Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Aviation Occurrence Report 200501977
Final

Collision with Terrain
11 km NW Lockhart River Aerodrome
7 May 2005
VH-TFU
SA227-DC (Metro 23)

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CONTENTS

The report also consists of the following appendices, which are referenced in the report.

Appendix A:	Flight Data Recorder Technical Analysis Report
Appendix B:	Cockpit Voice Recorder Technical Analysis Report
Appendix C:	Extract from Honeywell GPWS MK VI Warning System Pilot’s Guide
Appendix D:	Estimated aircraft weight and balance
Appendix E:	Transcript of radio transmissions from VH-TFU
Appendix F:	Honeywell GPWS MK VI Simulation
Appendix G:	Extracts from Transair’s operations manual – GPS Non precision approach, descent and GPWS procedures
Appendix H:	Summary of CASA oversight of Transair from 1998 to 7 May 2005
Appendix I:	Joint Aviation Authorities non-technical skills
Appendix J:	Summary of significant CFIT descent approach and landing accidents in Australia
Appendix K:	Flight Safety Foundation CFIT Checklist
Appendix L:	Flight Safety Foundation ALAR Toolkit, Standard Operating Procedures Template
Appendix M:	Media Release

DOCUMENT RETRIEVAL INFORMATION

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Abstract

On 7 May 2005, a Fairchild Aircraft Inc. SA227-DC Metro 23 aircraft, registered VH-TFU, with two pilots and 13 passengers, was being operated by Transair on an instrument flight rules regular public transport service from Bamaga to Cairns, with an intermediate stop at Lockhart River, Queensland. At 1143:39 Eastern Standard Time, the aircraft impacted terrain in the Iron Range National Park on the north-western slope of South Pap, a heavily timbered ridge, approximately 11 km north-west of the Lockhart River aerodrome. At the time of the accident, the crew was conducting an area navigation global navigation satellite system (RNAV (GNSS)) non-precision approach to runway 12. The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were no survivors.

The accident was almost certainly the result of controlled flight into terrain, that is, an airworthy aircraft under the control of the flight crew was flown unintentionally into terrain, probably with no prior awareness by the crew of the aircraft's proximity to terrain. The investigation report identifies a range of contributing and other safety factors relating to the crew of the aircraft, Transair's processes, regulatory oversight of Transair by the Civil Aviation Safety Authority, and RNAV (GNSS) approach design and chart presentation. It also details safety action taken by various agencies to address the identified safety issues, and includes safety recommendations relating to those safety issues that had not been addressed by relevant agencies at the time of publication of this report.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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Executive Summary

Sequence of events

On 7 May 2005, a Fairchild Aircraft Inc. SA227-DC Metro 23 aircraft, registered VH-TFU, with two pilots and 13 passengers, was being operated by Transair on an instrument flight rules (IFR) regular public transport (RPT) service from Bamaga to Cairns, with an intermediate stop at Lockhart River, Queensland. At 1143:39 Eastern Standard Time, the aircraft impacted terrain in the Iron Range National Park on the north-western slope of South Pap, a heavily timbered ridge, approximately 11 km north-west of the Lockhart River aerodrome.

At the time of the accident, the crew was conducting an area navigation global navigation satellite system (RNAV (GNSS)) non-precision approach to runway 12. The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were no survivors.

The accident was almost certainly the result of controlled flight into terrain; that is, an airworthy aircraft under the control of the flight crew was flown unintentionally into terrain, probably with no prior awareness by the crew of the aircraft's proximity to terrain.

Weather conditions in the Lockhart River area were poor and necessitated the conduct of an instrument approach procedure for an intended landing at the aerodrome. The cloud base was probably between 500 ft and 1,000 ft above mean sea level and the terrain to the west of the aerodrome, beneath the runway 12 RNAV (GNSS) approach, was probably obscured by cloud.

The flight data recorder (FDR) data showed that, during the entire descent and approach, the aircraft engine and flight control system parameters were normal and that the crew were accurately navigating the aircraft along the instrument approach track. The FDR data and wreckage examination showed that the aircraft was configured for the approach, with the landing gear down and flaps extended to the half position. There were no radio broadcasts made by the crew on the air traffic services frequencies or the Lockhart River common traffic advisory frequency indicating that there was a problem with the aircraft or crew.

Crew performance

As the copilot was making the radio broadcasts during the approach, it is very likely that the 40-year old pilot in command was the handling pilot. The pilot in command was Transair's base manager at Cairns and an experienced Metro pilot. However, given the relatively complex type of approach being flown, he would have been reliant on the relatively inexperienced 21-year old copilot to assist with the high cockpit workload. There was a significant potential for crew resource management problems within the crew in high workload situations, given that there was a high trans-cockpit authority gradient and neither pilot had previously demonstrated a high level of crew resource management skills.

The crew commenced the Lockhart River Runway 12 RNAV (GNSS) approach, even though the crew were aware that the copilot did not have the appropriate endorsement and had limited experience to conduct this type of instrument approach. A non-directional beacon approach was also available at Lockhart River, and both pilots were endorsed for that approach. Despite the weather and copilot inexperience, the pilot in command used descent and approach speeds and a rate of descent greater than specified for the aircraft in the *Transair Operations Manual*, and exceeding those appropriate for establishing a stabilised approach.

During the approach, the aircraft descended below the segment minimum safe altitude for the aircraft's position on the approach. The aircraft's high rate of descent, and the descent below the segment minimum safe altitude, were not detected and/or corrected by the crew before the aircraft collided with terrain.

While the investigation was complicated by an inoperative cockpit voice recorder, no witnesses, and the extent of destruction of the aircraft, it determined that the crew probably experienced a very high workload during the approach and probably lost situational awareness about the aircraft's position along the approach path.

The pilots' aircraft endorsements, clearance to line operations, and route checks did not meet all the relevant regulatory and operations manual requirements to conduct RPT flights on the Metro aircraft. However, these limitations were not considered to have had an influence on the conduct of the flight.

Ground proximity warning system

There was no evidence that the ground proximity warning system (GPWS) was not functioning as designed. Simulation by the GPWS manufacturer indicated that the crew should have received a one second 'terrain terrain' alert about 25 seconds prior to impact, followed by a second 'terrain terrain' alert and a continuous 'pull up' warning for the final 5 seconds of flight. However, research has shown that the alerts and warnings in the final 5 seconds of flight would not have been sufficient for the crew and aircraft to effectively respond to the GPWS annunciations.

A terrain awareness and warning system (TAWS, commonly referred to as enhanced GPWS) provided advantages over standard GPWS. It enhanced pilot situational awareness by providing coloured terrain information on a continuous terrain display in the cockpit and providing more timely alerts and warnings. Had the aircraft been fitted with a TAWS, it is probable that the accident would not have occurred.

Transair processes

In addition to the substantive crew actions and local conditions that contributed to the accident, the investigation identified a number of safety factors relating to Transair that contributed to the accident. In particular, the flight crew training program had significant limitations, such as superficial or incomplete ground-based instruction during endorsement training, no formal training for new pilots in the operational use of global positioning system (GPS) equipment, no structured training on minimising the risk of controlled flight into terrain, and no structured training in crew resource management (or human factors management) and operating effectively in a multi-crew environment.

Transair's processes for supervising the standard of flight operations at the Cairns base had significant limitations, such as not using an independent approved check pilot to review operations, reliance on passive measures to detect problems, and no defined processes for selecting and monitoring the performance of the base manager. In addition, Transair's standard operating procedures for conducting instrument approaches had significant limitations, such as not providing clear guidance on approach speeds, not providing guidance for when to select aircraft configuration changes during an approach, no clear criteria for a stabilised approach, and no standardised phraseology for challenging safety-critical decisions and actions by other crew members.

Transair's organisational structure, and the limited responsibilities given to non-management personnel, resulted in high work demands on the Transair chief pilot. This resulted in a lack of independent evaluation of training and checking, and created disincentives and restricted opportunities within Transair to report safety concerns with management decision making. There was no structured process within Transair for proactively managing safety-related risk associated with its flight operations. Furthermore, the chief pilot did not demonstrate a high level of commitment to safety and appeared to be over-committed, with additional roles as chief executive officer/managing director of the company, the primary check and training pilot, and working regularly in Papua New Guinea for an associated company.

In addition, limitations were also identified with Transair's flight crew proficiency checking program and the useability of the *Transair Operations Manual*. However, these issues were not considered to be contributing safety factors to the accident.

Regulatory oversight

The investigation also identified contributing safety factors relating to the regulatory oversight of Transair by the Civil Aviation Safety Authority (CASA). In particular, CASA did not provide sufficient guidance to its inspectors to enable them to effectively and consistently evaluate several key aspects of operators' management systems. These aspects included evaluating organisational structure and staff resources, evaluating the suitability of key personnel, evaluating organisational change, and evaluating risk management processes. CASA also did not require operators to conduct structured and/or comprehensive risk assessments, or conduct such assessments itself, when evaluating applications for the initial issue or subsequent variation of an Air Operator's Certificate.

In addition, CASA's oversight of Transair, in relation to the approval of Air Operator's Certificate variations and the conduct of surveillance, was sometimes inconsistent with CASA's policies, procedures and guidelines. However, this was not considered to have been a contributing safety factor.

Other safety factors

The investigation also identified a range of other safety factors which did not meet the definition of a contributing safety factor or which could not be as clearly linked to the accident because of lack of evidence, but which were still considered to be important to communicate in an investigation report with a focus on future safety. In addition to some aspects of Transair's processes and regulatory oversight activities, these safety factors related, among other things, to the possibility of poor intra-cockpit communication, instrument approach design, instrument approach chart presentation, and regulatory requirements.

The Australian convention for waypoint names in RNAV (GNSS) approaches did not maximise the ability to discriminate between waypoint names on the aircraft GPS display and/or on the instrument approach chart. In addition, there were several design aspects of the Jeppesen RNAV (GNSS) approach charts, which were very likely to have been used by the crew, that could lead to pilot confusion or a reduction in situational awareness. These included limited reference regarding the 'distance to run' to the missed approach point, mismatches in the vertical alignment of the plan-view and profile-view on charts such as that for the Lockhart River runway 12 approach, use of the same font size and type for waypoint names and altitude limiting steps, and not depicting the offset in degrees between the final approach track and the runway centreline. There were also limitations in the terrain information provided on Jeppesen instrument approach charts.

CASA's process for accepting an instrument approach did not involve a systematic risk assessment of pilot workload and other potential hazards and warnings, including activation of a GPWS. There was also no regulatory requirement for instrument approach charts (including the Lockhart River Runway 12 RNAV (GNSS) approach chart) to include coloured contours to depict terrain as required by the International Civil Aviation Organization (ICAO) Annex 4, to which Australia had not notified a difference.

Although CASA released discussion papers in 2000, and further development had occurred since then, there was no regulatory requirement for initial or recurrent crew resource management (CRM) training or for RPT operators to have a safety management system. In addition, there was no regulatory requirement for flight crew undergoing a type rating on a multi-crew aircraft to be trained in procedures for crew incapacitation and crew coordination including allocation of pilot tasks, crew cooperation and use of checklists. This was required by ICAO Annex 1, to which Australia had notified a difference.

The investigation also determined that CASA's guidance material provided to operators about the structure and content of an operations manual was not as comprehensive as that provided by ICAO in areas such as multi-crew procedures and stabilised approach criteria, and that its process for evaluating the content of an operations manual did not consider the useability of the manual, particularly in electronic format. There was also no regulatory requirement for multi-crew RPT aircraft to be fitted with a serviceable autopilot.

Safety action

This investigation identified important learning opportunities for pilots, operators and regulatory agencies to improve future aviation safety and to seek to ensure such an accident never happens again. During the course of the investigation, the ATSB issued 10 safety recommendations and encouraged other safety action.

Safety action has been taken by several organisations to address the safety issues identified during this investigation. A number of additional safety recommendations were issued by the ATSB, including seven recommendations to the Civil Aviation Safety Authority on its regulatory oversight activities and regulatory requirements. Recommendations on aspects of instrument approach charts were also issued to Airservices Australia and Jeppesen Sanderson Inc.

The ATSB did not issue recommendations regarding the serious safety issues of the operator because Transair had surrendered its Air Operator's Certificate on 4 December 2006 and ceased to operate.

How this report is organised

This report was prepared in accordance with the International Civil Aviation Organization (ICAO)[1] publication *International Standards and Recommended Practices, Annex 13 to the Convention on International Civil Aviation, Aircraft Accident and Incident Investigation*, Ninth Edition, July 2001, incorporating all amendments adopted by the council prior to 23 November 2006, and with Australian Transport Safety Bureau (ATSB) procedures for investigation reports.

In keeping with these procedures, the report is organised into the following main parts:

Part 1: Factual Information – Provides objective information that is pertinent to the understanding of the circumstances surrounding the occurrence.

Part 2: Analysis – Discusses and evaluates the factual information presented in Part 1 that the ATSB considered when formulating its conclusions and safety actions.

Part 3: Findings – Based on the analyses of the factual information, presents three categories of findings: contributing safety factors, other safety factors, and other key findings.

Part 4: Safety Action – Based on the findings of the investigation, records the main local actions already taken or being taken by the stakeholders involved and recommends safety actions required to be taken to eliminate or mitigate safety deficiencies.

1 The International Civil Aviation Organization (ICAO) is a specialised agency of the United Nations, which was established by the Convention on International Civil Aviation (Chicago 1944), commonly referred to as the Chicago Convention. Australia is a signatory to the Chicago Convention. Under the Convention, ICAO can issue standards and recommended practices for aviation activities through what are termed Annexes to the Chicago Convention.

Terminology used in ATSB investigation reports

Occurrence: accident or incident.

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

Contributing safety factor: a safety factor that, if it had not occurred or existed at the relevant time, then either:

- the occurrence would probably not have occurred;
- the adverse consequences associated with the occurrence would probably not have occurred or have been as serious; or
- another contributing safety factor would probably not have occurred or existed.[2]

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

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

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

Safety issues are sometimes termed 'safety deficiencies'. ICAO has stated that:

> During aircraft accident investigations, safety issues are often identified which did not contribute to the accident but which, nevertheless, are safety deficiencies. These safety deficiencies should be addressed in the Final Report.[3]

2 Research has shown that the terms 'probable' and 'likely' are generally considered equivalent. The Intergovernmental Panel on Climate Change (established by the World Meteorological Organization and the United Nations Environment Programme) has defined 'likely' as meaning a probability of more than 66 per cent, and 'very likely' as more than 90 per cent.

3 ICAO *Manual of Aircraft Accident and Incident Investigation* - Part 4 Reporting, Doc 9756, First Edition 2000. The purpose of this manual is to encourage the uniform application of the Standards and Recommended Practices contained in ICAO Annex 13 and to provide information and guidance to States on the procedures, practices and techniques that can be used in aircraft accident investigations.

