speeds, with the spoilers deployed, drag and reverse thrust provide approximately 50% of the total stopping force available. At lower speeds, drag and reverse thrust reduce to about 20% of stopping capability, and the brakes provide 80%.

1.18.5 Perceptual issues during approach

1.18.5.1 Overview

Perceptual factors that can adversely influence a pilot's aircraft handling during the approach and landing may include time of day, sloping terrain, sloping runways, width of runways, runway lighting, the intensity of ambient lighting and celestial illumination, and the type of instrument approach flown[38]. For example, a pilot is accustomed to seeing the runway making an angle to the approach path of about 3 degrees. If the runway slopes down at 1 degree, then the apparent approach path would only be 2 degrees, and the pilot would erroneously sense that the aircraft is too low. This illusion will result in a higher than normal approach. Using electronic glide slope systems, such as PAPI or Visual Approach Slope Indicator (VASI), when available, and maintaining optimum proficiency in landing procedures, may help to minimise this type of illusion.

1.18.5.2 Common visual illusions during approach and landing

A wider-than-usual runway can create the illusion that the aircraft is at a lower height than it actually is[39, 40]. When the runway is wider than that to which a flight crew is accustomed, it will appear closer and the aircraft will appear to be lower than what it actually is. The pilot who does not recognise this illusion will fly a higher approach, with the risk of levelling out high and landing hard, landing long or overshooting the runway.

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[38] Transport Canada. (1996). *Human factors for aviation: Basic handbook*. Ontario: Author.
[39] Ibid.
[40] Schiff, B. (1990). Visual illusions can spoil your whole day. *Accident Prevention, 47,* 1-4.

The ‘black hole’ phenomenon is particularly relevant when aircraft approach airports at night over the sea or unlit terrain. Black hole illusion occurs when darkness and an absence of visual cues, such as lights, may induce a false perception of altitude and/or attitude. When the environment along the approach path is dark, with only the distant runway or airport lights providing visual stimuli, an illusory or false sense of height and/or attitude may be perceived[41, 42].

The windshield location of an observed object, such as an airport or runway approach lighting, can lead to a misjudgment of height. The object will appear at the same spot on the windshield at a higher altitude with a low pitch angle (higher airspeed) as at a lower altitude with a high pitch angle (lower airspeed).

A multiple slope runway, like Darwin runway 29, can result in a flight crew temporarily losing sight, not only of the end of the runway, but also of any obstructions, including other aircraft, which may be on the runway.

There was a hump between the aircraft’s touchdown point and the end of runway 29. The crew reported that after landing, the end of the runway was not initially visible. However, the end of the runway would have become visible shortly before the aircraft passed the hump.

1.18.6 Flight crew comments

The flight crew reported that they were aware of the runway works in progress at Darwin airport, and that the available length of runway 29 had been shortened. The copilot also commented that there was the possibility that the full-length of the runway could have become available near their estimated arrival time.

The crew reported being quite surprised and a little confused when Darwin ATS advised that the ILS was available for approach to the circling minima. In particular, the copilot reported that, prior to top of descent, he had prepared for an ILS approach. The copilot reported initially discounting the NOTAM regarding the runway works because he thought that the full length was probably going to be available for their arrival. The pilot in command reported that he chose not to use the ILS because it was not appropriate for an arrival to a runway with a displaced threshold. The pilot in command briefed a runway 29 VOR/DME approach. The briefing included information that there was a displaced threshold and that a temporary PAPI had been installed.

The pilot in command reported that it was difficult to judge the approach and landing to a 60 m wide runway because he was accustomed to landing on a 45 m wide runway. He also mentioned that there was a hump in the middle of the runway near taxiway Bravo, which occluded the end of the runway during the initial stages of the landing roll. Moreover, the pilot in command commented that the middle of the runway was like a black hole. The crew reported that, on touch down, they could not see the end of the runway because of the undulating ground. The pilot in command described the approach as a black hole approach. The crew reported that they might have experienced an illusion associated with the wider runway and/or black hole phenomenon.

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[41] Leibowitz, H. W. (1988). The human senses in flight. In E. L. Wiener & D. C. Nagel (Eds.), *Human factors in aviation* (pp. 83-110). San Diego: Academic Press.

[42] Wilson, D. R. (1999). Darkness increases risks of flight. *Human Factors & Aviation Medicine, 46,* 1-8.

The crew also reported that the 737-800 was considerably faster and more difficult to slow down in the air compared to the earlier generation 737 aircraft on which they had obtained the majority of their jet experience.

With reference to CRM, the copilot commented that he could have done better. For example, when the copilot saw that the speed was high, he asked the pilot in command if he was happy with this. The pilot in command replied that the speed was coming back towards V_{ref} and that the aircraft was on the PAPI glide slope. The copilot said he probably should have been more forthright and called that the speed was high and called a go-around. The copilot also elected not to interrupt the pilot in command during the touchdown. The copilot wanted to ensure that that the thrust reversers, brakes and spoilers were fully functioning during the landing roll rather than to create confusion in the cockpit by confronting the pilot in command at a critical stage of the landing.

The copilot recalled the confusion amongst crewmembers during a runway overrun case study that he had studied during the operator's CRM course. That case study involved a situation where the pilot in command had cancelled a late go-around during the landing roll without informing the crew. The copilot did not want to replicate the confusion that was evident in that case study. Therefore, he did not challenge the pilot in command during the landing roll.

The crew commented that the tailwind during the approach compressed the time they had to configure and stabilise the aircraft.

The flight crew also stated that they had never practiced two-engine go-arounds from an unstable approach when in the simulator. They commented that such training would have been beneficial.

The crew recalled that there were no runway centreline lights or touchdown zone lights. The crew intimated that such lights might have minimised the potential for a black hole effect during landing.

1.18.7 Flight and duty times

Fatigue can arise from a number of different sources, including time on task, time since awake, acute and chronic sleep debt, excessive physical and/or cognitive activity, emotional strain, circadian disruption or a combination thereof. A review of fatigue research relevant to flight operations noted that fatigue can have a range of influences, such as increased anxiety, decreased short-term memory, slowed reaction time, decreased work efficiency, reduced motivation, increased variability in work performance, and increased errors of omission[43]. However, many of those symptoms generally only appeared after substantial levels of sleep deprivation were imposed. The review also made the following observations:

- A common symptom of fatigue is a change in the level of acceptable risk that a person tolerates, or a tendency to accept lower levels of performance and not correct errors
- Error rates increase during the period 0000 to 0600

[43] Battelle Memorial Institute. (1998). *An overview of the scientific literature concerning fatigue, sleep, and the circadian cycle* (Report prepared for the Office of the Chief Scientific and Technical Advisor for Human Factors, Federal Aviation Administration). Washington, DC: Author.

- Most people need eight hours sleep each day to achieve maximum levels of alertness and performance

- Decrements in performance intensify if the time awake is 16 to 18 hours. Performance decrements of 'high time-since-awake' crews tended to result from ineffective decision-making rather than deterioration in aircraft handling skills

- Fatigue is cumulative

- There is a discrepancy between self-reports of fatigue and actual fatigue levels, with people generally underestimating their level of fatigue.

To minimise the likelihood of fatigue influencing pilot performance, regulatory authorities and operators have restrictions on the flight and duty times for pilots. The flight and duty times of the occurrence flight crew complied with the requirements of Civil Aviation Order 48 (Flight Crew Limitations).