ABBREVIATIONS

AAL	Above Aerodrome Level
ABAS	Aircraft-Based Augmentation System
ADF	Automatic Direction-Finder
AGL	Above Ground Level
AIP	Aeronautical Information Publication
ALAR	Approach-and-Landing Accident Reduction
ALT	Altimeter
AMSL	Above Mean Sea Level
ANAO	Australian National Audit Office
AO	Audit Observations
AOC	Air Operator Certificate
APV	Approach Procedure with Vertical guidance
ASI	Airspeed Indicator
ASR	Aircraft Survey Report
ASSP	Aviation Safety Surveillance Program
ASTRA	Australian Strategic Air Traffic Management Group
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATOS	Air Transportation Oversight System
ATPL	Air Transport Pilot Licence
ATSB	Australian Transport Safety Bureau
AWIS	Aerodrome Weather Information Service
AWS	Automatic Weather Station
BoM	Bureau of Meteorology
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CAA	Civil Aviation Authority (United Kingdom)
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CAR	Civil Aviation Regulation
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulation
CDI	Course Deviation Indicator
CD-ROM	Compact Disc - Read Only Memory
CFIT	Controlled Flight Into Terrain
CMI	Compliance Management Instruction
CPL	Commercial Pilot Licence
CRM	Crew Resource Management

CROS	CASA Regulatory Oversight System
CTAF	Common Traffic Advisory Frequency
CVR	Cockpit Voice Recorder
DH	Decision Height
DME	Distance Measuring Equipment
DOP	Dilution of Precision
EGPWS	Enhanced Ground Proximity Warning System (a proprietary name for a TAWS)
ERSA	En-Route Supplement Australia
FAA	Federal Aviation Administration (United States)
FAF	Final Approach Fix
FAR	Federal Aviation Regulations (United States)
FDR	Flight Data Recorder
FL	Flight Level
FMS	Flight Management System
FP	Flying Pilot (handling pilot)
ft	Feet
ft/min	Feet per minute
GBAS	Ground-Based Augmentation System
GIT	GNSS Implementation Team
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GPS/NPA	Global Positioning System based Non-Precision Approach (RNAV (GNSS) approach)
GPWS	Ground Proximity Warning System
HDOP	Horizontal Dilution Of Precision
HFM	Human Factors Management
hPa	HectoPascal
HSI	Horizontal Situation Indicator
IAF	Initial Approach Fix
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
ICUS	In Command Under Supervision
IF	Intermediate Fix
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authorities (Europe)
JAR-OPS	Joint Aviation Regulation – Aircraft Operations (Europe)
kts	Knots
LHR	Lockhart River
LLZ	Localiser

LNAV	Lateral Navigation
LOFT	Line Orientated Flight Training
LSALT	Lowest Safe Altitude
MAPt	Missed Approach Point
mb	Millibar
MDA	Minimum Descent Altitude
MEL	Minimum Equipment List
MK	Mark
MSA	Minimum Safe Altitude
MTOW	Maximum Take-Off Weight
NASA-TLX	US National Aeronautics and Space Administration -Task Load Index
NAV	Ground-based VHF navigation
NCN	Non-Compliance Notice
NDB	Non-Directional radio Beacon
NFP	Non-Flying Pilot (non-handling pilot)
NM	Nautical Mile(s)
NOTAM	Notice To Airmen
NPA	Non-Precision Approach
OCTA	Outside Controlled Airspace
PANS-OPS	Procedures for Air Navigation Services – Aircraft Operations
PF	Pilot Flying (handling pilot)
PNF	Pilot Not Flying (non-handling pilot)
PNG	Papua New Guinea
PPL	Private Pilot Licence
QNH	Altimeter sub-scale setting to obtain elevation above mean sea level
RAAA	Regional Airlines Association of Australia
RAD ALT	Radio Altimeter
RAIM	Receiver Autonomous Integrity Monitoring
RCA	Request for Corrective Action
RDU	Receiver Display Unit
RMI	Radio Magnetic Indicator
RNAV (GNSS)	Area Navigation (Global Navigation Satellite System)
RPM	Revolutions Per Minute
RPT	Regular Public Transport
SBAS	Satellite-Based Augmentation Systems
SID	Standard Instrument Departure
SIL	Service Information Letter
SOP	Standard Operating Procedure
STAR	Standard Arrival
STC	Supplemental Type Certificate

STI	Safety Trend Indicator
TAF	Terminal Aerodrome Forecast
TAWS	Terrain Awareness and Warning System
TSO	Technical Standard Order
UTC	Coordinated Universal Time
V_A	Design manoeuvring speed
V_{AT}	Target threshold speed
VDOP	Vertical Dilution Of Precision
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
V_{MO}	Maximum operating speed
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Radio Range
V_{REF}	Reference landing speed
VSI	Vertical Speed Indicator

1 FACTUAL INFORMATION

1.1 History of the flight

On 7 May 2005, a Fairchild Aircraft Inc. SA227-DC Metro 23 aircraft, registered VH-TFU (Figure 1), with two pilots and 13 passengers, was being operated by Transair[4] on an instrument flight rules (IFR) regular public transport (RPT) service from Bamaga[5] to Cairns, with an intermediate stop at Lockhart River, Queensland. This service was operated as Aero-Tropics Air Services[6] flight HC675.

Figure 1: VH-TFU at Bamaga aerodrome on a previous flight

At 1143:39 Eastern Standard Time[7], the aircraft impacted terrain about 11 km north-west of the Lockhart River aerodrome. At the time of the accident, the crew was conducting an area navigation global navigation satellite system (RNAV (GNSS)) non-precision approach[8] to runway 12. It was very likely[2] that they were using Jeppesen Sanderson Inc. (Jeppesen) instrument approach charts (Figure 2). The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were no survivors.

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4 Transair was the trading name for Lessbrook Proprietary Limited, which was the company operating the aircraft and holding an Air Operator Certificate. 'Transair' will be used throughout this investigation report.

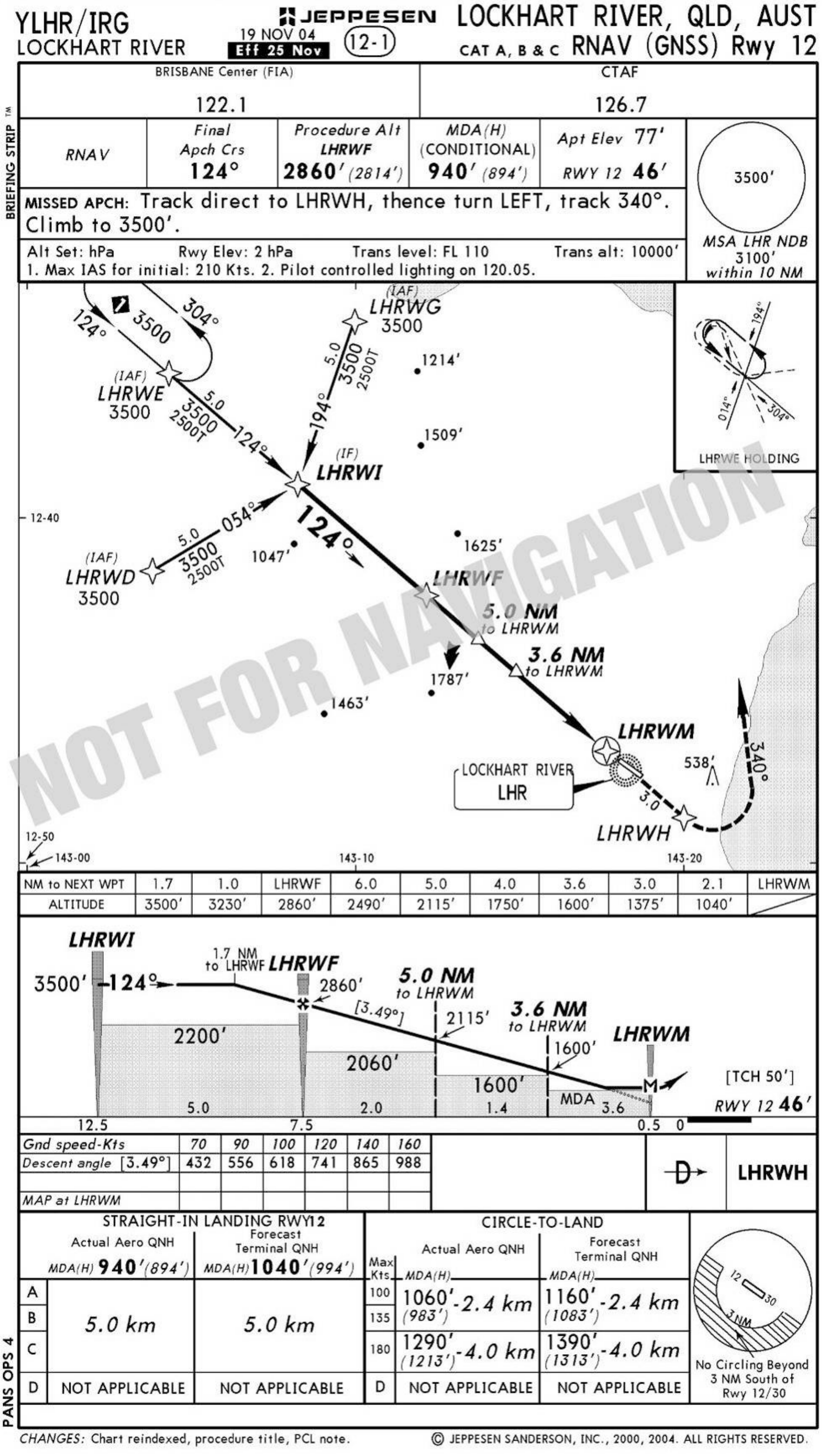
5 The full title of this aerodrome was Bamaga/Injinoo. 'Bamaga' will be used throughout this investigation report.

6 Aero-Tropics Air Services was the trading name of Lip-Air Proprietary Limited. 'Aero-Tropics' will be used throughout this investigation report. The commercial relationship between Aero-Tropics and Transair is discussed in Section 1.17.5.

7 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours. All radio broadcasts made by the pilots used UTC.

8 The term RNAV (GNSS) non-precision approach refers to an instrument approach, conducted with reference to information provided by the Global Navigation Satellite Systems. The equipment used for this type approach does not provide vertical path guidance. See Section 1.8 and 1.19.

Figure 2: Lockhart River Runway 12 RNAV (GNSS) approach chart



The pilot in command and copilot commenced duty in Cairns for the scheduled Cairns – Lockhart River – Bamaga – Lockhart River – Cairns flight. The published schedule for the flight showed that that the aircraft was due to depart Cairns at 0830 and was scheduled to arrive at Lockhart River at 0950 and then depart at 1010. It was then scheduled to arrive at Bamaga at 1045, and depart for Lockhart River at 1105. The aircraft was scheduled to arrive at Lockhart River at 1140. These published times referred to the departure and arrival time at the terminal, not the take-off or landing times. The times provided below for the northbound flight were for engine starts and shutdowns recorded on the aircraft's flight data recorder (FDR) (see Section 1.11.1 and Appendix A).

The aircraft departed Cairns at 0831 and, as the pilot in command was recorded as making the radio transmissions, it was very likely that the copilot was the handling pilot for the northbound flights.[9]

During the descent to Lockhart River on the northbound flight, the pilot in command broadcast on the common traffic advisory frequency (CTAF) the intention to perform a runway 30 RNAV (GNSS) approach into Lockhart River. Data from the FDR indicated that late in the approach, the crew appropriately manoeuvred the aircraft to land on runway 12. The engines were shutdown at 0950. The aircraft departed Lockhart River at 0958 and arrived at Bamaga at 1039.

The aircraft was refuelled at Bamaga for the return flight to Cairns via Lockhart River to collect two passengers (Figure 3).

The pilot in command commented to the ground agent prior to departing Bamaga that the weather was 'bad' at Lockhart River and it may not be possible to land there. The forecast conditions at the aerodrome included a broken[10] cloud base 1,000 ft above the aerodrome for periods of up to 60 minutes. The aircraft departed Bamaga at 1107 and, as the copilot was recorded as making the radio transmissions during flight, including during the approach[11], it was very likely that the pilot in command was the handling pilot for the accident flight.[12]

The following chronology of events leading up to the accident was constructed from data recovered from the FDR, recordings of radio communication between the crew and air traffic control (ATC), and broadcasts made by the crew on the Lockhart River CTAF. The FDR and radio communications were correlated using the time stamp on the ATC voice recording (see Section 1.11.1 and Appendix A). Conversations between the crew and other sounds in the cockpit during the last 30 minutes of the flight were not available due to a malfunction of the cockpit voice recorder (see Section 1.11.4 and Appendix B).

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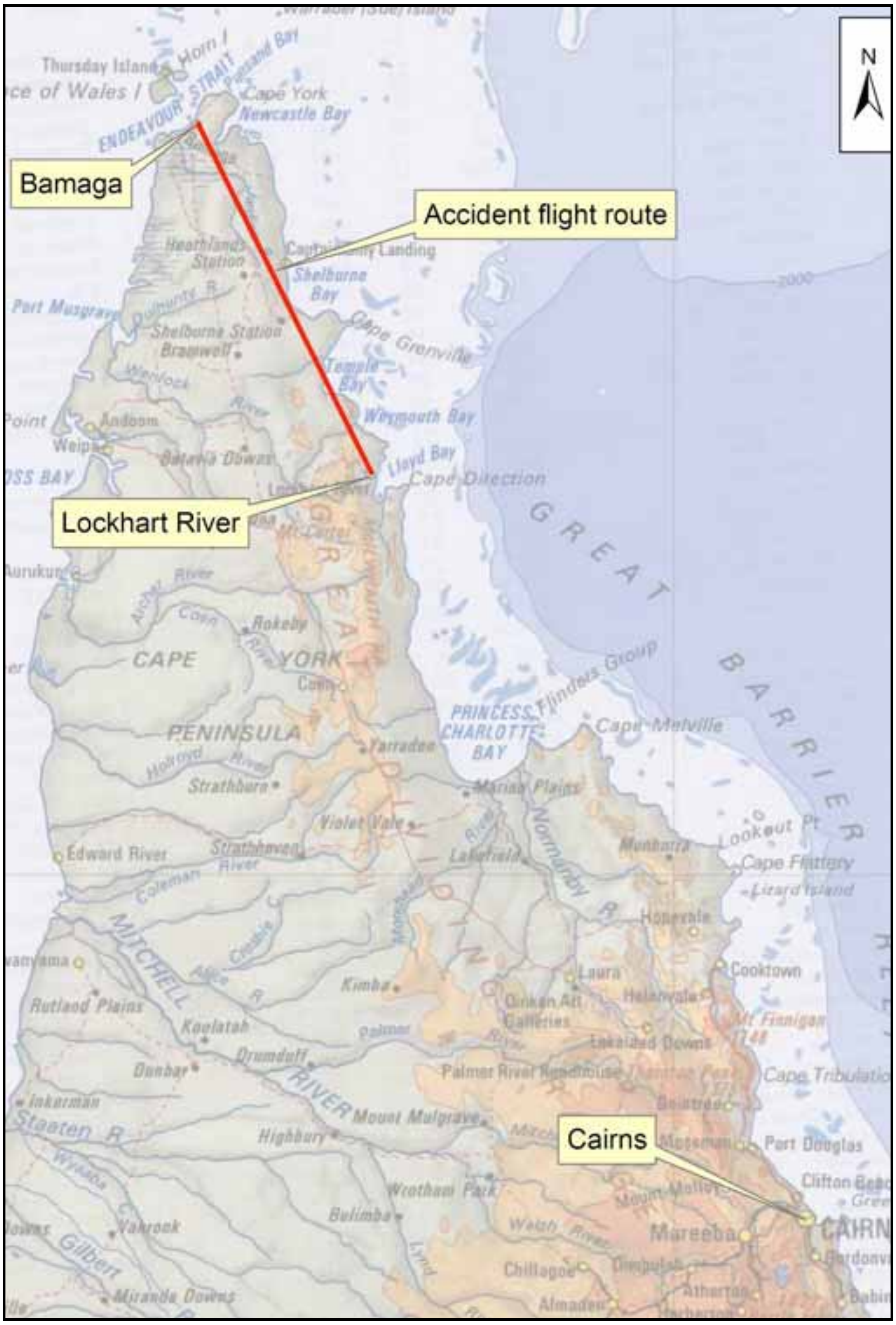
9 Transair pilots reported that the non-handling pilot was normally responsible for radio communications. This was consistent with procedures in the *Transair Operations Manual* and standard industry practice for multi-crew operations. Transair pilots also reported that when operating to Lockhart River and Bamaga, one pilot would be the handling pilot for all northbound sectors and the other pilot would be the handling pilot for all southbound sectors.