Details of the recent work and rest history for the crew indicated that the pilot in command had commenced duty about 5 hours before the occurrence and he had slept for 8 hours during the preceding night. He had been awake for 16 hours prior to the occurrence. The copilot reported that he had commenced duty about 5 hours before the occurrence and he had slept for 10 hours during the preceding night. He had been awake for 13 hours prior to the occurrence. The incident occurred at around 2335 Central Standard Time or 0005 Eastern Standard Time, that is, during the flight crew's normal sleep cycle. The flight crew reported that they did not think their performance had been affected by fatigue.

2. Analysis

2.1 Overview

In the present occurrence, the aircraft crossed the end of the runway at a groundspeed of between 35 and 40 kts and travelled 44 m into the 90 m runway end safety area. There was no damage to the aircraft.

Runway overruns feature prominently in accidents involving western-built transport category jet aircraft. Long and/or fast landings were factors in these occurrences. The analysis will discuss the conditions and factors that led to the runway overrun and will specifically address the following topics: landing fast, landing long, other aircraft performance issues, the handling techniques used by the crew, crew resource management, operator's standard operating procedures, safety management systems, aerodrome configuration, and environmental conditions.

2.2 Flight crew performance

2.2.1 Introduction

The high approach speed led to the long landing. The final approach speed deviated outside the limits stipulated by the company Operations Manual. Based on reports from company management pilots, including those pilots with instructional backgrounds on the 737 and its variants, the 737-800 is a heavier and more aerodynamically efficient aircraft, which requires more time to slow down. However, they indicated that the problem was not related to the performance of the 737-800. Rather, the primary problem was that the aircraft had not been slowed down and configured early enough to permit a stable approach. Furthermore, a review of the operator's technical training and procedures indicated that the flight crew was adequately equipped to appropriately handle the situation. Overall, the crew experienced difficulties judging the progress of the approach and configuring the aircraft in a timely manner to ensure that stabilised approach parameters were met.

2.2.2 Pilot in command

The pilot in command did not comply with the stable approach requirements stipulated in company standard operating procedures. Moreover, the pilot in command continued with an unstabilised approach and did not go-around. Throughout the approach, there were various cues available to both crewmembers to indicate that the approach was unstable.

From the perspective of standard operating procedures, the crew was required to stabilise the aircraft by 500 ft in VMC. Although there were a number of opportunities for the crew to modify or discontinue the approach at an earlier stage, the pilot in command appeared to wait until the last approach gate of 500 ft to determine whether he could stabilise the aircraft.

The pilot's decision to continue the approach from 500 ft was consistent with a low perception of the risks associated with an unstable approach. An individual's risk perception is often inaccurate. When dealing with familiar tasks in familiar environments, it appears that individuals operate with a ‘zero’ level of risk perception[44]. That is, individuals do not believe there is any chance of an accident occurring by performing the task in a particular manner, such as procedural non-compliance. Consequently, an individual’s behaviour is more concerned with satisfying other demands or desires, such as task completion.

There may have been some time compression and workload difficulties associated with the tail wind during the approach that influenced the crew’s ability to appropriately configure and stabilise the aircraft. The pilot in command reported that he was aware that the aircraft was a little high and fast during the approach and that he was trying to get the aircraft under control. He thought that he had managed to reduce the speed to within company limits and he had acquired the PAPI glideslope. The pilot in command’s assessment was not consistent with the recorded information.

The pilot in command’s execution of his approach plan did not achieve the desired stable approach. The displaced threshold, non-precision approach, tail wind and night time conditions probably contributed to the pilot in command’s difficulty attempting to obtain an appropriate approach speed. In particular, the pilot in command commented that the wide runway and black hole phenomenon made it difficult to judge the approach.

The excessive float along the runway during the flare appeared to have been partially a function of the aircraft’s excessive speed and the handling pilot’s difficulty with depth perception associated with a wider than normal runway perspective, and a reported black hole sensation. In particular, the pilot in command reported difficulty with judging the aircraft’s height above the runway.

The pilot in command reported that, in hindsight, he should have considered going around when the aircraft floated for a considerable time without touching down. Once the thrust reversers had been selected, the pilot in command was committed to the landing.

The aircraft’s AUTOBRAKE 2 setting was marginal for the available runway length. In particular, the company’s Operations Manual indicated that AUTOBRAKE 3 setting was more appropriate for the conditions. The fact that the aircraft had touched down and was decelerating appeared to remove any consideration for a go-around. It was not until the aircraft passed over the hump in the runway that the pilot in command saw the end of the runway. Only then did he become concerned about the aircraft’s stopping distance requirements.

It was possible that the pilot in command was experiencing some fatigue due to his number of hours of continued wakefulness and the time of day when the incident occurred. However, there was insufficient evidence to draw any definite conclusions with respect to fatigue affecting specific events or ‘behaviours’ during the approach and landing.

[44] Summala, H. (1988). Risk control is not risk adjustment: The zero-risk theory of driver behaviour and its implications. *Ergonomics, 31,* 491-506.

2.2.3 Copilot

The copilot did not announce that the approach was unstable and instruct the pilot in command to go-around. The investigation did not have access to the cockpit voice recorder. Consequently, the nature of the communications between the crew could not be clearly established.

With reference to the high airspeed at around 500 ft during the approach, the copilot recalled asking the pilot in command if he was happy with the situation. The copilot recalled that the pilot in command replied along the lines that the speed was coming back in. The copilot observed at this point that the glideslope had been reacquired, but that the airspeed was still high. He could not recall if any further comments were made prior to touchdown. Both crewmembers felt that the airspeed was kept within company criteria for a stable approach.

The copilot configured the aircraft in accordance with instructions from the pilot in command, but was hesitant to challenge the pilot in command's handling of the aircraft when he noticed that the speed was becoming high. This may have been a function of a less than optimum trans-cockpit authority gradient[45], or an over confidence in the pilot in command's ability to rectify the situation[46]. A copilot is more likely to effectively inform and query the pilot in command when an optimum trans-cockpit authority gradient[47] is present and brusquely challenge the pilot in command when a reverse trans-cockpit authority gradient[48] is present.

Issues associated with the authority relationship between an aircraft captain (pilot in command) and the first officer (copilot) have been cited in a number of accidents and incidents. Research has shown that there is an optimum trans-cockpit authority gradient to allow an effective interface between pilots on the flight deck[49]. The gradient may be too flat, such as two equally qualified individuals occupying the flight deck, or it may be too steep, as with a dominating senior captain and an unassertive and less experienced first officer. In these cases, the likelihood of errors going undetected and/or uncorrected increases. A study of 249 airline pilots found that nearly 40% of first officers reported that they had, on several occasions, failed to communicate their doubts to the captain about the operation of the aircraft. Reasons appeared to be a desire to avoid conflict and a deference to the experience and authority of the captain[50]. Those reasons were more consistent with or indicative of a steep trans-cockpit authority gradient.

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45 US research on communications breakdowns between flight crews found that significant differences in seniority, age, experience, stature, status, culture, reputation, assertiveness and/or a combination of these factors between the pilot in command and copilot often led to a communications gulf on the flight deck. The term 'Trans-Cockpit Authority Gradient' was developed to describe how these variables within an aircraft's flight crew might influence the communications interface between crewmembers. A less than optimum gradient occurs when the pilot in command's role is either over-emphasised (steep gradient) or underplayed (reverse gradient). The cockpit gradient may be too flat when two pilots have similar qualifications, experience, communication styles, or are friends, or too steep where the pilot in command is domineering towards an unassertive copilot or vice-versa.

46 Flat trans-cockpit authority gradient - Crew interaction and supervision tend to diminish once individual members assume that other crew are fully capable of conducting safe operations and as a result the type of detailed assistance and/or supervision and/or cross checking that they might normally provide to other crewmembers is reduced.