10 Broken referred to 5 to 7 eighths of the sky obscured by cloud.

11 The pilot in command made the initial radio transmissions while on the ground at Bamaga, however, once airborne the copilot was recorded as making the radio transmissions.

12 Regardless of who was the handling pilot, Civil Aviation Regulation 1988 (CAR) 224(2) stated that 'A pilot in command of an aircraft is responsible for ... the operation and safety of the aircraft during flight time'.

Figure 3: Accident flight route



Local time	Event	
1107:32	Aircraft engine start at Bamaga.	
1112:19	Aircraft took off from runway 13 at Bamaga.	
1114:33	The copilot advised Brisbane ATC that the aircraft had departed Bamaga at 1111 and it was on climb to flight level (FL[13]) 180 with an estimated time of arrival at Lockhart River at 1143. In response to a query from ATC regarding the proposed cruise level, the copilot advised that the level would be FL 170. ATC replied that there was no IFR traffic at that level.	
1124:36	In response to an ATC instruction, the copilot contacted Brisbane ATC on a different radio frequency.	
1128:32	Aircraft at top of climb at FL 170.	
1132:26	Aircraft commenced descent from FL 170.	
1133:06	The copilot advised Brisbane ATC that the aircraft had left FL 170 and requested traffic information. ATC provided traffic information on VH-PAR, an aircraft that was operating to the north of Lockhart River aerodrome.	
	Altitude: 16,130 ft[14]	Indicated airspeed (IAS): 226 kts[14]
1134:19	Brisbane ATC provided further information to the crew about the position of VH-PAR and advised that the area QNH[15] was 1011 hectoPascals (hPa).	
	Altitude: 13,440 ft	IAS: 248 kts
1135:48	The copilot advised Brisbane ATC that the aircraft was on descent, passing 10,000 ft above mean sea level (AMSL) with an estimated time of arrival at Lockhart River of 1138.	
	Altitude: 10,376 ft	IAS: 250 kts
1136:16	Aircraft about 30 NM (55.6 km) north-west of Lockhart River aerodrome.	
	Altitude: 9,450 ft	IAS: 249 kts
1136:18	The copilot broadcast the aircraft's altitude and estimated time of arrival of 1139 on the Lockhart River CTAF.	
	Altitude: 9,369 ft	IAS: 250 kts
1138:21	Aircraft descended through 5,000 ft.	
	Altitude: 4,978 ft	IAS: 247 kts
1139:30	Aircraft was about 1.2 NM abeam the LHRWG waypoint, which was an initial approach fix for the runway 12 RNAV (GNSS) approach (Figure 2). Aircraft briefly levelled and then began to climb, which may have been a manoeuvre to decelerate the aircraft.	
	Altitude: 3,505 ft	IAS: 229 kts

13 Flight level is a surface of constant atmospheric pressure related to a datum of 1013.25 hPa, expressed in hundreds of feet; thus FL 180 indicates 18,000 ft above that datum.

14 Pressure altitude data derived from the FDR was accurate to ±300 ft at 18,000 ft and ±100 ft below 3,000 ft. The calculated airspeed data was accurate to ±15 kts above 150 kts. See Appendix A for details.

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

Local time	Event	
1139:50	Aircraft at top of deceleration manoeuvre (see 1139:30).	
	Altitude: 3,992 ft	IAS: 195 kts
1139:56	Descent recommenced. The copilot broadcast on the CTAF that the crew was conducting the runway 12 RNAV (GNSS) approach, and that the aircraft was at the 'Whisky Golf' (LHRWG) waypoint and tracking for the 'Whisky India' (LHRWI) waypoint (Figure 4).	
	Altitude: 3,992 ft	IAS: 192 kts
1140:26	The copilot broadcast on the CTAF to the pilot of VH-PAR 'Papa alpha romeo go ahead'.	
	Altitude: 3,457 ft	IAS: 197 kts
1140:28	First stage (9 degrees) of flap selected.	
	Altitude: 3,513 ft	IAS: 197 kts
1140:33	Aircraft levelled. The copilot transmitted on the CTAF advising the pilot of VH-PAR that the weather conditions in the Lockhart River area were 'Ah fairly dismal really, [a]bout nine hundred foot clear… *[indistinct: clearance or clearing]'.*[16]	
	Altitude: 3,600 ft	IAS: 190 kts
1141:07	Aircraft over LHRWI waypoint.	
	Altitude: 3,596 ft	IAS: 176 kts
1141:11	Descent recommenced at 4.8 NM from the LHRWF waypoint. This was 3.1 NM before the descent point specified on the approach chart for the 3.49 degree constant angle approach path to the missed approach point (Figure 5).	
	Altitude: 3,588 ft	IAS: 179 kts
1141:52	Aircraft levelled.	
	Altitude: 2,998 ft	IAS: 188 kts
1142:19	Second stage (18 degrees) of flap selected.	
	Altitude: 3,039 ft	IAS: 180 kts
1142:29	Aircraft commenced descent 1.4 NM before the LHRWF waypoint. This was 0.3 NM (approximately 7 seconds) after the descent point specified for the constant angle approach path (Figure 5). Average rate of descent was 1,000 ft/min.	
	Altitude: 3,043 ft	IAS: 174 kts

16 This word was subjected to forensic speech analysis and the second syllable could not be positively identified. The word may have been 'clearance' or 'clearing' (see Section 1.16.1).

Figure 4: Approach track (in red) derived from FDR data overlayed on an extract of the Airservices Australia Runway 12 RNAV (GNSS) approach chart[17]

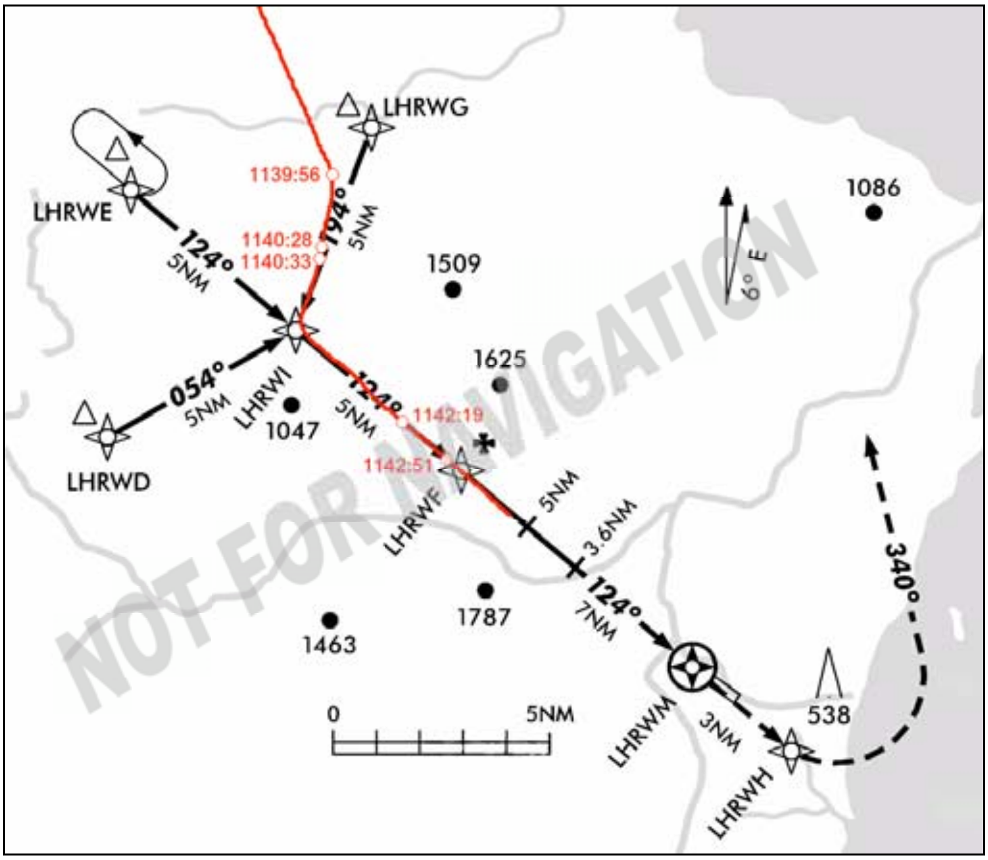
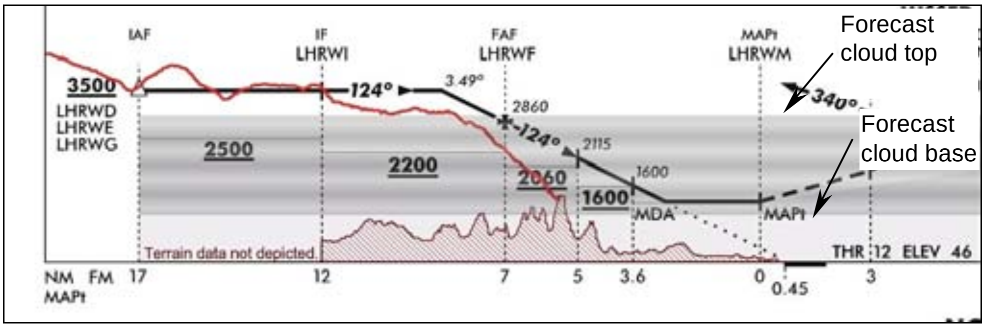


Figure 5: Approach profile (in red) derived from FDR data and terrain profile (in brown) overlayed on an extract of the Airservices Australia Runway 12 RNAV (GNSS) approach chart[17]



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17 The accident flight crew used Jeppesen Sanderson Inc approach charts (see Section 1.19.3). The Airservices Australia chart was used in Figure 4 and Figure 5 due to the profile diagram being in scale, vertically, and it included the segment from the initial approach fix (IAF) to the intermediate fix (IF).

Local time	Event
1142:51	Engine torque reduced from about 36 per cent to about 30 per cent. Average aircraft rate of descent increased to 1,700 ft/min and continued at about this rate for remainder of flight with increased turbulence evident during the final 25 seconds prior to the impact. Altitude: 2,648 ft IAS: 173 kts
1143:00	Aircraft over the LHRWF waypoint. Altitude: 2,379 ft IAS: 177 kts
1143:11	Aircraft descended through the segment minimum safe altitude of 2,060 ft. Altitude: 2,057 ft IAS: 177 kts
1143:38	Minimum altitude recorded on the FDR. Altitude: 1,292 ft IAS: 158 kts
1143:39	Aircraft 5.5 NM prior to LHRWM waypoint. End of recorded data.

At 1158, when the crew had not reported having landed at the Lockhart River aerodrome, ATC declared an uncertainty phase. When attempts to contact the crew were unsuccessful, a search for the aircraft was commenced. AusSAR[18] reported that there were no signals from an emergency locator transmitter received in the Lockhart River area at or about the time of the accident. At 1625, the burnt wreckage of the aircraft was located in the Iron Range National Park on the north-western slope of South Pap, a heavily timbered ridge, approximately 11 km north-west of the Lockhart River aerodrome (Figure 6).

Figure 6: Topographic map of Lockhart River area with accident site and RNAV(GNSS) approach waypoints

18 Australian Search and Rescue (AusSAR) was a business unit of the Australian Maritime Safety Authority. AusSAR coordinated the response to aviation search and rescue incidents.

The accident site was located on the published Lockhart River Runway 12 RNAV (GNSS) final approach track (Figure 4). The initial impact point with trees was at an elevation of 1,210 ft AMSL. At that point on the approach, the segment minimum safe altitude was 2,060 ft AMSL (Figure 5).

1.2 Injuries to persons

Injuries	Crew	Passengers	Other	Total
Fatal	2	13		15
Serious				
None				
Total	2	13		15

1.3 Damage to aircraft

The aircraft was destroyed by impact forces and an intense, fuel-fed, post-impact fire.

1.4 Other damage

The impact, spillage of fuel and post-impact fire caused damage to vegetation.

1.5 Personnel information

1.5.1 Pilot in command

Personal details	Male, 40 years of age
Type of licence	Airline transport pilot (aeroplane) licence
Total flying hours	6,071.8 hours
Total flying hours on Metro	3,248.5 hours
Total flying last 90 days	176.1 hours
Total flying last 30 days	69.0 hours
Total flying last 7 days	9.6 hours
Total flying hours multi-crew ops	3,248.5 hours
Last proficiency check	28 February 2005 (base check)
Medical certificate	Class 1 – valid to 18 January 2006 - nil restrictions

Prior experience

The pilot in command obtained a commercial pilot (aeroplane) licence on 26 May 1993 and an airline transport pilot (aeroplane) licence on 19 January 1998.

Before commencing his Metro endorsement, the pilot in command had 2,823.3 hours flying experience recorded in his logbook, including 1,210.6 hours on multi-engine aircraft. He had some experience in single-pilot RPT operations, but no previous turbine-engine aircraft experience, nor experience in multi-crew operations.

Transair endorsement and post-endorsement training

According to company documentation, the pilot in command commenced employment with Transair on 29 March 2001. His Metro 3 command endorsement flying was conducted by the Transair chief pilot over 2 days in January and February 2001. After completing the command endorsement flying, a *Command Metro 3* class endorsement[19] was entered into the pilot in command's logbook (see also Section 1.17.8). As noted in Section 1.17.8, there were several administrative problems with the endorsement process which meant that the endorsement did not meet regulatory requirements.

The pilot in command's logbook showed that he had flown for 12.2 hours as copilot and 50.2 hours in command under supervision after his endorsement flying, before he commenced to log command flight hours on the Metro aircraft. The supervised flying was conducted with a supervisory pilot.[20] Contrary to the requirements of the *Transair Operations Manual*, he was not checked by a check pilot prior to commencing line operations (see Section 1.17.8).

The *Transair Operations Manual* required that a competency certification had to be completed by a check pilot for each aerodrome and route to be flown and the competency forms be kept on the pilot's file. Examination of the pilot in command's pilot file revealed that there were no completed competency forms on file for any of the routes that Transair operated or aerodromes operated into. This included the Cairns – Lockhart River – Bamaga route and associated aerodromes.

There was no evidence on the pilot in command's pilot file of him ever having completed crew resource management training[21], even though the *Transair Operations Manual* required it to be completed within 6 months of induction and at 15 monthly intervals thereafter.[22] There was no record of the pilot in command completing a crew resource management course before joining Transair.

The pilot in command had acknowledged receipt of the *Transair Operations Manual* in CD-ROM form on 2 February 2004.

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19 Civil Aviation Order (CAO) 40.1.0 Appendix 1B defined a Metro 3 class endorsement as including the following aeroplanes – Fairchild SA227 (Merlin IIIC, Metro III and 23) (all models).

20 The *Transair Operations Manual* stated that supervisory pilots were responsible for the supervision of endorsed pilots acting in command. They were not approved to conduct flight proficiency checks. See Section 1.17.8 for further information.

21 Crew resource management training was referred to as 'human factors management training' in the *Transair Operations Manual.*

22 There were no specific regulatory requirements in Australia for operators to provide CRM training (see Section 1.20.7). However, by including a requirement for CRM training in the *Transair Operations Manual*, the provision of that training to Transair pilots was mandatory and subject to regulatory enforcement. CAR 215(9) stated that 'Each member of the operations personnel of an operator shall comply with all instructions contained in the operations manual in so far as they relate to his or her duties or activities'.

Line operations

The pilot in command's logbook showed that he commenced operations as a pilot in command of Metro aircraft on 27 March 2001. The majority of his flying with Transair was from the Cairns base and primarily involved RPT freight flights on the Cairns – Port Moresby – Cairns route and RPT passenger flights on the Cairns – Bamaga – Cairns route.

The pilot in command was promoted to the position of supervisory pilot in September 2002. In August 2003 he was made the base manager at Cairns. This position entailed the responsibility for administrative duties in addition to his flying duties (see also Sections 1.17.4 and 1.17.9).

Recency

The pilot in command's logbook showed that he had logged 8.4 hours flight time under instrument meteorological conditions (IMC) within the preceding 90 days. The logbook also showed that he had conducted three RNAV (GNSS) approaches within the preceding 90 days, and one NDB approach within the preceding 90 days.[23] All of these were conducted in VH-TFU.

Proficiency checks

The table below is a summary of the flight proficiency checks recorded in the pilot in command's pilot file and logbook. Consistent with the requirements of Civil Aviation Regulation (CAR) 217, the *Transair Operations Manual* required that the pilot in command undergo two proficiency checks each year (see Section 1.17.8). The *Transair Operations Manual* stated that each 'flight check' was to consist of a 'proficiency base check' and a 'proficiency line check'. A check pilot was required to conduct each type of check. A Civil Aviation Order (CAO) 20.11 emergency procedures test was also required each year.

All the flight proficiency base checks were conducted by the Transair chief pilot except for the check on 3 January 2003, which was conducted by a contractor check pilot. The contractor check pilot commented in the 'overall assessment' section on the check form that the pilot in command '… has shown a commonsense approach to his flying. Scan rate poor at times. Systems knowledge poor'. No other evaluative comments were included in the overall assessment section on any other base check forms. The only evaluative comment against a specific item on a base check form was 'slow on turns' against the item for a RNAV (GNSS) approach (see below). There were also very few qualitative comments on the pilot in command's line check forms.[24] On one line check form, the chief pilot had noted 'taxied on the fast side'. On another line check form a supervisory pilot had noted 'flown [aircraft] well'.

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23 CAO 40.2.1 stated that before conducting an RNAV (GNSS) instrument approach in instrument meteorological conditions (IMC), a pilot was required to have conducted three such approaches in flight or a synthetic flight trainer using the same type of GPS receiver.

24 An examination of check forms on other Transair pilot files noted that there were very few qualitative comments regarding pilot skill and knowledge levels.

Date	Check
2 February 2001	Flight proficiency base check
26 April 2001	Flight proficiency line check (with supervisory pilot only)
6 December 2001	CAO 20.11 emergency procedures check
27 January 2002	Flight proficiency base check
14 March 2002	Flight proficiency line check
24 September 2002	Right-hand seat proficiency check (for supervisory pilot duties)
7 November 2002	Logbook entry as 'route check' (with supervisory pilot only)[25]
3 January 2003	Flight proficiency base check
14 March 2003	CAO 20.11 emergency procedures check
7 July 2003	Flight proficiency line check
24 September 2003	CAO 20.11 emergency procedures check
3 January 2004	CAO 20.11 emergency procedures check
1 February 2004	Flight proficiency base check
2 February 2004	CAO 20.11 emergency procedures check
26 July 2004	Flight proficiency line check (with supervisory pilot only)[26]
5 November 2004	Logbook entry as 'route check' (with supervisory pilot only)[25]
28 February 2005	CAO 20.11 emergency procedures check
28 February 2005	Flight proficiency base check

Instrument approach endorsements

The pilot in command obtained his initial multi-engine command instrument rating on 13 November 1993. The rating was renewed regularly.

The pilot in command's logbook showed that he completed training on the use of the GNSS for en-route navigation and position fixing as required by CAO 40.2.1 on 12 December 1997. This training was on the Garmin GNC-300 model of global positioning system (GPS) receiver.

The pilot in command completed his command instrument rating renewal on 3 January 2003. He obtained an endorsement to conduct RNAV (GNSS) approaches on the same day.

The pilot in command's instrument rating current at the time of the accident was endorsed for the following types of instrument approaches: non-directional beacon (NDB), very high frequency omnidirectional radio range (VOR), instrument landing system (ILS), localiser approach (LLZ) and RNAV (GNSS).

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25 No completed check form was found on the pilot's file. The purpose of the check could not be determined.

26 This flight was recorded on Transair's Flight Proficiency Line Check form and filed in the pilot in command's pilot file. However, the pilot in command's logbook and company rosters indicated that the pilot in command did not fly on 26 July 2004. The last flight recorded in the logbook with the supervisory pilot who completed the form was 26 August 2003. The next flight recorded with this supervisory pilot was on 5 November 2004. The supervisory pilot's logbook indicated that he did not operate a flight with the pilot in command on 26 July 2004.

The pilot in command completed a competency check on RNAV (GNSS) approaches during his flight proficiency base check / instrument rating renewal in January 2004 and February 2005. On the February 2005 flight proficiency base check form, the chief pilot had written 'slow in turns' against the item for the RNAV (GNSS) approach. The chief pilot reported that the pilot's initial turn on the Mareeba RNAV (GNSS) approach was slow, but that the pilot in command then 'gathered it up'.

The pilot in command had recorded in his logbook 16 RNAV (GNSS) approaches as the handling pilot at various locations between 3 January 2003 and 16 April 2005.[27] There was also evidence that the pilot in command had conducted other RNAV (GNSS) approaches prior to receiving his endorsement (see 'Operating practices' below).

Operational experience into Lockhart River

The pilot in command had operated into Lockhart River on 46 occasions before 7 May 2005, the first being on 23 February 2002. He had conducted one runway 12 RNAV (GNSS) approach at Lockhart River as the handling pilot on 27 September 2004. His last flight into Lockhart River prior to the day of the accident was on 27 April 2005 (see Section 1.11.3).

Operating practices

A number of pilots indicated that the pilot in command had good aircraft handling skills, whereas some others indicated that his skills were average.

Some of the pilots who had operated as copilots with the pilot in command reported that he would operate the aircraft faster than other pilots on approach (see Section 1.11.3). Some pilots also reported that the pilot in command could be quick when carrying out procedures, and would sometimes perform the duties of the other pilot. It was also reported that the pilot in command was generally a confident pilot.

A supervisory pilot reported that several copilots had expressed concern to him regarding the pilot in command not following company procedures, including not flying within speed limits. It was reported that some of these concerns had been expressed to the chief pilot. Another pilot also reported that he had expressed concerns to the chief pilot regarding the pilot in command's compliance with procedures. The chief pilot reported that he could not recall ever receiving any specific complaints about the operational performance of the pilot in command.

Two Transair pilots reported that, while operating as copilot with the pilot in command, the pilot in command regularly conducted RNAV (GNSS) approaches into Bamaga in IMC for more than a year before he had obtained an RNAV (GNSS) approach endorsement (that is, 3 January 2003). These copilots also did not have an RNAV (GNSS) approach endorsement at the time. Another copilot reported that the pilot in command had proposed conducting an RNAV (GNSS) approach before either pilot had been qualified but that copilot had objected and the approach was not flown.

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27 CASA stated that 'Instrument approaches are to be credited to the pilot … manipulating the controls or providing input to the auto-pilot during the approach.' Therefore, the pilot in command probably did not record instrument approaches where he was the non-handling pilot.

A copilot reported that the pilot in command had adopted a practice, when operating into Bamaga, of descending to the minimum safe altitude early and then flying level towards the aerodrome until he could make visual contact with the runway. The terrain around Bamaga is generally flat. However, that copilot also reported that he would never undertake this practice into Lockhart River due to the significant terrain around the aerodrome. This view was supported by another copilot, who also reported that the pilot in command and other Transair pilots were aware of the terrain on the Lockhart River Runway 12 RNAV (GNSS) approach. Friends of the pilot in command reported that, about a week before the accident, he had expressed surprise regarding the close proximity of the mountains on a recent runway 12 RNAV (GNSS) approach into Lockhart River, and that he was going to 'talk to someone' about the approach procedure. This flight probably[2] occurred on 27 April 2005 (see Section 1.11.3).

Dispatch personnel and pilots indicated that the pilot in command would arrive at the airport for the scheduled flights typically about 20 minutes before departure, although there were indications that he arrived earlier when inexperienced copilots were rostered. Other pilots typically arrived an hour before departure.

The managing director of another low capacity RPT operator reported that, when the pilot in command was employed by that operator, he had a history of not following standard operating procedures. He was formally counselled and had his probation period extended. The managing director also reported that he was advised by another company employee that the pilot in command once landed at an aerodrome during a passenger-carrying flight when the weather conditions were below those specified in that company's operations manual.

Medical status

A review of the pilot in command's medical records found no indication of any medical problem that was likely[2] to have been influencing his performance. This was consistent with information received from his family and colleagues.

Recent history

The pilot in command had returned to Cairns 3 days before the accident flight following a 7-day interstate holiday with friends. On the 2 days prior to the accident, he operated the Cairns – Bamaga – Cairns route, finishing about 1300 each day. Over these 2 days, he completed 9 hours and 40 minutes of flight time and 12 hours 20 minutes of duty time.

Two nights before the accident, the pilot in command had entertained friends at his house with no alcohol being consumed, and used the internet from 2224 until 2324. On the night before the accident, it was reported that pilot in command had dinner at his neighbour's house and drank about three standard alcohol drinks during a 3-hour period from 1830. The pilot in command then used the internet at his home from 2233 to 2318, which appeared to be a normal routine.

The pilot in command's colleagues and friends reported that he was fit and generally relaxed due to having just finished a holiday, and he was relaxed and happy when he arrived at work on the morning of the accident, as well as during the turn-around in Bamaga. He arrived at Cairns airport between 0800 and 0810 for the 0830 departure. He had planned to go motorcycle riding with a friend after work on the day of the accident.

1.5.2 Copilot

Personal details	Male, 21 years of age
Type of licence	Commercial pilot (aeroplane) licence
Total flying hours	655.4 hours
Total flying hours on Metro	150.5 hours
Total flying last 90 days	151.2 hours
Total flying last 30 days	87.3 hours
Total flying last 7 days	19.5 hours
Total flying hours multi-crew ops	150.5 hours
Last proficiency check	22 December 2004
Medical certificate	Class 1 – valid to 26 August 2005 - nil restrictions

Prior experience

The copilot obtained a commercial pilot (aeroplane) licence on 30 January 2004. Before commencing his Metro endorsement, the copilot had 500.5 hours flying experience recorded in his logbook. He had no previous turbine-engine aircraft experience or experience in multi-crew operations.

Transair endorsement and post-endorsement training

According to company documentation, the copilot commenced employment with Transair on 9 March 2005. The copilot's Transair pilot file recorded that his ground school on the Metro aircraft was completed by the Transair chief pilot on 12 December 2004. A family member reported that the copilot was given a training manual to study and was not provided with any formal classroom training during his ground school. The copy of the engineering examination on the copilot's file indicated that he had achieved 77 per cent on the written engineering examination.[28] The *Aircraft Ground Training* form on the copilot's file indicated that the type examination result was recorded as 'passed'. There were no other written engineering or endorsement examinations on the copilot's file.

The copilot underwent three endorsement flights totalling 4.2 hours on the Metro aircraft between 19 and 22 December 2004. The chief pilot completed a flight proficiency base check form for the copilot on 22 December 2004. At the completion of the endorsement flying, the chief pilot entered a *Co-pilot Metro 3* class endorsement into the copilot's logbook. As noted in Section 1.17.8, there were several administrative problems with the endorsement process which meant that the endorsement did not meet regulatory requirements.

Following his 4.2 hours endorsement flying, the copilot's next flight in a Metro aircraft was on a night charter flight with a Transair supervisory pilot on 28

28 The engineering examination contained a series of questions testing the pilot's knowledge of aircraft systems and operating limitations. The *Transair Operations Manual* stated that the pass mark for a company engineering examination '…shall be 80%. Each completed exam shall be debriefed with the candidate and 'corrected' to 100%. Supplementary exams shall be available for candidates who fail.'

February 2005. Contrary to the requirements of the *Transair Operations Manual*, he was not checked by a check pilot prior to commencing line operations (see Section 1.17.8).

The copilot had not been provided with any crew resource management training.[21] As the copilot had not been employed for longer than 6 months, the *Transair Operations Manual* requirement to undertake crew resource management training within 6 months had not been reached. The investigation found no evidence that training was planned within that 6-month period.

The copilot had acknowledged receipt of the *Transair Operations Manual* in CD-ROM format on 3 March 2005.

Line operations

The copilot started operations on RPT freight flights from Cairns on 9 March 2005 (with 8.4 hours on type) and on RPT passenger flights on 4 April 2005.[29]

The copilot's logbook indicated that he had operated as a crew member into Lockhart River on three occasions before 7 May 2005.

Recency

The copilot's logbook showed that he had logged 26.1 hours flight time under IMC within the preceding 90 days.[30]

Proficiency checks

The following table is a summary of the flight proficiency checks recorded in copilot's pilot file and logbook.

Date	Check
22 December 2004	Flight proficiency base check
22 December 2004	CAO 20.11 emergency procedures check

Instrument approach endorsements

The copilot obtained his initial multi-engine command instrument rating on 19 March 2004. He completed a command instrument rating renewal on 3 April

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29 Transair provided the investigation with a completed 'route training report form' for the copilot dated between 9 and 17 March 2005. The form was completed by a supervisory pilot. The flight times listed on the form did not match the flight times entered in either the supervisory pilot's logbook or the copilot's logbook. Furthermore, the 'in command under supervision' section had been completed and the flights listed constituted the second, third, fourth, fifth and sixth line flights with Transair as copilot. The copilot's logbook listed these flights as copilot flight time.

30 The copilot was apparently over-recording flight time in instrument meteorological conditions as he had logged a total of 202.1 hrs instrument flight time, which comprised approximately 30 per cent of his total aeronautical experience. By way of comparison, the pilot in command's logged instrument flight time was 497.5 hrs, which was 8 per cent of his total aeronautical experience.

2005.[31,32] The copilot's instrument rating current at the time of the accident was endorsed for the following types of instrument approaches: NDB, VOR, ILS, LLZ and DME/GPS arrival.

The copilot's instrument rating and his logbook were not endorsed to authorise him to use GNSS during instrument flight. The copilot did not have an RNAV (GNSS) approach endorsement, and there was no record that he had received any training on RNAV (GNSS) approaches by an appropriately qualified instructor, or any formal training on such approaches while employed at Transair. The copilot's Transair pilot file did not include any evidence that he had completed the GPS training syllabus specified in the *Transair Operations Manual*. That syllabus related to the use of GPS as the primary means of en route navigation or the use of GPS for non precision approaches.

The Transair chief pilot and a Cairns supervisory pilot also reported that the copilot was not endorsed to conduct RNAV (GNSS) approaches. The supervisory pilot reported that he had demonstrated RNAV (GNSS) approaches to the copilot in visual meteorological conditions (VMC) during RPT flights to Bamaga on about two occasions. The supervisory pilot and a contractor check pilot both reported that the copilot was keen to learn about RNAV (GNSS) approaches and had indicated that he was intending to undergo training for an endorsement in the near future.

In addition to the accident flight, FDR information indicated that the crew conducted a runway 30 RNAV (GNSS) approach to Lockhart River on the northbound flight on the day of the accident (see Section 1.11.3). It was very likely that the copilot was the handling pilot during that approach as the pilot in command was recorded as making the radio transmissions on this flight, and it was very likely that the pilot in command was the handling pilot for the southbound flight.[9]

Operational experience into Lockhart River

The copilot had operated into Lockhart River on four occasions before 7 May 2005, involving a total of five approaches and four landings. Two of these occasions were with the pilot in command. On 23 April, the crew flew into Lockhart River from Bamaga. Data from the FDR showed that a Lockhart River Runway 12 RNAV (GNSS) approach was not conducted on that flight.