47 An optimum gradient is where the copilot is able to effectively inform the pilot in command of a problem and the pilot in command responds to the information in an appropriate manner.

48 A reverse gradient is when the pilot in command's role is underplayed and the co-pilot is overly assertive.

49 Wheale, J. (1983). Crew coordination on the flight deck of commercial transport aircraft. *Flight Operations Symposium.* Irish Airline Pilots Association. Dublin.

50 Ibid.

One of the findings from the operator's LOSA audit, which was conducted after the occurrence, indicated that the trans-cockpit authority gradient amongst their crews may be too flat. That finding "related to the captain [pilot in command] failing to adequately discipline the first officer [copilot] for breaches of SOPs [standard operating procedures]."

The copilot's comment that he did not have access to a list of advisory calls to communicate with the pilot in command during an unstable approach was somewhat at odds with the material contained in the section on standard call outs in the company's FCTM. The copilot also commented that a concise list of advisory calls and appropriate actions in the case of non-response would have assisted his ability and confidence in communicating clearly with the pilot in command during an uncomfortable situation.

The company FCTM's section on standard call outs stated that:

> On the approach after 500 feet above field elevation call out significant deviations from the programmed airspeed, descent, and instrument indications.

The operator's documentation also did not advise crews to repeat calls with increasing emphasis if the handling pilot did not take corrective action; nor did company documentation provide a standard list of phrases for crews to communicate such urgency[51].

2.2.4 Overall crew performance

The proper execution of any flight demands constant situation awareness, frequent cross-checking, and sharing of information. Situation awareness involves interpreting cues to recognise that a problem exists, which may require a decision or action[52]. The flight crew recognised that the airspeed was high, but did not appear to fully consider the significance of this cue and the associated risks with continuing the approach. The fact that the crew did not select the landing gear out of sequence, or use the speed brake to help slow the aircraft, indicated that they were not aware of the extent of the developing problem until a late stage in the approach.

In addition, the crew's approach briefing could have considered the following aspects in more detail: the autobrake setting; the likelihood of a constant tailwind during the descent; the PAPI crossing height and glideslope giving an aim point further down the runway; any alternatives to a straight-in runway 29 approach; and a discussion of the difference in visual cues of the flare for landing on a 60 m wide runway at night over a displaced threshold.

A study of 244 in-flight incidents classified 143 of the events either as difficulties in perceiving that a problem existed (57%) or in recognising the significance of the cues for the safety of flight (43%)[53]. If a crew does not recognise that they have a problem, they are not in a position to begin trying to solve it. By the time that the crew is aware that a problem exists, the level of risk in the situation may have escalated considerably.

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[51] For example, some operators use terms such as "Captain, you must listen" when flight safety may be compromised.

[52] Orasanu, J. M. (1993). Decision-making in the cockpit. In Wiener, E. L., Kanki, B. G., & Helmreich, R. L. (Eds.) *Cockpit resource management* (137-172). San Diego: Academic Press Inc.

[53] Freeman, C., & Simmon, D. A. (1991). Taxonomy of crew resource management: Information processing domain. In R. S. Jensen (Ed.), *Proceedings of the Sixth International Symposium on Aviation Psychology* (pp. 391-397). Columbus, OH: The Ohio State University.

A US National Transportation Safety Board (NTSB) study of 37 air carrier accidents reported the following relevant findings[54]. The captain was flying in 81% of events and, in 53% of cases, the first officer was in the first year of employment with the carrier. In addition, in 73% of cases, it was the first time that the crew had flown together. In 44% of cases, the accidents occurred on the first leg of the first trip that the crew had flown together. In particular, almost half the accidents were precipitated by an error made by the captain and not challenged by other crewmembers.

The NTSB study concluded that, when captains are the handling pilots, they appear to have difficulty in monitoring their own performance while the first officers had difficulty voicing their concerns about the captain's decision-making, particularly when they had not flown together before. In 84% of the accident case studies, "monitor/challenge" failures were involved. That is, one crewmember made a mistake and the other crewmember did not challenge it. These unchallenged mistakes played a major role in the accident trajectory.

The crew composition and incident trajectory in the current case was consistent with that profile. The profile appears more consistent with a steep trans-cockpit authority gradient, however, some of those problems can also occur with a flat trans-cockpit authority gradient. Without access to the cockpit voice recorder[55], it was not possible to clearly determine the type of trans-cockpit authority gradient that may have been operative during the occurrence flight.

2.3 Organisational issues

2.3.1 Introduction

The ATSB investigation examined the processes of the operator's Safety and Flight Operations Departments for any systemic organisational issues that may have increased the likelihood of adverse operational events. That examination included a review of the company's 737-800 operations, the configuration options for landing a heavy 737-800 on a shortened runway, as well as company procedures and training relating to unstable approaches, go-arounds and crew resource management.

That examination of the operator's 737 operations revealed some deficiencies in the manner in which the operator evaluated its operations. Specifically, the investigation identified some deficiencies related to the capabilities of the operator's safety management system at the time of the occurrence. The processes for identifying hazards were primarily reactive rather than proactive. In particular, the operator relied considerably upon crew reports of adverse operational events and hazards. Furthermore, the operator did not have a flight data monitoring and analysis programme. The operator is addressing these issues.

2.3.2 CRM training

The CRM training being delivered at the time of the occurrence contained the elements of a current generation CRM course. The airline also augmented its CRM awareness-based training programme with skills-based training in the form of LOFT exercises for

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54 National Transportation Safety Board. (1994). *A review of flightcrew-involved, major accidents of US air carriers, 1978 through 1990* (Report No. NTSB/SS-94/01). Springfield, VA: Author.

55 See Section 1.11 Flight Recorders

flight crew. In summary, the operator's CRM training programme was in an embryonic stage with a number of initiatives yet to be implemented at the time of the occurrence. Nonetheless, the current and proposed CRM training did contain all the elements of what is currently regarded as sound industry practice.

2.3.3 Hazard identification and safety management

The identification of operational risks and safety trends was reliant upon flight and cabin crew reports and internal and external safety audits. The reliability, validity, and diagnosticity of the data that the operator had obtained through these processes were variable and subjective. An FDM programme would have enabled the operator to monitor the pattern of in flight parameter exceedences, thereby enabling the objective identification of problematic safety trends and the subsequent development of appropriate remedial actions[56].

The safety management system had not identified unstable approaches as a problem. In particular, the go-around or missed approach data derived from flight crew reports appeared to be unrelated to unstable approaches. There has been an increase in crew reporting of go-arounds since the runway overrun for reasons that could not be established.

2.4 Summary

Overall, there were a number of safety issues identified during the course of the investigation. Those issues included: a non-precision approach at night which was conducive to illusions; a displaced threshold which limited the landing distance available; crew resource management problems; aircraft handling difficulties; an underdeveloped landing approach risk assessment by the crew; and a safety management system that had yet to incorporate the flight data monitoring programmes advocated by ICAO and industry associations. As part of the relatively new operator's maturation process, the operator has developed a number of measures which are being implemented over the short, medium and longer terms to improve the training of crews, and the capability of their safety management system.

[56] Lewis, C. (2002). Flight operations quality assurance (FOQA). *Flight Safety Information, 1*, 10-14.

3.0 CONCLUSIONS

3.1 Findings

Aircraft

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

2. The weight and centre-of-gravity were within certified limits during the flight.

3. There were no aircraft, engine or system malfunctions that adversely contributed to the aircraft's deceleration during the landing roll.