On 13 April 2005, the crew flew the Cairns – Lockhart River – Bamaga – Lockhart River – Cairns sectors. The forecast weather conditions at the time of approaching Lockhart River from Bamaga were similar to the conditions on the day of the accident flight. Weather information recorded by an authorised observer was not available for 13 April 2005. However, no rainfall was recorded at the aerodrome. An email from the copilot to friends and family described a series of flights at about this time. Although other flights where the weather conditions were poor were described in some detail, no mention was made of the weather conditions on the 13 April flight. The Lockhart River CTAF automatic voice recording equipment was also unserviceable on that date. The copilot had recorded in his

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31 The copilot's command instrument rating was renewed on 3 April 2005 at the second attempt. Both the initial attempt (2 April 2005) and second attempt were conducted in an aircraft type that he had not previously flown.

32 The Transair chief pilot reported that the company provided copilot instrument rating renewals for copilots, but when a copilot wanted a command instrument rating renewal, they were required to arrange and pay for the renewal.

logbook that he conducted an instrument arrival and approach into Cairns, which indicated that he was the handling pilot for the southbound flights. The recorded flight time for the flight from Bamaga to Lockhart River was consistent with other flights where a straight-in approach to runway 12 was conducted.

The other two occasions that the copilot operated into Lockhart River involved a pilot in command who did not hold an RNAV (GNSS) endorsement and reportedly did not conduct RNAV (GNSS) approaches. One flight involved a missed approach from a runway 30 NDB instrument approach and a diversion to Weipa. The other flight involved Cairns – Lockhart River – Cairns sectors. Both of these flights involved northbound approaches to Lockhart River.

Operating practices

Pilots who flew with the copilot reported that he was keen to learn. The copilot's flying ability and systems knowledge was generally reported as being consistent with his experience level.

A Transair supervisory pilot stated that the copilot's flying was good despite his low hours and that, although he initially found it difficult to keep up with the aircraft, his flying ability had improved by the time he last flew with him about four weeks before the accident. The supervisory pilot had noted on an undated *Transair Flight Proficiency Line Check* form that the copilot's '… overall ability flying the Metro is well above standard. …knowledge of systems + performance very good'.

Another supervisory pilot who flew with the copilot during the week before the accident indicated that he was confident in the copilot's monitoring skills. A third supervisory pilot who flew with the copilot about 2 weeks before the accident indicated that the copilot was 'struggling a bit' when he was put under pressure during the descent. Another Transair pilot indicated that the copilot was procedurally good and worked hard, and would monitor the handling pilot when acting as the support pilot, but due to his low experience he needed to fly with supervisory pilots to 'fine tune' his flying skills.

During his command instrument rating renewal flight test 5 weeks before the accident, the copilot's instrument flying ability (on an aircraft type he had previously not flown) was reported as being not as good as would be expected from a pilot who flew every day.

Medical status

A review of the copilot's medical records found no indication of any medical problem that was likely to have been influencing his performance. This was consistent with information received from his family and colleagues.

Recent history

The day of the accident was the copilot's fifth consecutive duty day, prior to which he had been rostered free of duty for 4 days. During the 4 days of duty prior to the day of the accident, he completed 19 hours and 32 minutes of flight time, and 26 hours and 26 minutes of duty time. On the day before the accident, he operated on the Cairns – Bamaga – Cairns route and finished duty at about 1300.

On the 2 days prior to the day of the accident, it was reported that the copilot went for bicycle rides in the afternoon after work. He spent the night before the accident at home, and had about one standard alcohol drink. It was reported that he went to bed on the night before the accident at about 2130, which was a normal routine.

The copilot normally woke between 0600 and 0630 and left for work by 0700. This routine was reported to have occurred on the day of the accident. He arrived at Cairns airport at about 0715 for the 0830 departure.

The copilot's family and colleagues reported that he was fit and healthy, and that he had competed in a triathlon during the weekend before the accident. It was reported that when leaving for and arriving at work on the day of the accident, as well as during the turn-around in Bamaga, the copilot appeared to be happy and normal.

1.5.3 Crew relationship

Based on logbook entries and Transair's crew roster, the pilot in command and copilot operated as a crew on 10 days (involving 27 sectors) before 7 May 2005, the first time being on 23 March 2005. The crew had operated together on the Cairns – Bamaga – Cairns route on six occasions, the first being 7 April 2005. Of these 6 days, the crew operated via Lockhart River twice, on 13 and 23 April 2005. The copilot's initial flights at the Cairns base were mostly with the other Cairns-based supervisory pilot.

There was a large difference in age and experience levels between the pilot in command and copilot. In particular, the pilot in command was the Transair's base manager for Cairns, was a supervisory captain, had been with the operator for more than 4 years and had over 6,000 hours total flying time. In contrast, the copilot had only been with Transair and flying Metro aircraft for 2 months, and had about 600 hours total flying time.

The pilot in command's communication style in the cockpit was reported as being direct. He was reported as being frank or curt with copilots if they could not keep up with the aircraft's progress. If decisions or actions by the pilot in command were challenged by a copilot, one copilot reported that the pilot in command would respond, but in his own time. Another copilot reported that if excess speed was challenged by a copilot, the pilot in command would slow down only if he respected the copilot. Another copilot reported that the pilot in command would slow down performing procedures when asked, but that a copilot who was not assertive enough to ask him to slow down may never catch up with the pilot in command.

Another copilot reported that he had to be assertive to prevent the pilot in command deviating below the minimum sector altitude. The copilot who reported that he had refused to conduct RNAV (GNSS) approaches before they were qualified to fly them (see Section 1.5.1) reported that the pilot in command became less friendly after this event.

The copilot was generally described as quiet or shy. One pilot in command indicated that the copilot had relatively low assertiveness in the cockpit, and another pilot in command reported that sometimes he needed prompting to make his own decisions.

One Transair pilot reported that the copilot had talked with him about the pilot in command. He had reported that initially there was tension between the pilot in command and the copilot, but that it was becoming less problematic as the copilot became more experienced. The copilot reported to this pilot that the pilot in command was not providing effective instruction, and also not complying with standard operating procedures. The copilot asked the pilot for advice on handling the pilot in command. The pilot reported that he advised the copilot to work together as a team with the pilot in command.

Another pilot reported that the copilot had discussed the pilot in command with him, and stated that he was difficult to fly with, and did not actively seek the copilot's input. A family member of the copilot reported that the copilot had stated in the week before the accident that the pilot in command was difficult and authoritarian. Other Transair pilots and management reported that the copilot had not talked about the pilot in command to them.

There was no evidence that the pilot in command had expressed any concerns regarding the copilot to any Transair pilots or management, or to friends or family members.

1.6 Aircraft information

1.6.1 Aircraft data

VH-TFU was a twin-engine (turbo-propeller), low-wing aeroplane certified to seat up to 19 passengers and two crew (see Figure 1).

The aircraft had a pressurised cabin to allow operation up to 25,000 ft without the need to provide supplemental oxygen to the crew and passengers.[33]

33 Only an emergency supply of oxygen was required to be carried in accordance with the Civil Aviation Orders.

Manufacturer	Fairchild Aircraft, Inc.
Model	SA227-DC
Serial number	DC-818B
Registration	VH-TFU
Year of manufacture	1992
Certificate of airworthiness issuing authority	Civil Aviation Safety Authority
Issue date	4 July 2003
Certificate of registration issuing authority	Civil Aviation Safety Authority
Issue date	2 July 2003
Total airframe hours/cycles	26,877.8 hours / 28,529 cycles[34]
Maintenance release issued on/at	17 April 2005/26,805.8 hours
Maintenance release valid to	17 April 2006/26,975.8 hours
Next scheduled maintenance due	26,955.8 hours
Maximum certified take-off weight	7,484 kg
Maximum certified landing weight	7,110 kg
Aircraft weight at time of occurrence	(see Section 1.6.18)
Centre of gravity at time of occurrence	(see Section 1.6.18)

1.6.2 Engine and propeller data

The aircraft was fitted with two 1,100 shaft-horsepower turbo-propeller engines, each fitted with a four-blade, constant-speed propeller.

Left engine

Manufacturer	Garrett (AiResearch) - now Honeywell International Inc.
Model	TPE331-12UHR-701G
Part number	3103870-7
Serial number	P70151C
Last significant maintenance completed	On 7 October 2004: hot section and gearbox inspection - the gearbox bull gear and pinion were replaced and the engine had a re-compensation (performance) check carried out.
Total time since new	21,510.5 hours[35]
Cycles since new	22,971 cycles[35]
Time since last overhaul	4,233.5 hours[35]

34 The aircraft's *Flight/Maintenance Log* dated 6 May 2005 (the day prior to the accident) indicated that the aircraft had completed 26,875.5 hours and 28,527 cycles. A cycle refers to a takeoff and landing. Based on the times and cycles recorded by the FDR on 7 May 2005, the aircraft had logged 26,877.8 hours and 28,529 cycles at the time the FDR recording ceased.

35 The engine total time, cycles since new and time since last overhaul include the times and cycles recorded by the FDR on 7 May 2005.

Left propeller

Manufacturer	McCauley Propeller Systems
Model	4HFR34C652-J
Serial number	980176
Last significant maintenance completed	17 April 2005; Phase 2C inspection in accordance with Transair's maintenance manual
Total time since new	10,753.6 hrs
Time since last overhaul	1,725.9 hrs

Right engine

Manufacturer	Garrett (AiResearch) - now Honeywell International Inc.
Model	TPE331-12UAR-701G
Part number	3103870-4
Serial number	P70011C
Last significant maintenance completed	6 April 2005: hot section and gearbox inspection - the gearbox bull gear, pinion and gearbox diaphragm were replaced and the engine had a re-compensation (performance) check carried out.
Total time since new	21,960.1 hours[36]
Cycles since new	22,942 cycles[36]
Time since last overhaul	3,496.1 hours[36]

Right propeller

Manufacturer	McCauley Propeller Systems
Model	4HFR34C652-J
Serial number	971746
Last significant maintenance completed	17 April 2005; Phase 2C inspection in accordance with Transair's maintenance manual
Total time since new	10,680.8 hours
Time since last overhaul	3,321.8 hours

1.6.3 Aircraft history

VH-TFU was previously owned and operated by a regional airline in Mexico. The aircraft was sold by that airline in February 2003 to a leasing company before being purchased by Transair and imported into Australia in June 2003.

36 The engine total time, cycles since new and time since last overhaul include the times and cycles recorded by the FDR on 7 May 2005.

1.6.4 Aircraft certification and multi-crew operation

The Fairchild Aircraft Inc. SA227-DC Metro 23 aircraft were manufactured in the United States (US) and certificated in the Commuter Category to the standards of US Federal Aviation Regulations Part 23 (FAR 23) *Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes*.[37] The Metro 23 was designed to carry up to 19 passengers and was approved for operation in day, night, visual flight rules (VFR), IFR and icing conditions. The maximum tailwind component indicated in the certified landing performance data was 15 kts.

Provided that the instrument panel was configured correctly, the Metro 23 was certified for operation by a single pilot.[38] Due to the aircraft being operated on an RPT service and certified to carry more than nine passengers, the Australian CAO 82.3 required that the aircraft be operated with two pilots.[39]

1.6.5 Flight controls

The Metro 23 aircraft had a conventional three-axis control system consisting of mechanically-operated ailerons, elevator and rudder. The ailerons and rudder included mechanically-operated trim systems. The pitch-axis trim was provided by an electrically-operated horizontal stabiliser positioning system.

The aircraft also had electrically controlled and hydraulically-actuated trailing edge wing flaps. The flaps could be set in four discrete detented positions; up (0 degrees), ¼ (9 degrees), ½ (18 degrees) and down (36 degrees). The design of the wing flap system included a mechanical interconnect to ensure symmetrical operation and required normal hydraulic system pressure to operate. In the event of a loss of hydraulic system pressure, the flaps could not be operated from the emergency hydraulic system.

Of the aircraft controls accessible to the pilots, only the nose wheel steering control had not been replicated on, or was not readily accessible from, the copilot's position. Therefore, the copilot could perform all aircraft control functions except ground steering at low speed.

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37 The term *Commuter Category* was defined in FAR 23 Subpart A – General as being 'limited to propeller-driven, multiengine airplanes that have a seating configuration, excluding pilot seats, of 19 or less, and a maximum certificated takeoff weight of 19,000 pounds [8,618 kg] or less'. Commuter Category aircraft had additional design and performance requirements to the Normal Category requirements of FAR 23.

38 Approval for single-pilot operation was based on the instrument/avionics arrangement shown by Fairchild Drawing 27-86081. Any significant deviation from that arrangement had to be evaluated for single pilot suitability.

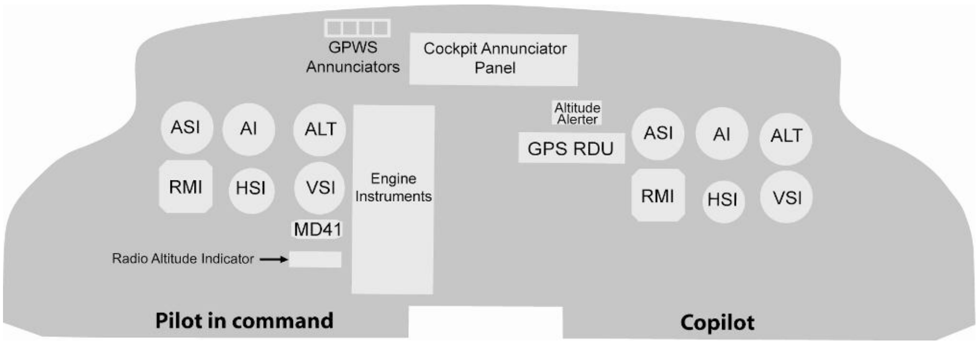
39 Following an accident in 1980 involving an Australian RPT aircraft, which was operated by a single pilot, CAO 82.3 was amended so that two pilots were required to operate an aircraft in which more than nine passenger seats could be fitted and the aircraft was to be used in RPT operations. Refer to recommendation 1, *Crew Complement,* contained in the *Report of Chairman of Board of Accident Inquiry on Accident to Beech Super King Air 200 Aircraft VH-AAV at Mascot, New South Wales on 21 February 1980,* Australian Government Publishing Service Canberra, 1983.

1.6.6 Cockpit layout and instrumentation

VH-TFU's basic cockpit layout was typical of the Metro 23 aircraft type. The flight instruments including the airspeed indicator (ASI), attitude indicator with slip indicator (AI), altimeter (ALT), horizontal situation indicator (HSI), vertical speed indicator (VSI) and a radio magnetic indicator (RMI) were positioned in front of each pilot on their respective sides of the panel (Figure 7).

The engine and aircraft systems instruments, such as hydraulic system pressure, fuel quantity, flap and pitch trim position, were positioned primarily to the immediate right of the pilot in command's primary flight instruments, between the pilots' panels.

Figure 7: Representation of the instrument panel layout for VH-TFU[40]



As the aircraft appeared to be on the correct track, but below the segment minimum safe altitude when it impacted the terrain, the indicating and warning systems relating to the aircraft's altitude and height above ground were examined in detail. These systems included the barometric altimeters, vertical speed indicators, the radio altimeter, the altitude alerter and the ground proximity warning system (GPWS). The presentation of information on the GPS satellite navigation system was also examined as it was the primary means of positional situational awareness information during an RNAV (GNSS) approach.

1.6.7 Barometric altimeters

CAO 20.18, Appendix II required that aeroplanes engaged in RPT operations be equipped with two sensitive pressure altimeters. International Civil Aviation Organization (ICAO) Annex 6, *Operation of Aircraft, Part I, International Commercial Air Transport – Aeroplanes* paragraph 6.9.1 also required that the aircraft be equipped with two sensitive pressure altimeters, but restricted the requirement to only include altimeters with a counter drum-pointer or equivalent presentation. The annex also contained a note indicating that three-pointer altimeters did not satisfy this requirement.