Flight crew

1. The crew was properly licensed and medically fit to conduct the flight.

2. The crew conducted a non-precision (VOR/DME) approach at night with visual glide slope guidance for the final segment provided by a portable PAPI.

3. The pilot in command did not fly the aircraft accurately during the final approach.

4. The pilot in command did not comply with the stable approach requirements stipulated in the operator's standard operating procedures.

5. The pilot in command continued with an unstabilised approach and did not go-around.

6. The copilot did not announce that the approach was unstable and instruct the pilot in command to go-around.

7. The flight crew did not respond appropriately to the GPWS sink rate alert during final approach (the sink rate alert was another indication that the criteria for a stable approach had been exceeded and that the situation required a go-around).

8. The crew was trained in appropriate missed approach manoeuvres on the 737.

9. The crew had completed crew resource management training, which included a runway overrun case study and a discussion of the operator's published stable approach requirements.

10. The crew responded appropriately when they realised that the aircraft might overrun the runway during the landing roll.

Operator’s documentation, training, procedures, and safety management system

1. The operator provided its operations personnel with an Operations Manual, in compliance with Civil Aviation Regulation 215.

2. The Operations Manual and Flight Crew Training Manual contained the criteria for a stable approach and the requirement for a go-around if the criteria were exceeded during an approach.

3. The Operations Manual contained advice on instrument approach procedures.

4. The Operations Manual contained advice on missed approach manoeuvres.

5. The operator’s crew resource management training regime was continuing to mature at the time of the occurrence.

6. The operator’s crew resource management training was consistent with sound industry practice.

7. The processes for identifying hazards were underdeveloped and primarily reactive at the time of the occurrence.

8. The operator did not have a flight data monitoring programme in place at the time of the occurrence.

Meteorology and environment

1. The ATIS indicated that the wind was light and variable.

2. Recorded data indicated that crew experienced a significant tail wind during the approach and landing.
3. The operational environment was conducive to visual illusions, such as the black hole effect, during the approach and landing.

Air Traffic Services

1. Air traffic control personnel offered the crew an ILS approach to the circling minima.

2. Aircraft inbound to Darwin were not subject to the standard 250 kt speed limit below 10,000 ft.

3. The Tower controller indicated that a tailwind component of up to 4 kts could be expected during the landing.

Aerodrome

1. The landing threshold for runway 29, the active runway, was temporarily displaced 1,173 m beyond the permanent threshold to enable runway re-surfacing.

2. The reduced landing distance available of 2,181 m was of sufficient length for the landing on the evening of the occurrence.

3. The full length of the runway could not be opened at short notice, except in an emergency.

4. There was a hump in the runway, which precluded the crew from seeing the end of the runway in the early stages of the landing roll.

5. Runway 29 was 60 m wide.

6. The temporary threshold was equipped with threshold lights and a temporary PAPI set at 2.85 degrees and with an eye height over the threshold of 60 ft.

7. The ILS was serviceable but was not available for a precision approach to the runway because of the displaced threshold.

8. The crew was notified by NOTAM of the temporary runway 29 infrastructure changes.

9. The crew was aware of the temporary infrastructure arrangements for runway 29. However, the copilot thought that the full length of the runway might have become available around their arrival time.

3.2 Significant factors

1. The pilot in command did not fly the aircraft accurately during the final approach.

2. The pilot in command did not comply with the stable approach requirements stipulated in the operator’s standard operating procedures.

3. The pilot in command continued with an unstabilised approach and did not go-around.

4. The copilot did not announce that the approach was unstable and instruct the pilot in command to go-around.

4 SAFETY ACTION

4.1 Safety actions

The operator advised that the deficiencies identified as a result of the incident were being addressed. The operator undertook some immediate actions after the incident as follows:

1) Distributing a Flight Crew Operational Notice reminding crews of stable approach requirements and emphasising the need to carefully consider various operational requirements before and during flight, such as aircraft configuration options.

2) Conducted an internal investigation of the incident.

3) Incorporated the internal investigation report into initial and recurrent CRM training as a case study.

4) Conducted a review of operational procedures.

As part of the relatively new operator's maturation process, the operator has also developed a number of measures which are being implemented over the short, medium and longer terms to improve the training of crews, and the capability of their safety management system as follows:

1) Introducing an FDM system to assist in hazard identification and risk assessments.

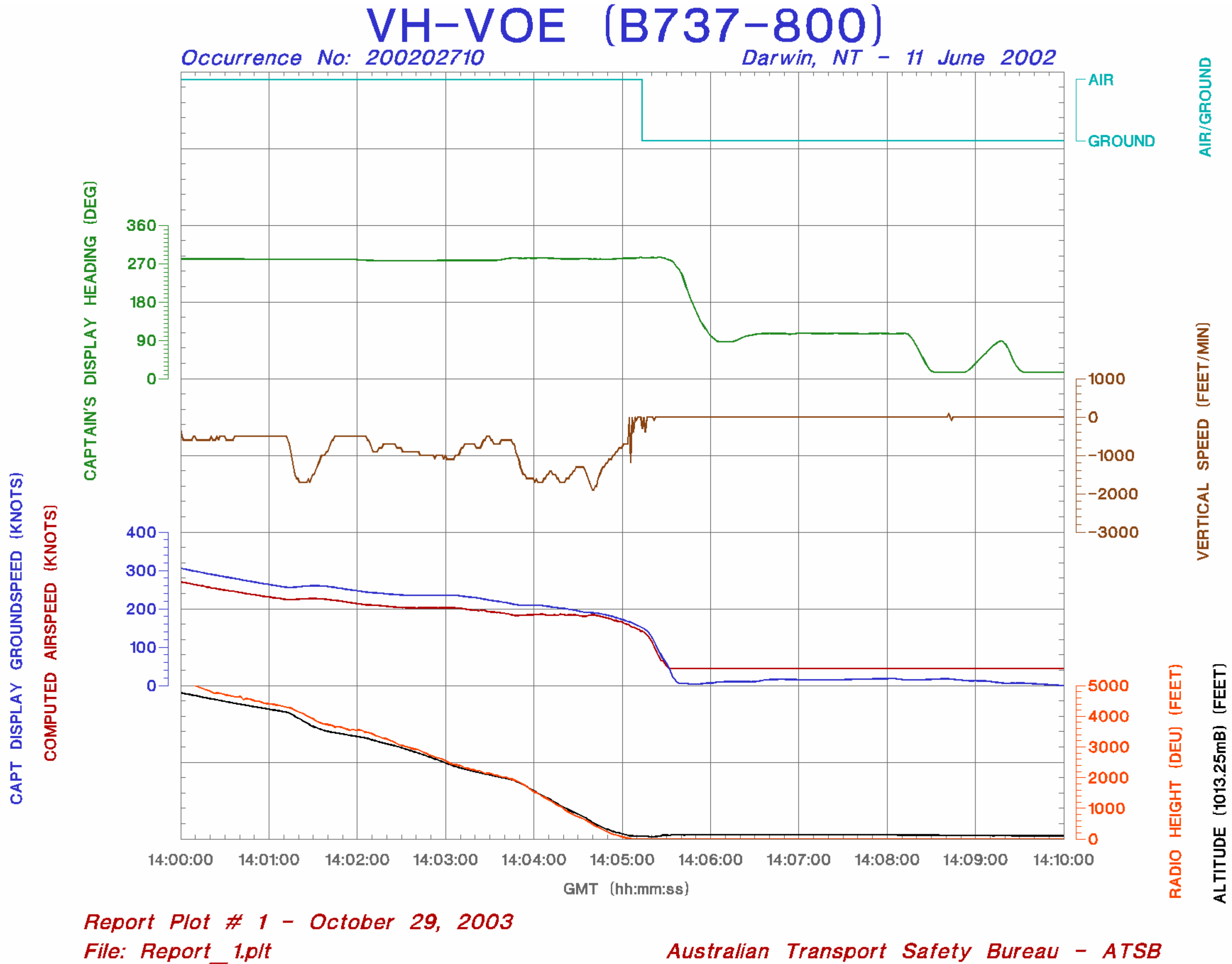
2) Refining current CRM training and developing and delivering a command CRM training course.

3) Since the occurrence, the operator has actively sought and received various independent external audits, including a Boeing audit and a LOSA audit.

4) Equipping their aircraft with Vertical Situation Displays (VSD). The VSD displays a side view of the aircraft's flight path to the flight crew. It enhances safety by showing the aircraft's current and predicted flight path relative to terrain. Additionally, it helps the pilot determine a stable and appropriate glide path during approach and landing.

5 APPENDIXES

Appendix 1 – FDR data plots


VH-VOE (B737-800)
Occurrence No: 200202710
Darwin, NT - 11 June 2002
AIR
GROUND
AIR/GROUND
CAPTAIN'S DISPLAY HEADING (DEG)
360
270
180
90
0
1000
0
-1000
-2000
-3000
VERTICAL SPEED (FEET/MIN)
CAPT DISPLAY GROUNDSPEED (KNOTS)
COMPUTED AIRSPEED (KNOTS)
400
300
200
100
0
5000
4000
3000
2000
1000
0
RADIO HEIGHT (DEU) (FEET)
ALTITUDE (1013.25mB) (FEET)
14:00:00
14:01:00
14:02:00
14:03:00
14:04:00
14:05:00
14:06:00
14:07:00
14:08:00
14:09:00
14:10:00
GMT (hh:mm:ss)
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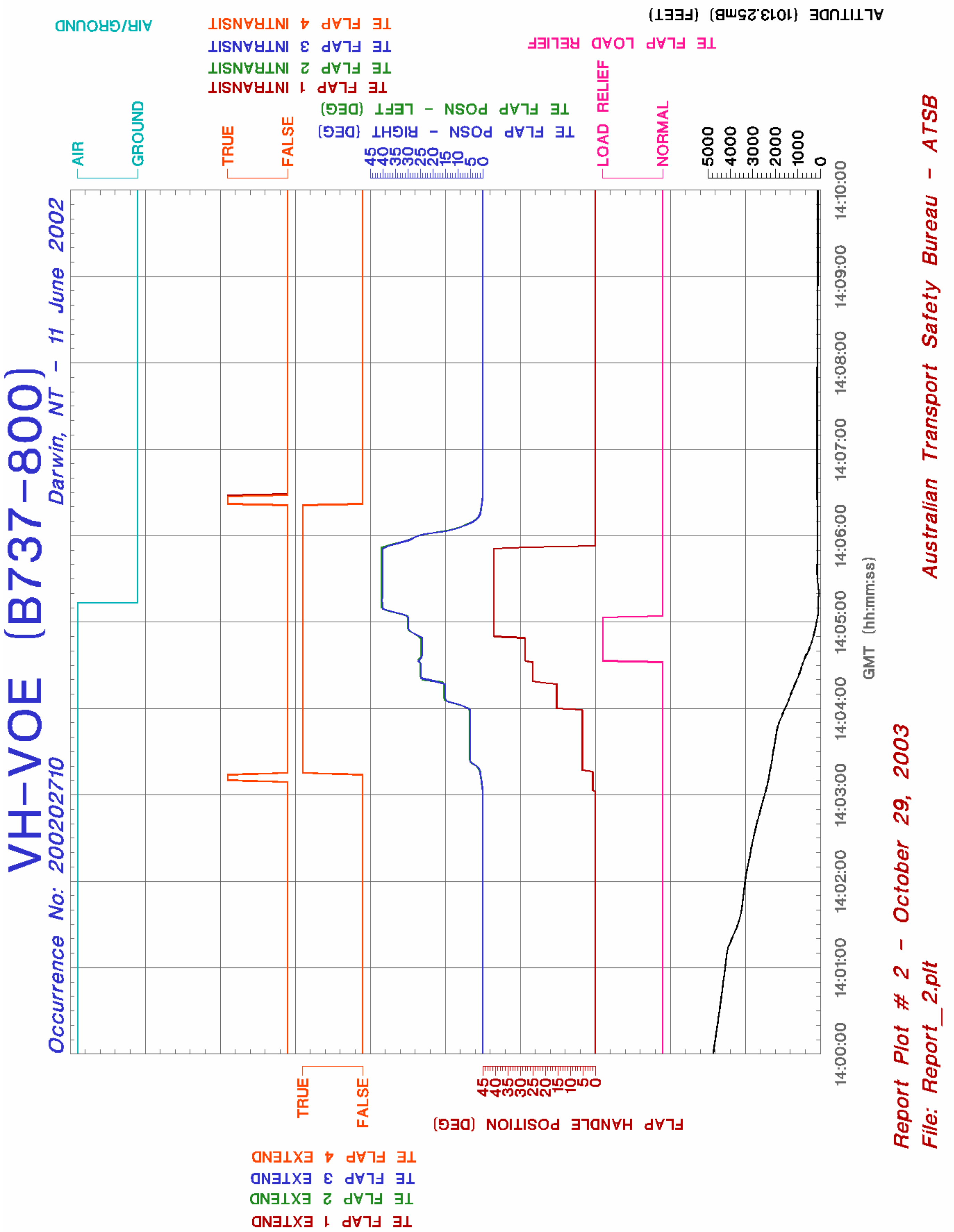
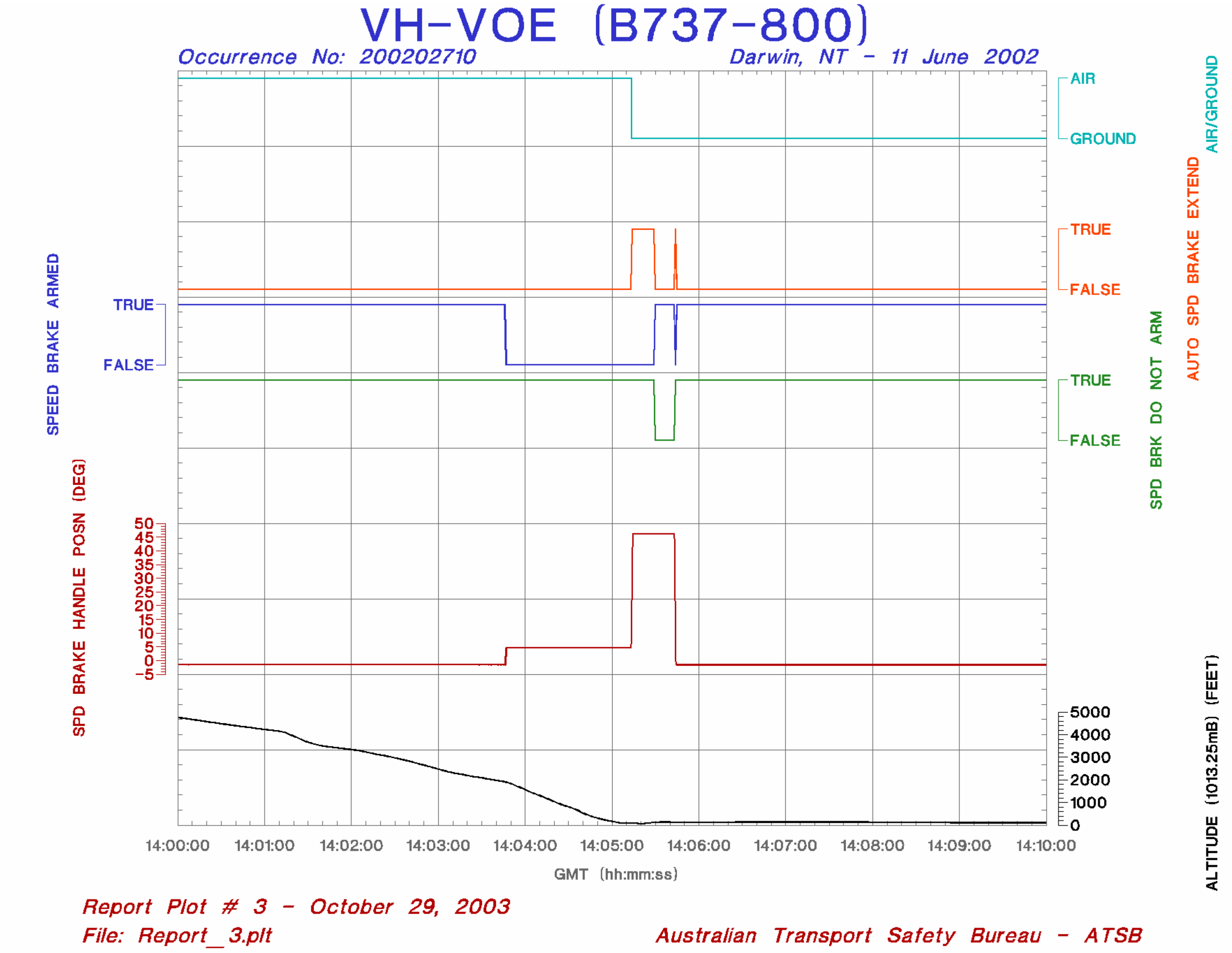
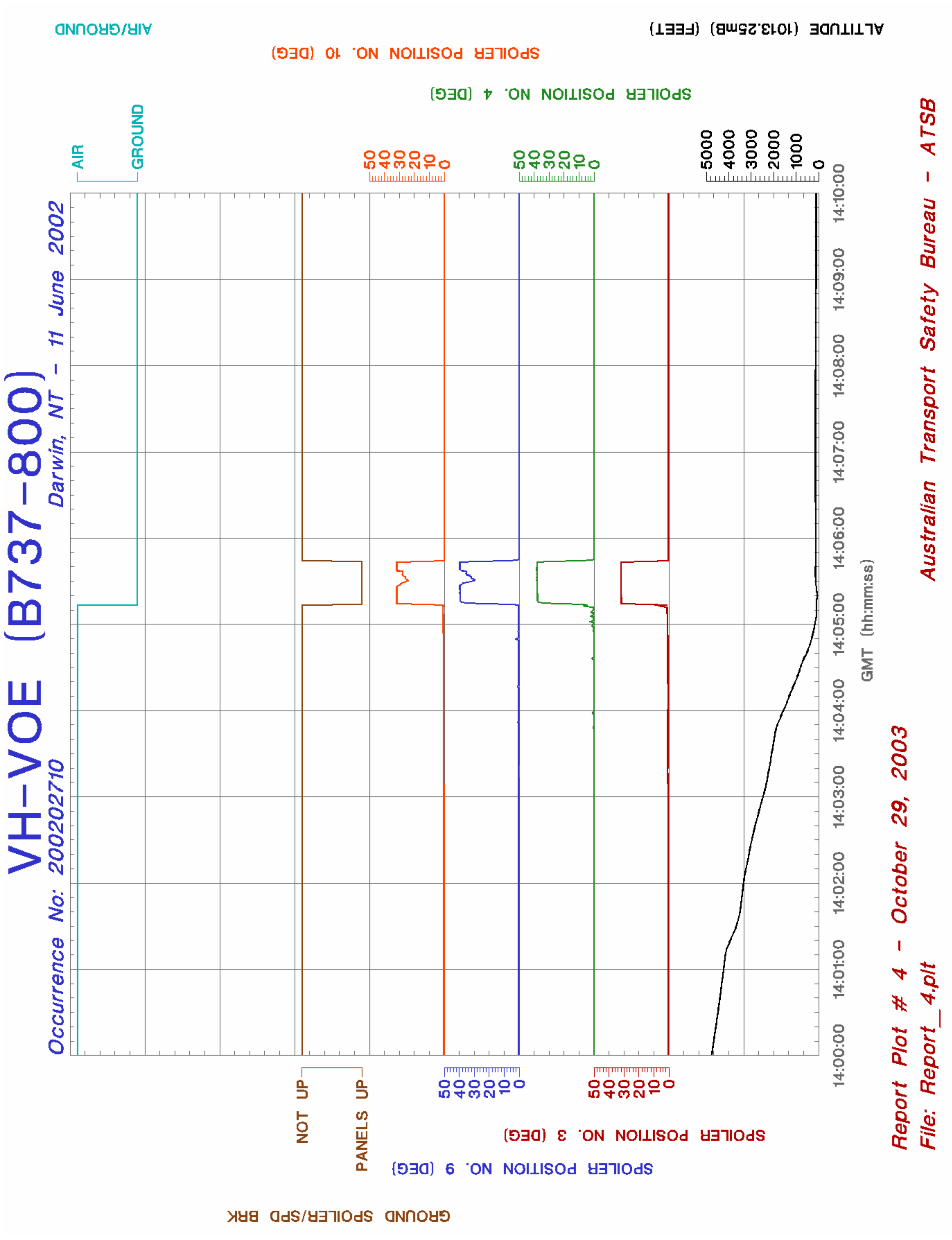
File: Report_1.plt
Australian Transport Safety Bureau - ATSB