The aircraft was fitted with two sensitive pressure altimeters, one for the pilot in command and one for the copilot, that were supplied by independent static pressure

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40 The panel does not show all of the instruments that were fitted to VH-TFU, only those of interest to this investigation, and their relative positions on the panel.

systems.[41] Both instruments displayed barometric corrected altitude, but had two significant differences: the method of sensing and conversion of air pressure into altitude; and the method of presentation of the altitude reading.

The pilot in command's Kollsman Avionics altimeter was of an electro-mechanical counter drum pointer encoding type (Figure 8, left). Air pressure was converted into an electrical signal which was used to drive the indicator. This electrical signal was also converted to a digital signal to provide pressure altitude data to other avionics, such as the transponder, altitude alerter and the GPS. A red flag on the instrument face indicated that the instrument had lost power. The last altitude at which power was applied remained displayed on the indicator.

The copilot's Aerosonic Corporation altimeter was of a conventional three-pointer mechanical type (Figure 8, right). A series of mechanical linkages directly converted air pressure into the movement of pointers on the instrument face.

Figure 8: Altimeters - Pilot in command's (left), copilot's (right) (Images of representative items, not specific items in VH-TFU)

The pilot in command's altimeter presented the altitude on the counter drum in ten thousands, thousands and hundreds of feet and the pointer in hundreds of feet in 20 foot sub-increments, or one revolution per thousand feet (the example shown on the left in Figure 8 presents an altitude of 1,860 ft).

The copilot's altimeter presented altitude on three pointers for tens of thousands (long narrow line with triangle at end), thousands (short, wide arrow) and hundreds (long, wide arrow) of feet in 20 foot sub-increments (the example shown on the right in Figure 8 presents an altitude of about 1,620 ft).

The pilots could set the local barometric pressure on both altimeters by rotating the knob at the bottom corner of the instruments. This setting was presented on the pilot in command's altimeter in both millibars (normally referred to as hectoPascals, or hPa) and inches of mercury, while the copilot's was presented in hPa only.

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41 Static pressure is the pressure of the still air through which the aircraft is travelling. Static pressure systems in aircraft consist of tubes connected to small ports (plates with holes) in the sides of the fuselage, which supply the aircraft's instruments. These systems are designed to measure this still air pressure with minimal effect from the aircraft.

1.6.8 Vertical speed indicators

CAO 20.18, Appendix II required that aeroplanes engaged in RPT operations be equipped with a rate of climb and descent indicator, also known as a vertical speed indicator (VSI).

VH-TFU was fitted with two Aerosonic Corporation VSIs, one for the pilot in command and one for the copilot. These instruments (see Figure 24) sensed the rate of change in altitude and displayed it to the pilots on a split scale (from 0 to 6,000 ft/min), indicating either climb (increasing altitude) or descent (decreasing altitude).

1.6.9 Radio altimeter system

The aircraft was equipped with a Rockwell Collins ALT55B radio altimeter system that comprised a receiver/transmitter, two antennae located on the lower surface of the fuselage, and a digital radio altimeter indicator in the cockpit (Figure 9). The system computed the aircraft's height above ground level (AGL) directly below the flight path from 0 to 2,500 ft. This computed altitude was presented as a digital number in the left window of the radio altitude indicator (labelled RAD ALT on Figure 9).

The digital radio altitude indicator was located on the pilot in command's instrument panel below the vertical speed indicator and GPS annunciation control unit (Figure 7).

Figure 9: Digital radio altitude indicator
(Image of representative item, not specific item in VH-TFU)

The crew could select a height from 0 to 990 ft on a rotating drum scale using the 'push test' radio altimeter decision height[42] knob. During an approach, a 'minimums – minimums' aural message was annunciated by the ground proximity warning system as the aircraft descended through the decision height set on the radio altimeter indicator (see Section 1.6.11). The decision height (DH) light also illuminated and remained on for the remainder of the approach.

The 'minimums' message was annunciated once per approach and if it was not required, setting the decision height to a value below 50 ft would result in the message not being annunciated. A red warning flag came into view over the decision height drum scale if the radio altitude computations stopped, there was a power failure to the radio altimeter unit or indicator, or there was an internal failure detected in the radio altitude indicator unit.

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42 Decision height (DH). A specified height in the precision approach or approach with vertical guidance at which a missed approach must be initiated if the required visual reference to continue the approach has not been established. Decision height (DH) is referenced to the threshold elevation.

While human factors research has shown that digital displays are better when people need to check a stable value, they are not as effective as moving pointers (analogue displays) at attracting attention and conveying magnitude and trend (increasing or decreasing).[43]

1.6.10 Altitude alerting system

CAO 20.18 paragraph 7.2 required that pressurised turbine engine aircraft operating in controlled airspace under the IFR shall be equipped with an altitude alerting system.

VH-TFU was equipped with a Kollsman altitude alerter (Figure 10), which provided automatic visual and aural signals to alert the flight crew that the aircraft was approaching, or departing from, a preselected pressure altitude. The altitude alerter unit was located on the centre instrument panel above the GPS receiver (see Figure 7). The preselected altitude was set in 100 ft increments on the unit by rotating a knob on the lower right of the unit. The alerting system received digital pressure altitude information from the pilot in command's encoding altimeter.

Figure 10: Altitude alerter
(Image of representative item, not specific item in VH-TFU)

As the aircraft approached 1,000 ft above or below the preselected altitude, an aural tone would sound for 2 seconds and the altitude alert light on the display unit would illuminate. The light would remain illuminated until the aircraft approached 300 ft above or below the preselected altitude. If the aircraft subsequently departed from the preselected altitude by more than 300 ft the aural tone and light would again activate. The light would remain illuminated until the aircraft returned to within 300 ft of the preselected altitude or until the flight crew selected a new altitude.

1.6.11 Ground proximity warning system

Regulatory requirements

CAO 20.18 required that a turbine-engine aeroplane that was carrying 10 or more passengers and engaged in RPT operations must not be operated under the IFR unless it was fitted with a ground proximity warning system (GPWS) that met the requirements of CAO 108.36. CAO 108.36 required that the GPWS equipment comply with either United States Federal Aviation Administration (FAA)

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43 Kroemer and Grandjean (1999). *Fitting the task to the human. A textbook of occupational ergonomics.* (5th edition). Taylor & Francis: London.

Technical Standard Order (TSO) C92b[44], or United Kingdom Civil Aviation Authority specification No. 14.[45]

System description

A Sundstrand (Honeywell) MK VI GPWS was installed in VH-TFU by the previous owner in Mexico in January 2003 in accordance with FAA Supplemental Type Certificate[46] (STC) number SA8805SW, and some locally approved deviations. The aircraft was purchased by Transair and imported into Australia with the system already fitted. The MK-VI GPWS was certified to FAA TSO C92b.

The GPWS incorporated a ground proximity warning computer and various cockpit annunciator lamps and switches. The computer received height above ground information from the radio altimeter system, airspeed and rate of climb from a dedicated air data module, glideslope deviation information from the VHF navigation receiver, height above ground information from the radio altitude system, landing gear position (retracted or extended) and flap position.[47] The ground proximity warning computer processed the information and provided visual and/or auditory (computer generated voice) alerts and warnings of possible terrain danger.

The visual alerts were provided by a set of annunciators (Figure 11) located on the pilot in command's instrument panel (Figure 7).

Figure 11: GPWS cockpit annunciators and switches (Image of representative item, not specific item in VH-TFU)

The aural alerts and warnings were generated by the ground proximity warning computer and provided to crew headsets and overhead cockpit speaker through the aircraft's audio system. The audio level was preset to a level above that of the normal audio system and could not be adjusted by the crew.

The GPWS was operable whenever the electrical power was on and power was provided to the avionics bus. The GPWS provided six modes of alerts and warnings to the crew, shown in the table below.

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44 Ground proximity warning-glide slope deviation alerting equipment; Technical Standard Order (TSO) C92b.

45 Ground proximity warning systems; Specification No. 14, Issue 2.

46 A type certificate was a legal document allowing a manufacturer to offer an aircraft or engine for sale. A supplemental type certificate authorised alterations to an aircraft or engine under an approved type certificate.

47 The flap position was provided by a dedicated switch that was activated by a cam on the flap position sensor shaft. The switch provided the GPWS with an indication that the flaps were in the landing position. This was designed to occur at a setting greater than ½ flap.

Mode	Description	Visual indication	Aural annunciation
Mode 1	Excessive rate of descent with respect to terrain when below 2,450 ft AGL	Red GPWS	'Sink rate' and/or 'pull-up'
Mode 2A	Excessive rate of closure with terrain when below 1,800 ft AGL.	Red GPWS	'Terrain - terrain' and 'pull-up'
Mode 2B	Excessive rate of closure with terrain with landing flap or flap override switch selected when below 600 ft AGL.		
Mode 3	Altitude loss after takeoff or missed approach before reaching 925 ft AGL.	Red GPWS	'Don't sink'
Mode 4	Approach to within 500 ft AGL with the landing gear up, to within 170 ft AGL with the landing gear down and the flaps not fully down, or proximity to terrain during takeoff or a go-around.	Red GPWS	'Too low, gear', 'too low, flaps', or too low, terrain', respectively.
Mode 5	Excessive deviation below the glideslope when below 925 ft AGL with the landing gear down.	Amber BELOW G/S	'Glideslope'
Mode 6	Descent below the decision height selected on the radio altimeter[48], 500 ft, 200 ft[49] or excessive bank angle.	None	'Minimums – minimums', 'five hundred', 'two hundred', or 'bank angle', respectively.

The sensitivity of mode 2 terrain warnings was greatly reduced when the flaps were in the landing position or the flap override (GPWS FLAP OVRD) switch was activated. The *Approved Airplane Flight Manual* supplement for the MK VI GPWS applicable to VH-TFU indicated that the GPWS flap override switch could be used to cancel the 'too low flaps' warnings when full flap could not be deployed. The switch could also be used to cancel the 'don't sink' warning during engine out emergency operations or to desensitise terrain warning modes for 'untypical' approach procedures, such as high speed environments or visual approaches in areas of steep terrain (see Appendix C).

A computer simulation of the final minutes of the flight carried out by the GPWS manufacturer (see Section 1.16.2) indicated that the GPWS should have produced a repetitive mode 2A warning during the final 5 seconds of the accident flight.

48 The radio altimeter provided a signal to the GPWS when the radio altitude passed through the decision height. This activated the mode 6 "minimums-minimums" aural alert.

49 The 500 ft and 200 ft call-outs were options on the MK VI GPWS. The installation/certification documentation indicated that these options were disabled on VH-TFU. However, several Transair pilots recalled hearing the 500 ft call-out in VH-TFU.

GPWS serviceability checks and maintenance

The GPWS had a self-test feature which could be conducted on the ground only. The self-test was activated by pressing and holding the GPWS P/TEST annunciator switch. The flight manual supplement provided detail on the procedure in the Before Take-off checklist. Several of Transair's pilots reported that they conducted a GPWS test prior to each flight and that the system fitted to VH-TFU passed the test on those flights prior to the accident flight.

The GPWS was checked on a regular basis as part of the aircraft's system of maintenance (see Section 1.6.17). The maintenance was reported as having been carried out in a manner which reflected the aircraft manufacturer's maintenance manual for the factory fitted system.[50] Those checks consisted of GPWS self tests with and without artificial system faults[51] and checking for the expected results. They did not include configuration checks; that is, checking that the correct options were configured (for example, disabling of mode 6 altitude calls) and that changes in aircraft configuration were sensed at the correct point (for example, whether the landing flap setting was sensed at the correct point and the landing gear down setting was sensed). Components, such as landing gear position sensor and the radio altimeter system, may have been checked as part of other system checks, but components dedicated to the GPWS, such as the flap position switch, were not checked.

The aircraft maintenance manual included a detailed check of the factory fitted GPWS, which consisted of checking the continuity of all wires connected to the ground proximity warning computer, GPWS configuration checks (that included a check to ensure that the system sensed when the flap was in the landing position) and a series of system self tests. This section of the maintenance manual was only referred to when any rectification work was required. There were no entries in the aircraft maintenance history documentation regarding defects of the GPWS or any rectification work carried out on the GPWS.

The GPWS manufacturer had published a recommended maintenance interval of 5,000 hours for a bench test of the ground proximity warning computer when the aircraft manufacturer did not specify maintenance intervals. Further checking was recommended by the manufacturer in a Service Information Letter (SIL No. GPWC-Mk VI-34-1 Rev 1 dated Jan 12/94). This procedure had not been performed as the aircraft had not reached 5,000 hours time in service since the installation of the GPWS.

The investigation found no maintenance documents specific to the installation of the GPWS under STC SA8805SW that were utilised in the maintenance of VH-TFU.

The only checks that were identified as having been carried out on the GPWS fitted to VH-TFU consisted of self tests. There was no evidence to indicate that the entire

50 The factory fitted GPWS was the same model as the system in VH-TFU, but had some different configuration options, such as the 200 ft and 500 ft callouts.

51 The artificial faults were induced by pulling the circuit breakers for the primary GPWS inputs, for example, the radio altimeter, the air data module and the GPWS computer.

system (including configuration settings such as flap position sensing[52]) had been checked since the GPWS was installed.

The amber GPWS INOP annunciator illuminated, and remained illuminated, whenever the system detected a partial or total failure of the GPWS, either in flight or on the ground.

1.6.12 Global positioning system

Regulatory requirements

CAR 179A and *Aeronautical Information Publication*[53] (AIP) GEN 1.5 Section 8.5 specified that GNSS receivers used for IFR navigation must be certified to the FAA TSO-C129, C129a, C145, C145a, C146, C146a or an equivalent standard approved by CASA.

In June 2003, prior to importation into Australia and under instruction from Transair, VH-TFU was fitted with a Garmin GPS 155XL receiver. The Garmin GPS 155XL was certified to the TSO-C129a standard, which allowed the unit to be used for IFR en-route, terminal and non-precision approach procedures in accordance with the AIP. The installation and approval was carried out by FAA-approved organisations in accordance with the Garmin GPS155XL/GNC300XL Installation Manual.

At the time that the aircraft entered Australia, CASA's preferred method of approval for the fitment of a GPS system into an aircraft within Australia was described in Civil Aviation Advisory Publication (CAAP) 35-1(0), *Global Positioning System (GPS): general installation guidelines*. CASA indicated that the CAAP did not apply to VH-TFU, as the GPS system had been fitted in the US under an FAA approval. The CASA records for the assessment of the aircraft for the issue of the Australian certificate of airworthiness did not record the GPS installation.

The installation in VH-TFU consisted of the GPS 155XL receiver display unit (RDU), an external antenna, an MD41 annunciation control unit and the pilot in command's HSI. The RDU (Figure 12) received and processed signals from up to 12 GPS satellites to determine the aircraft's position, velocity and time. Software within the unit provided navigation information to the flight crew for navigating the aircraft through a series of earth-referenced waypoints. The receiver display unit was located on the centre instrument panel (Figure 7).

The navigation information was presented in various user-selectable forms on a liquid crystal display. This information included groundspeed, aircraft track,

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52 There were no maintenance requirements to test the configuration settings such as flaps and landing gear position sensors, even though they performed important functions within the GPWS. For example, if the flap position switch was set incorrectly or was malfunctioning, the mode 2 warning envelope could reduce from mode 2A to mode 2B at an incorrect point on the approach and reduce the time available to warn the crew of an excessive closure rate with terrain.