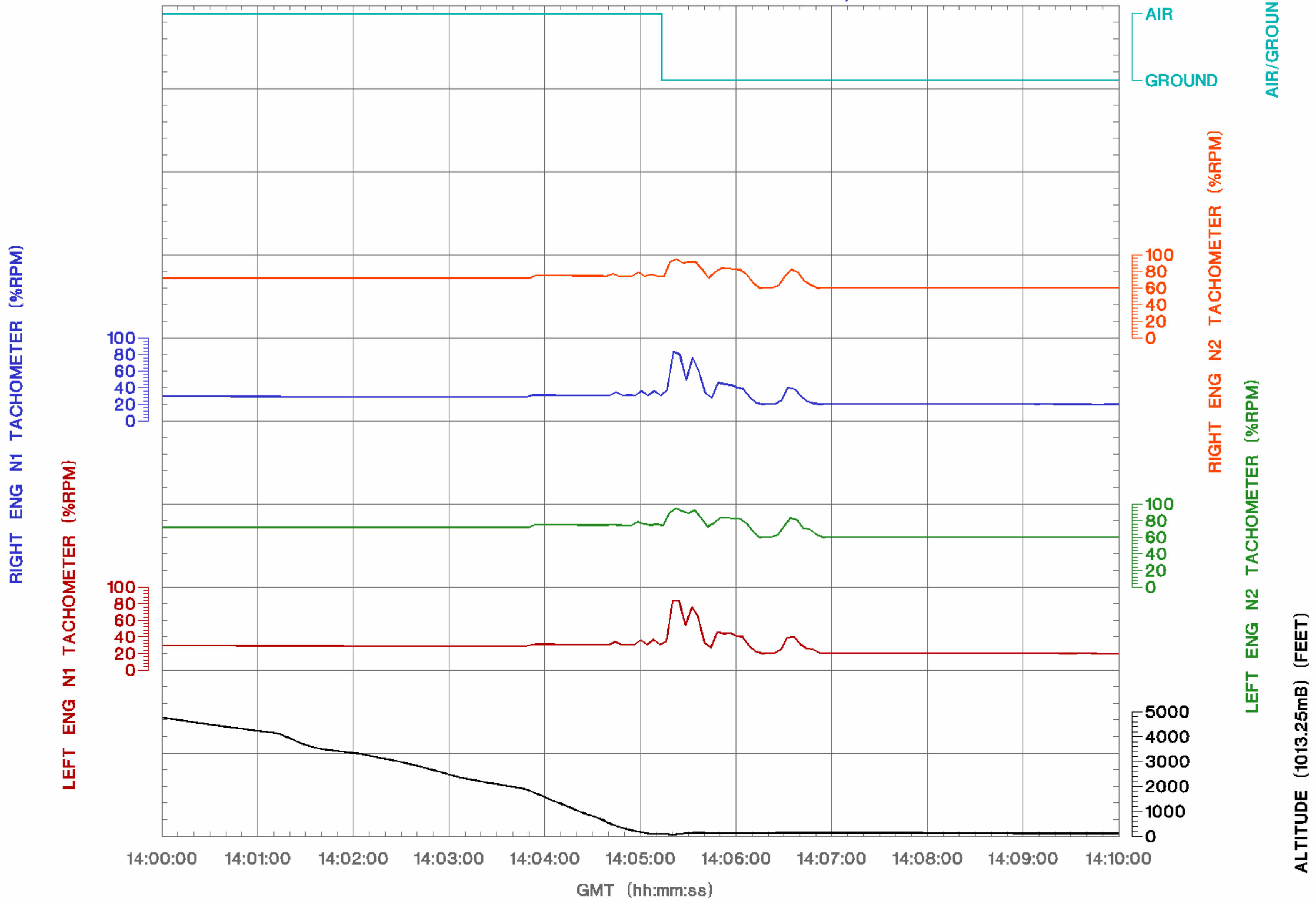

VH-VOE (B737-800)
Occurrence No: 200202710
Darwin, NT - 11 June 2002
AIR/GROUND
AIR
GROUND
TE FLAP 1 INTRANSIT
TE FLAP 2 INTRANSIT
TE FLAP 3 INTRANSIT
TE FLAP 4 INTRANSIT
TRUE
FALSE
TE FLAP 1 EXTEND
TE FLAP 2 EXTEND
TE FLAP 3 EXTEND
TE FLAP 4 EXTEND
TE FLAP POSN - LEFT (DEG)
TE FLAP POSN - RIGHT (DEG)
FLAP HANDLE POSITION (DEG)
TE FLAP LOAD RELIEF
LOAD RELIEF
NORMAL
ALTITUDE (1013.25mB) (FEET)
5000
4000
3000
2000
1000
0
14:00:00
14:01:00
14:02:00
14:03:00
14:04:00
14:05:00
14:06:00
14:07:00
14:08:00
14:09:00
14:10:00
GMT (hh:mm:ss)
Report Plot # 2 - October 29, 2003
File: Report_2.plt
Australian Transport Safety Bureau - ATSB


VH-VOE (B737-800)
Occurrence No: 200202710
Darwin, NT - 11 June 2002
AIR
GROUND
AIR/GROUND
TRUE
FALSE
AUTO SPD BRAKE EXTEND
SPEED BRAKE ARMED
TRUE
FALSE
TRUE
FALSE
SPD BRK DO NOT ARM
SPD BRAKE HANDLE POSN (DEG)
50 45 40 35 30 25 20 15 10 5 0 -5
5000 4000 3000 2000 1000 0
ALTITUDE (1013.25mB) (FEET)
14:00:00 14:01:00 14:02:00 14:03:00 14:04:00 14:05:00 14:06:00 14:07:00 14:08:00 14:09:00 14:10:00
GMT (hh:mm:ss)
Report Plot # 3 - October 29, 2003
File: Report_3.plt
Australian Transport Safety Bureau - ATSB


VH-VOE (B737-800)
Occurrence No: 200202710 Darwin, NT - 11 June 2002
AIR/GROUND
AIR
GROUND
SPOILER POSITION NO. 10 (DEG)
SPOILER POSITION NO. 4 (DEG)
ALTITUDE (1013.25mB) (FEET)
5000 4000 3000 2000 1000 0
50 40 30 20 10 0
GROUND SPOILER/SPD BRK
NOT UP
PANELS UP
SPOILER POSITION NO. 9 (DEG)
SPOILER POSITION NO. 3 (DEG)
14:00:00 14:01:00 14:02:00 14:03:00 14:04:00 14:05:00 14:06:00 14:07:00 14:08:00 14:09:00 14:10:00
GMT (hh:mm:ss)
Report Plot # 4 - October 29, 2003
File: Report_4.plt
Australian Transport Safety Bureau - ATSB

VH-VOE (B737-800)

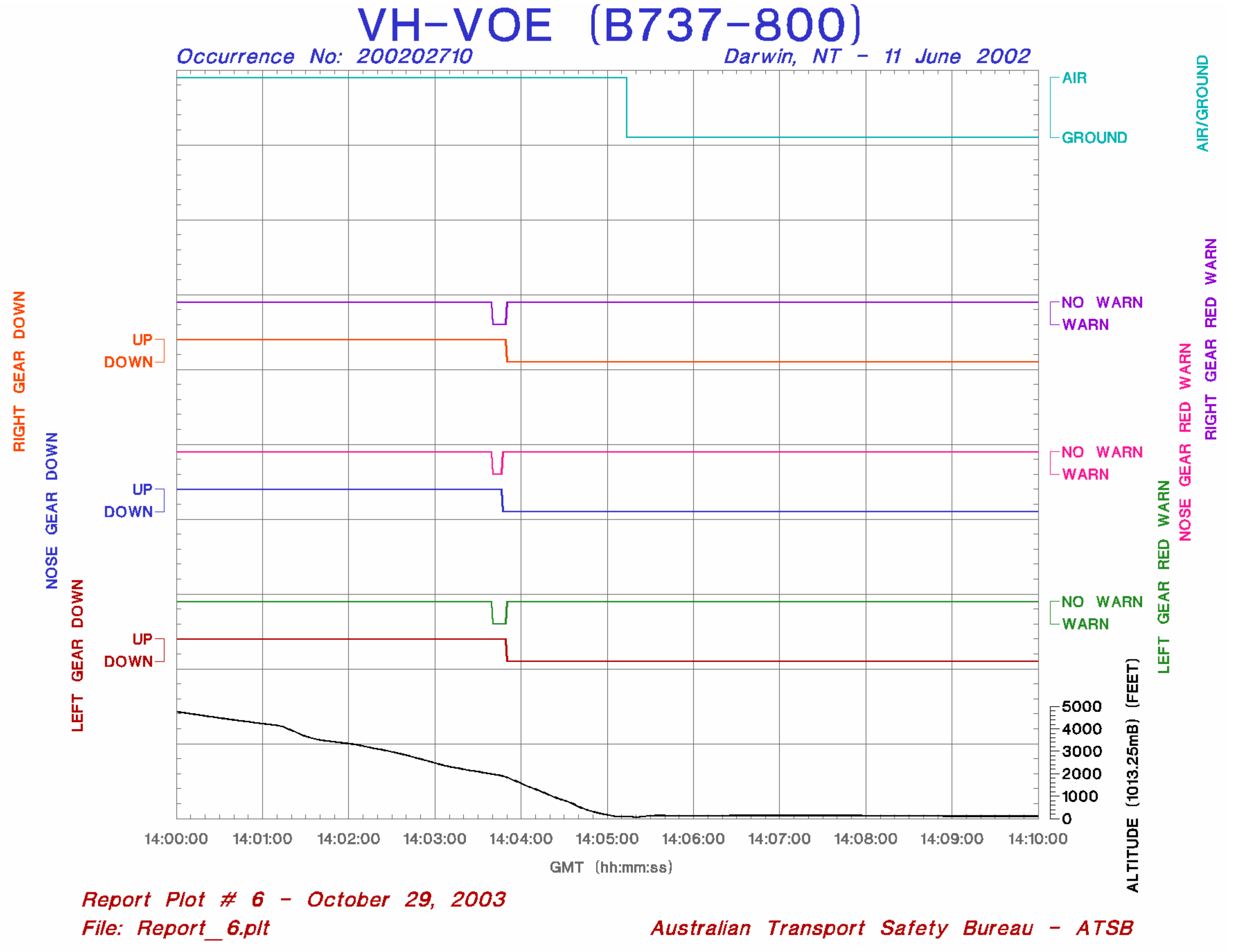
Occurrence No: 200202710 Darwin, NT - 11 June 2002