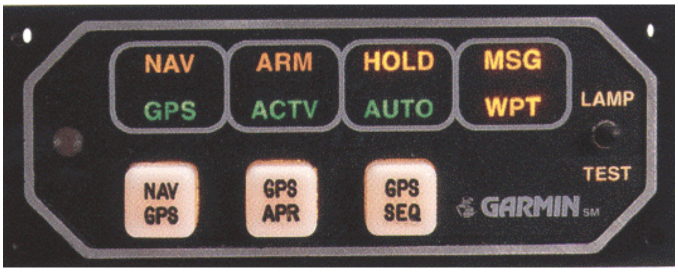
53 The *Aeronautical Information Publication* (AIP) was a suite of Australian operational documents used by pilots. The AIP contained the rules of the air and air traffic control procedures related to relevant Civil Aviation Regulations, Civil Aviation Orders, Air Services Regulations and Air Navigation Regulations.

distance, bearing and time to the next waypoint and a graphical course deviation indicator (CDI). Waypoint information was either user input or stored in a navigation database on a replaceable datacard. Selection of navigation data and presentation of the navigation information was controlled by the pilot using a series of function keys and rotary knobs on the face of the unit. The display also presented various messages regarding the navigation mode and operational status of the receiver.

Figure 12: Garmin GPS 155XL receiver display unit

The MD41 annunciation control unit (Figure 13) was a combined annunciation and switching unit that allowed the pilot to select the navigation source (GPS or ground-based VHF navigation aids (NAV)) for presentation on the pilot in command's HSI, manually arm and disarm a non-precision approach, and hold the automatic sequencing of waypoints. The unit also provided annunciation of the selected navigation source (GPS or NAV), the approach status (armed or active), the status of the automatic sequencing of waypoints (hold or auto) and advisory annunciation to alert the pilot that the receiver display unit had a message and that a waypoint was being approached. The MD41 was located on the pilot in command's side of the instrument panel (Figure 7).

Figure 13: MD41 annunciation control unit



The pilot in command's HSI could present course deviation indication based on information derived from the GPS receiver. When GPS was selected for display on the pilot in command's HSI, the CDI reflected the graphical CDI displayed on the receiver display unit. GPS derived information could not be presented on the copilot's HSI on VH-TFU.

Waypoint coordinates for RNAV (GNSS) non-precision approaches were stored in a navigation database on a data card, similar to a computer flash memory card. The data card was inserted into the GPS receiver display unit. The data card waypoint coordinates could not be edited by the flight crew. Jeppesen provided an updated database for the GPS receiver every 28 days. Transair's Operations Manager in Brisbane downloaded the updated database and refreshed the Garmin GPS data cards, which were then forwarded to the Cairns Base. At Cairns, the data cards were inserted into the aircraft's GPS unit by one of Transair's pilots. The database in use in the aircraft at the time of the accident was valid from 14 April 2005 until 12 May 2005. It was standard practice for Transair pilots to verify that the correct database was in place before programming the GPS prior to the commencement of each flight.[54]

There were no problems reported by Transair's pilots with this database. The investigation subsequently verified that the co-ordinates for the Lockhart River Runway 12 RNAV (GNSS) approach waypoints were correct.

System integrity

The GPS receiver display unit verified the integrity of the satellite signals it received through an inbuilt software function called receiver autonomous integrity monitoring (RAIM). The RAIM function used satellites additional to those used in the position solution to determine if any of the satellite signals were corrupted. For RAIM to function, the receiver needed a minimum of five satellites in view, or four satellites and barometric altitude.[55] The receiver display unit provided three messages regarding RAIM: *RAIM not available*, *RAIM position warning* and *No RAIM FAF to MAP* [final approach fix to the missed approach point]. *RAIM not available* meant that there were insufficient satellites in view to perform the RAIM function for the current phase of flight. *RAIM position warning* informed the pilot that the RAIM function had detected position errors exceeding those allowed for the phase of flight. In both cases the pilot was to revert to an alternate source of navigation. The *No RAIM FAF to MAP* would be displayed when RAIM was predicted to be unavailable for a non-precision approach and the approach phase would not arm.[56]

1.6.13 Cockpit annunciator panel

A multi-segment annunciator panel was positioned in the top-centre of the instrument panel immediately below the glare shield (Figure 7). The annunciator panel provided colour-coded warnings (red), alerts (yellow/amber) and advisory (green) lights for various aircraft systems (Figure 14). Each of the coloured glass segments had two incandescent bulbs to provide a backlight. The panel in VH-TFU utilised 43 of the 48 segments available.

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54 The expiry date of the database was displayed on the start-up pages of the GPS unit when it was switched on.

55 To provide a higher level of redundancy in the RAIM function, TSO-C129a certified receivers require barometric aiding from an altitude source on the aircraft. The barometric height obtained from the altitude source and the local barometric pressure could be compared with the GPS derived altitude as part of the integrity monitoring function. The GPS receiver in VH-TFU obtained digital altitude data from the pilot in command's encoding altimeter.

56 The RAIM prediction function was an in-built software function which used the satellite orbital parameters to predict ahead in time if RAIM would be available. TSO-C129a required that the receiver automatically perform a RAIM prediction 2 NM before the final approach fix. This function also had to be available to the pilot, upon request, to determine if RAIM would be available at the destination within 15 minutes each side of the estimated time of arrival.

Figure 14: Cockpit annunciator panel representation

L ENG FIRE	R ENG FIRE	CABIN DOOR	L BETA	R BETA	LOW SUCTION	L INTAKE HT	R INTAKE HT
L WING OVHT	R WING OVHT	BATT FAULT	L CHIP DET	R CHIP DET	———	L W/S HT	R W/S HEAT
L OIL PRESS	R OIL PRESS	———	L XFER PUMP	R XFER PUMP	GPU PLUG IN	AWI NO 1 PUMP ON	AWI NO 2 PUMP ON
L HYD PRESS	R HYD PRESS	CARGO DOOR	L BATT DISC	R BATT DISC	L SRL OFF	NWS	SAS DE-ICE
———	———	SAS SERVO FAIL	L AC BUS	R AC BUS	R SRL OFF	L SAS FAIL	R SAS FAIL
CABIN ALT	GEAR DOOR POSITION	———	L GEN FAIL	R GEN FAIL	NWS FAIL	L FUEL FILTER	F FUEL FILTER

1.6.14 Emergency locator transmitter

VH-TFU was fitted with an Artex ELT 110-4 emergency locator transmitter that was mounted at the back of the rear baggage compartment, in the tail-cone area.

1.6.15 Serviceability of the cockpit instruments and systems

A review of the aircraft's maintenance documentation indicated that for the period from 8 January to 6 May 2005 there were no reported unserviceabilities with the above listed cockpit instruments and systems. The copilot's flight instrument lighting was recorded as unserviceable (see Section 1.6.17).

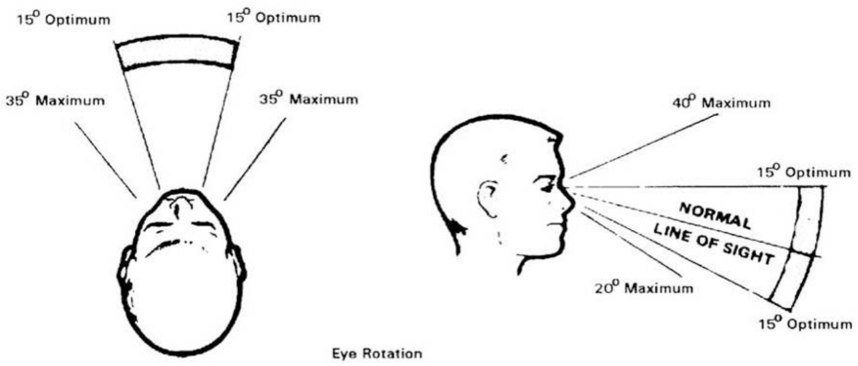
1.6.16 Pilot field of view

The US Federal Aviation Regulations (FAR 23.1321) stated that:

> Each flight, navigation, and powerplant instrument for use by any required pilot during takeoff, initial climb, final approach, and landing must be located so that any pilot seated at the controls can monitor the airplane's flight path and these instruments with minimum head and eye movement.

The FAA Advisory Circular 23.1311-1B, *Installation of electronic displays in Part 23 airplanes*, stated that a pilot's primary *optimum* field-of-view was 15 degrees to the left and right, and above and below, a pilot's normal line of sight (Figure 15). The normal line of sight was defined as straight ahead and 15 degrees below the horizontal. The primary optimum field-of-view was based on the area that can be seen with eye rotation only, and was 'normally reserved for primary flight information and high priority alerts'.

Figure 15: Primary optimal and maximum vertical and horizontal fields of view



The primary *maximum* field-of-view was defined as +/- 35 degrees horizontally and 40 degrees above and 20 degrees below the pilot's normal line of sight. The primary maximum field-of-view was based on eye rotation and limited head rotation, and was 'normally used for important and frequently used information'. The advisory circular stated that warnings and cautions can be presented within 35 degrees when they were associated with a unique aural tone or master warning/caution light within 15 degrees.[57]

Radio altitude indicator location

The radio altitude indicator was estimated to be positioned about 19 degrees below the pilot in command's normal line of sight. There was no radio altitude indicator on the copilot's side of the cockpit. The radio altitude indicator was about 39 degrees left of the copilot's straight-ahead line of sight.

Ground proximity warning system annunciator/switches location

The GPWS cockpit annunciators and switches were estimated to have been 41 degrees to the left of the copilot's normal line of sight. The installation documentation required that they should be positioned in approximately the centre of the instrument panel in an area where both pilots' normal field of view overlapped.

CAO 108.36 required that the visual warnings for GPWS modes 1 through 4 should be in the *'field of view'* [58] of both pilots. CASA indicated to the investigation that it considered the annunciators to be in the field of view of both pilots due to the small size of the Metro 23 cockpit and the small space between the pilots.

Global positioning system location

The GPS receiver display unit was installed in the centre instrument panel to the right of the engine instruments. This unit was estimated to be 29 degrees to the right of the pilot in command's normal line of sight and 19 degrees to the left of the copilot's normal line of sight.[59] The Transair chief pilot reported that the GPS display could be difficult to read from the left seat of VH-TFU by the handling

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57 FAA AC 23.1311-1B, *Installation of electronic displays in Part 23 airplanes*, was released after the accident (14 June 2005). The preceding advisory circular (AC 23.1311-1A, released 12 March 1999) did not define primary *optimum* and *maximum* fields-of-view, but indicated that a pilot's 'primary field-of-view' in relation to primary flight controls was considered to be +/- 30 degrees horizontally from the centreline of the pilot's seat forward. The definitions provided in AC 23.1311-1B were consistent with guidance provided by the FAA's *Human Factors Design Standard* (DOT/FAA/CT-03/05) released May 2003 and the US Department of Defense's *Design Criteria Standard, Human Engineering* (MIL-STD-1472F) released in August 1999 (first published in 1968).

58 CASA indicated to the investigation that the term *'field of view'* as described in CAO 108.36, paragraph 3.8, meant that the pilot in command was able to see it and it was not obscured from the view of the copilot. It did not specify a required field of view.

59 Estimated fields of view were based on measurements taken by the investigation of distances to the middle of each display on the instrument panel in a Metro 23 cockpit from the eyes of people that were about the same height as the two pilots involved in the accident. Angles were calculated using trigonometry and the distances measured. The estimated field of view to a cockpit instrument will vary depending on the seat position.

pilot, especially in turbulence. However, other pilots could not recall having any difficulty reading the GPS from the left seat in VH-TFU.

The MD41 annunciation control unit was estimated to be 17 degrees below the pilot in command's normal line of sight and 39 degrees left of the copilot's normal line of sight.

1.6.17 Aircraft airworthiness and maintenance

Aircraft history

A review of the aircraft maintenance documentation showed that the aircraft had been imported from the United States and issued with an Australian certificate of airworthiness on 4 July 2003. At that time, the aircraft had a total time in service of 24,704.7 hours and 27,078 cycles.

Aircraft system of maintenance

The aircraft had been maintained as a Class A aircraft[60] in accordance with Transair's approved system of maintenance. The system of maintenance was contained in Transair's maintenance manuals and had been approved by CASA under the provisions of CAR 42M.

The approved system of maintenance for Transair's Metro aircraft was based on the aircraft manufacturer's scheduled inspection program, which comprised six phase inspections. The inspections were to be conducted every 170 hours aircraft time in service, with all six inspections being completed over a 1,020 hour cycle every 12 months. The approved system of maintenance included a Class B aircraft[61] radio inspection. That inspection was an IFR radio inspection based on a radio category inspection schedule contained in the Civil Aviation Advisory Publication (CAAP) 42B-1(0), *CAA Maintenance Schedule*.[62] The IFR radio inspection was scheduled for completion every 340 hours aircraft time in service. The aircraft manufacturer also provided an avionic inspection schedule as part of the inspection program but this schedule was not used by Transair.[63] Although the maintenance provider used the CAAP schedule, all avionics systems and component inspections of VH-TFU were carried out in accordance with the

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60 CAR 2(1) defined the term Class A aircraft to mean '… an Australian aircraft, other than a balloon, that satisfies either or both of the following paragraphs:
(a) the aircraft is certificated as a transport category aircraft;
(b) the aircraft is being used, or is to be used, by the holder of an Air Operator's Certificate which authorises the use of that aircraft for the commercial purpose.'

61 CAR 2(1) defined the term Class B aircraft as meaning an Australian aircraft that was not a Class A aircraft.

62 CAR 42B provided that the Certificate of Registration holder of Class B aircraft could elect to use the CASA Maintenance Schedule, which was included as Schedule 5 to the CARs. CAAP 42B-1(0) contained that schedule, modified to include provision for the certification of each task and a final category and co-ordination certification thereby permitting its use as a worksheet. CAAP 42B was not intended for the maintenance of Class A aircraft.

63 CASA issued Airworthiness Bulletin AWB 02-003 (2) after the accident in June 2006, which stated that '… the CASA Maintenance Schedule does not replace the manufacturer's maintenance schedule…'. The aircraft manufacturer of VH-TFU had issued an avionics maintenance schedule.

manufacturers' approved maintenance data and CASA's airworthiness directives and other requirements.

Aircraft maintenance history

A review of the maintenance records for VH-TFU showed that all scheduled maintenance was done in accordance with Transair's approved system of maintenance. All applicable airworthiness directives were carried out and the manufacturer's service bulletin information was transcribed into the maintenance instructions.

The aircraft was issued with a Transair maintenance release on 17 April 2005. The maintenance release was valid until 17 April 2006 or 26,975.8 hours, whichever came first. Transair's *Flight/Maintenance Log*, which was carried onboard the aircraft, was completed by flight crew whenever there was a maintenance issue with the aircraft. Copies of the log were normally forwarded to Transair's maintenance controller and maintenance provider at the completion of each day's operations. Any entry in the log, other than a permissible unserviceability or an unserviceability listed in Transair's approved minimum equipment list (MEL), would result in the aircraft being deemed unserviceable until the defect was rectified and the entry signed off by a licensed aircraft maintenance engineer.

The last recorded entry in the *Flight/Maintenance Log* for VH-TFU was on 5 May 2005 regarding the unserviceability of the copilot's flight instrument lighting. The instruments affected were the copilot's altimeter, airspeed indicator, turn and slip indicator, vertical speed indicator, and radio selector lighting. The unserviceability was covered by the MEL, which permitted operation of the aircraft with those lights being unserviceable. The MEL required rectification work on the lights to be carried out by 16 May 2005. The unserviceability did not affect the GPS receiver lighting.

An extensive search was conducted at the accident site for aircraft documentation, but the original *Flight/Maintenance Log* was not located, and very little documentation was recovered from the site due to the post-impact fire. There was no evidence found in the aircraft maintenance documentation of any pre-existing defects that may have contributed to the accident. There was no evidence found in the maintenance documentation to indicate that the aircraft was not serviceable at the commencement of the accident flight.