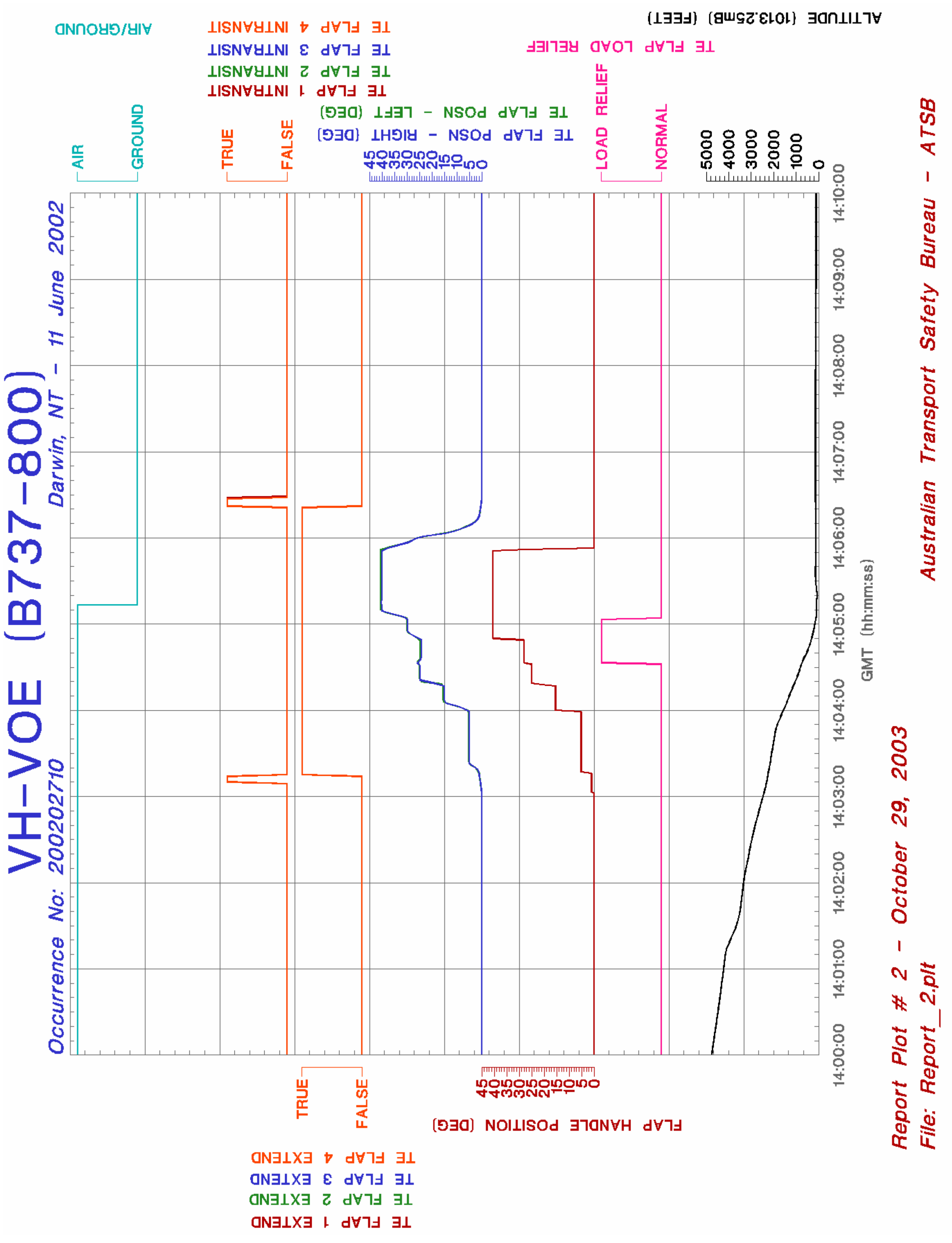


Report Plot # 5 - October 29, 2003

File: Report_5.plt

Australian Transport Safety Bureau - ATSB


VH-VOE (B737-800)
Occurrence No: 200202710
Darwin, NT - 11 June 2002
AIR
GROUND
AIR/GROUND
NO WARN
WARN
RIGHT GEAR RED WARN
UP
DOWN
RIGHT GEAR DOWN
NO WARN
WARN
NOSE GEAR RED WARN
UP
DOWN
NOSE GEAR DOWN
NO WARN
WARN
LEFT GEAR RED WARN
UP
DOWN
LEFT GEAR DOWN
5000
4000
3000
2000
1000
0
ALTITUDE (1013.25mB) (FEET)
14:00:00
14:01:00
14:02:00
14:03:00
14:04:00
14:05:00
14:06:00
14:07:00
14:08:00
14:09:00
14:10:00
GMT (hh:mm:ss)
Report Plot # 6 - October 29, 2003
File: Report_6.plt
Australian Transport Safety Bureau - ATSB



VH-VOE (B737-800)
Occurrence No: 200202710
Darwin, NT - 11 June 2002
AIR/GROUND
AIR
GROUND
TE FLAP 1 INTRANSIT
TE FLAP 2 INTRANSIT
TE FLAP 3 INTRANSIT
TE FLAP 4 INTRANSIT
TRUE
FALSE
TE FLAP POSN - LEFT (DEG)
TE FLAP POSN - RIGHT (DEG)
TE FLAP LOAD RELIEF
LOAD RELIEF
NORMAL
ALTITUDE (1013.25mB) (FEET)
TE FLAP 1 EXTEND
TE FLAP 2 EXTEND
TE FLAP 3 EXTEND
TE FLAP 4 EXTEND
FLAP HANDLE POSITION (DEG)
GMT (hh:mm:ss)
14:00:00
14:01:00
14:02:00
14:03:00
14:04:00
14:05:00
14:06:00
14:07:00
14:08:00
14:09:00
14:10:00
Report Plot # 2 - October 29, 2003
File: Report_2.plt
Australian Transport Safety Bureau - ATSB

ATSB **Aviation Safety Investigation Report 200202710 - Runway overrun at Darwin International Airport**

ISBN 1 877071 57 9

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