1.6.18 Weight and balance

Regulatory requirements regarding load sheets

CAO 20.16.1 required that both the operator and the pilot in command were to ensure that a load sheet was carried in the aircraft and, for those aircraft engaged in RPT services, that a copy of the load sheet was retained on the ground at the aerodrome of departure. The primary purpose of leaving a load sheet was to assist investigations in the event of an accident.

Transair practices

The *Transair Operations Manual* stated that the pilot in command shall 'ensure the load sheet is carried in the aircraft and that a copy is retained on the ground at the aerodrome of departure'. However, several current and former Transair pilots reported that they did not leave load sheets at the aerodromes on the Cairns – Lockhart River – Bamaga route, and one supervisory pilot who occasionally operated on the route stated that they were not required to leave a copy of the load sheet. Another supervisory pilot, who operated into Bamaga on a few occasions more than a year before the accident reported that he left load sheets with the Aero-Tropics agent. The Aero-Tropics agent at Bamaga reported that Transair crew never left load sheets at Bamaga.

Accident flight weight and balance

A copy of the load sheet for the accident flight from Bamaga to Lockhart River for VH-TFU on 7 May 2005 was not located at Bamaga and a copy was not found at the accident site. While a load sheet relating to the accident flight was not available, the investigation estimated that the weight of the aircraft at the time of the accident was below the maximum take-off and landing weights specified in the aircraft's *Approved Airplane Flight Manual*. The centre of gravity position could not be conclusively determined (see Appendix D).

1.6.19 Autopilot

CAO 20.18 required that an aircraft engaged in RPT operations under IFR had to be equipped with an approved automatic pilot unless the aircraft was equipped with fully functioning dual controls and two control seats. In that case, the second seat was to be occupied by a pilot who held a commercial pilot (aeroplane) licence or an air transport pilot (aeroplane) licence, with an endorsement for that type of aeroplane and at least a copilot (aeroplane) instrument rating.

VH-TFU was not fitted with an autopilot, nor was an autopilot required to be fitted by provisions of CAO 20.18 and CAO 82.3. Other Metro operators reported that the autopilots available for Metro aircraft at the time of the accident were limited in capability.

1.6.20 Terrain awareness and warning system

The terrain awareness and warning system (TAWS), also known as predictive GPWS or enhanced GPWS (EGPWS), was an improvement on the conventional ground proximity warning system. VH-TFU was not fitted with TAWS, nor was this system required to be installed in the aircraft at the time of the accident.

System description

TAWS was capable of providing increased warning time to pilots about potential terrain conflicts by incorporating additional functions into the conventional ground proximity warning system. TAWS also enhanced pilot situational awareness by providing coloured terrain information on a continuous terrain display in the cockpit. CAO 20.18 required that the TAWS fitted to Australian aircraft had to meet the standard for the Class A TAWS specified in the FAA TSO C-151, TSO C-151a or TSO C-151b.[64]

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64 FAA TSO-C151 *Terrain Awareness and Warning System*. Class B TAWS was intended for fitment to small general aviation aircraft.

The Class A TAWS system was required to provide the same six modes of alerting as the TSO-C92b GPWS systems (see Section 1.6.11) and have an additional two functions: the forward looking terrain avoidance function, and the premature descent alert function.

The forward looking terrain avoidance function compared the aircraft's present position and flight path, using data from the aircraft's GPS receiver, with a terrain database to compute if there were any potential conflicts with the terrain. The function 'looked' along and below the aircraft's lateral and vertical flight path and provided suitable alerts and warnings if a potential conflict with terrain existed.

The premature descent alert function compared the aircraft's current position and flight path with an aerodrome database to determine if the aircraft was hazardously below the normal approach path for the nearest runway.

The Class A TAWS coloured continuous terrain display provided the pilots with a graphical presentation of terrain information (see Appendix F). The continuous terrain display also provided indications of imminent contact with the ground for excessive rates of descent; excessive closure rate to terrain; negative climb rate or altitude loss after takeoff; flight into terrain when not in a landing configuration; and excessive downward deviation from an ILS glideslope.

Comparison of TAWS and GPWS

Appendix F includes simulations using a Honeywell EGPWS (TAWS Class A equipment). These simulations show the increased flight crew alerting times for the accident flight profile as compared with the conventional GPWS. Other advantages of TAWS compared with standard GPWS were:

- improved situational awareness of the terrain being provided by the continuous terrain display (conflicting terrain would have been indicated by a solid red area on the display); and
- improved reliability as the TAWS forward-looking terrain avoidance functions relied on GPS data rather than a radio altimeter.

The Flight Safety Foundation[65] defined the term 'controlled flight into terrain' (CFIT) as when 'an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew'. The US Department of Transportation Volpe Center conducted a study of nine CFIT accidents and the potential of TAWS to prevent those accidents.[66] The study showed that TAWS would have provided the same or increased warning durations as compared with GPWS if each aircraft continued along the accident track, and should have provided sufficient warning to effectively prevent the accidents studied.

The study emphasised that the accident prevention in all cases would have resulted not so much from increased warning durations following the system detection of terrain threats, but from the flight crews perceiving these terrain threats from the

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65 The Flight Safety Foundation is an independent, non-profit, international organisation engaged in research, auditing, education, advocacy and publishing to improve aviation safety.

66 Cited in US Department of Transportation (Federal Aviation Administration), *14 CFR Parts 91, 121, 135 Terrain Awareness and Warning System; Final Rule*. Federal Register, Vol. 65, No. 61, Wednesday, March 29, 2000, Rules and Regulations, pages 16735-16756.

continuous terrain display and responding to them well before TAWS was required to generate warnings.

Regulatory requirements

In November 1996, CASA issued a discussion paper on the fitment of GPWS to turbine powered aircraft that were over 5,700 kg or authorised to carry more than nine fare-paying passengers. In 1996 the Australian regulatory requirements regarding GPWS only covered turbine aircraft that were above 15,000 kg or authorised to carry more than 30 fare-paying passengers.

The CASA discussion paper resulted from an amendment to ICAO Annex 6, which required GPWS to be fitted to these aircraft from 1 January 1999. The amendment was the result of ICAO's concern about the increasing number of CFIT accidents that were occurring around the world. CASA indicated in the discussion paper that it supported the fitment of GPWS to turbine powered aircraft above 5,700 kg and those aircraft authorised to carry more than nine passengers from 1 January 1999.

In October 1998, CASA amended CAO 20.18 to include the requirement to fit GPWS to aircraft above 5,700 kg or carrying more than nine passengers in commercial operations by 1 October 1999. Following developments in the technology associated with GPWS, TAWS was starting to be developed and manufacturers indicated that this type of equipment would become available for fitment in mid 2000.

In May 1999, the Regional Airlines Association of Australia (RAAA) asked CASA to consider an exemption from fitting the older technology GPWS to meet the 1 October 1999 deadline. During these discussions the RAAA offered to have operators undertake to fit 'predictive GPWS' (or TAWS) in affected aircraft by 1 January 2001. CASA agreed to the proposal and amended CAO 20.18 on 6 September 1999 to incorporate the 2001 deadline for TAWS.

CASA advised operators that there was no legal means available to permit operators to continue normal operations in affected aircraft after 1 October 1999 unless GPWS was fitted or the operator had undertaken to fit TAWS by 1 January 2001. Those operators who gave an undertaking to fit TAWS by January 2001, and not install GPWS, had to provide a CFIT awareness training course to their pilots, and this course had to be included in the operator's operations manual by 1 October 1999.

In August 2000, the RAAA advised CASA that some of the affected aircraft that were required to be fitted with TAWS by 1 January 2001 had not been issued with a FAA Supplemental Type Certificate (STC) for the fitment of TAWS or that it was unlikely that the equipment would be developed to meet the deadline. It was reported that the Metro 23 aircraft was one of those aircraft that did not have an STC for the fitment of TAWS.

CASA amended the CAO 20.18 on 23 October 2000 to require those operators of aircraft affected by the lack of an STC to fit conventional GPWS in lieu of TAWS by 1 January 2001. To be covered by this amendment, CASA required operators to have a statement in writing from the manufacturer of an approved TAWS that the operator's affected aircraft did not have an STC covering the fitment of the TAWS. The October 2000 amendment also included a requirement to fit TAWS by the end of June 2005. The requirements for CFIT awareness training no longer applied after 31 December 2000.

CASA reported that several operators requested exemptions or extensions to the CAO 20.18 requirement to install TAWS by the end of June 2005, but all of these requests had been refused.

Proposed installation of TAWS on Transair aircraft

In accordance with the September 1999 amendment to CAO 20.18, Transair advised CASA on 24 September 1999 that:

- Transair pilots would be provided with CFIT awareness training using a video presentation;
- the *Transair Operations Manual* would be amended to reflect this training requirement; and
- Transair would be fitting ‘predictive GPWS’ to its aircraft.

A review of a sample of Transair pilot files found that one pilot employed prior to the end of 2000 had completed CFIT awareness training in December 1999. No record of such training existed for another pilot employed in December 1999. The relevant section of the *Transair Operations Manual*, dated October 2000, did not include a training syllabus for CFIT awareness training and it did not mention the video stated in the letter to CASA (see also Section 1.17.8).

During the investigation, Transair reported that it was intending to comply with the CAO 20.18 requirement to install a Class A TAWS in VH-TFU by 30 June 2005.

1.7 Meteorological information

1.7.1 Area forecast

The valid Bureau of Meteorology (BoM) forecast that was available to the crew prior to departure from Cairns, for meteorological forecast area 45[67], indicated that there would be isolated showers in the area until 1200. The wind direction up to FL 140 was from the south-east and wind speeds were between 15 and 20 kts. The forecast indicated broken stratus cloud with a base of 1,000 ft and tops of 3,000 ft in precipitation. There was scattered[68] cumulus 2,000 to 9,000 ft with the base at 4,000 ft over land. There was also scattered stratocumulus 4,000 to 8,000 ft over the sea and east coast ranges, becoming locally broken. The visibility for this forecast indicated 4,000 m in showers of rain.

1.7.2 Aerodrome forecasts

Original aerodrome forecast

On 7 May 2005, the BoM issued a terminal aerodrome forecast (TAF) for Lockhart River aerodrome at 0416 local time, with a validity period from 0600 to 1800 local time. The forecast wind was from 120 degrees true at 14 kts; visibility 10 km or greater; light rain showers; and cloud, three to four eighths sky coverage, with a

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67 Meteorological forecast area 45 included the route from Cairns to Bamaga.

68 Scattered referred to 3 to 4 eighths of the sky obscured by cloud.

cloud base of 3,000 ft above aerodrome elevation. The temperature and QNH, forecast for the time of the accident, were 28 degrees C and 1013 hPa, respectively.

Amended aerodrome forecast

The BoM issued an amended terminal aerodrome forecast for Lockhart River aerodrome at 0921 local time, with a validity period from 0900 to 1800 local time. The forecast wind was from 130 degrees true at 15 kts, gusting to 25 kts; visibility 10 km or greater; light rain showers; cloud of one to two eighths coverage with a base of 1,000 ft and five to seven eighths coverage with a base of 2,500 ft above aerodrome elevation. The temperature and QNH, forecast for the time of the accident, were 27 degrees C and 1012 hPa.

For periods of 30 minutes or more, but less than one hour, between 0900 and 1200, the visibility was forecast to be 4,000 m in moderate rain showers, and the cloud cover broken with a base of 1,000 ft above aerodrome elevation.

For periods of less than 30 minutes, between 1200 and 1800, the visibility was forecast to be 4,000 metres in moderate rain showers, and the cloud broken coverage with a base of 1,000 ft above aerodrome elevation.

Provision of weather information to crew

At 0932, Brisbane ATC advised the crew:

> Tango foxtrot uniform…hazard alert[69] for you. An amended aerodrome forecast has just come out on Lockhart River. It now has a tempo period[70] from two three zero zero till zero two zero zero [0900 to 1200 local time]. Visibility four thousand metres, moderate rain, cloud broken one thousand, and it also shows wind gusts in the main body of the TAF. Wind one three zero degrees, one five, gusting two five knots.

The pilot in command acknowledged the ATC transmission and requested the QNH. The controller advised that the QNH from 0900 local time was 1013 hPa.

1.7.3 Actual weather information

Automatic weather station data

The BoM Automatic Weather Station (AWS) located at the Lockhart River aerodrome was configured to record weather data at 10-minute intervals. It recorded wind, temperature and rainfall data, but did not include visibility or cloud base information.

During the period from 1130 until 1140, which included the descent and commencement of the instrument approach, the AWS recorded the following data: average wind direction 130 degrees; average wind speed 12 kts, maximum wind

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69 Hazard alerts relating to weather were issued by air traffic services personnel when observations, pilot reports, or amended forecasts at the destination had unexpectedly deteriorated below the instrument flight rules or visual flight rules alternate minima.

70 Tempo period referred to temporary fluctuations in meteorological conditions, lasting for periods of 30 minutes or more, but less than 1 hour in each instance. This covered the period when VH-TFU was making the approach to land.

speed 17 kts; air temperature from 24.2°C to 25.0 degrees C; and QNH 1013.2 hPa. There was no rainfall recorded at the station between 1130 and 1140.

During the period from 1140 until 1150, which encompassed the estimated time when the aircraft collided with the terrain, the AWS recorded the following data: average wind direction 136 degrees; average wind speed 9 kts; maximum wind speed 14 kts; air temperature from 24.6°C to 26.0 degrees C; and QNH 1013.1 hPa. There was no rainfall recorded at the station between 1140 and 1150.

The AWS information was available to flight crew via telephone, however it was not broadcast on any radio frequency. Examination of the telephone records for the mobile phones held by both flight crew revealed that they had not dialled the listed number for the Lockhart River aerodrome weather information service (AWIS) on the morning of the accident.

Pilot observation

The pilot of VH-PAR, who flew to the east of Lockhart River about 30 minutes before the accident, reported the cloud base was generally 1,000 ft and conditions were clear. However, in the vicinity of the aerodrome there was a significant rain shower and it was not possible to remain in VMC. Over the coast, the cloud was scattered and he estimated the base was between 2,000 and 3,000 ft.

At 1140, when the pilot was approaching Lockhart River from the north, he asked the crew of VH-TFU for an appreciation of weather conditions. He could not understand the transmission he received in response (see Section 1.1). On his arrival at Lockhart River, the pilot reported that the weather was fine, but he did not notice if the hills to the west of the aerodrome were obscured. Later, when taxiing for departure, the pilot reported that the hills were clear and that on climb-out he entered cloud at 2,000 ft and that the cloud tops were 7,000 or 8,000 ft.

Bureau of Meteorology observations

Observations were made at the aerodrome at 0900, 1200 and 1500 on the day of the accident by a BoM approved meteorological observer. The Lockhart River observer did not have the capability to communicate with pilots using radio or any other means of telecommunication equipment while an aircraft was in flight.

The 0900 synoptic observation was recorded as: temperature 25.3 degrees C; dew point[71] temperature 24.1 degrees C; mean sea level pressure 1013.4 hPa; wind from the south-east at 10 kts; rainfall 1.6 mm; present weather, slight intermittent drizzle; past weather, slight intermittent drizzle; cloud 6 eighths of stratus cloud with a base of 600 ft above ground level, total cloud cover 6 eighths.

The 1200 synoptic observation was recorded as: temperature 25.4 degrees C; dew point temperature 23.5 degrees C; mean sea level pressure 1012.8 hPa; wind from the south-east at 8 kts; rainfall 0.4 mm; present weather, rain within past hour; past weather, moderate intermittent rain. No cloud information was recorded by the observer.

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71 Dewpoint referred to the temperature at which, under ordinary conditions, condensation began to occur in a cooling mass of air.

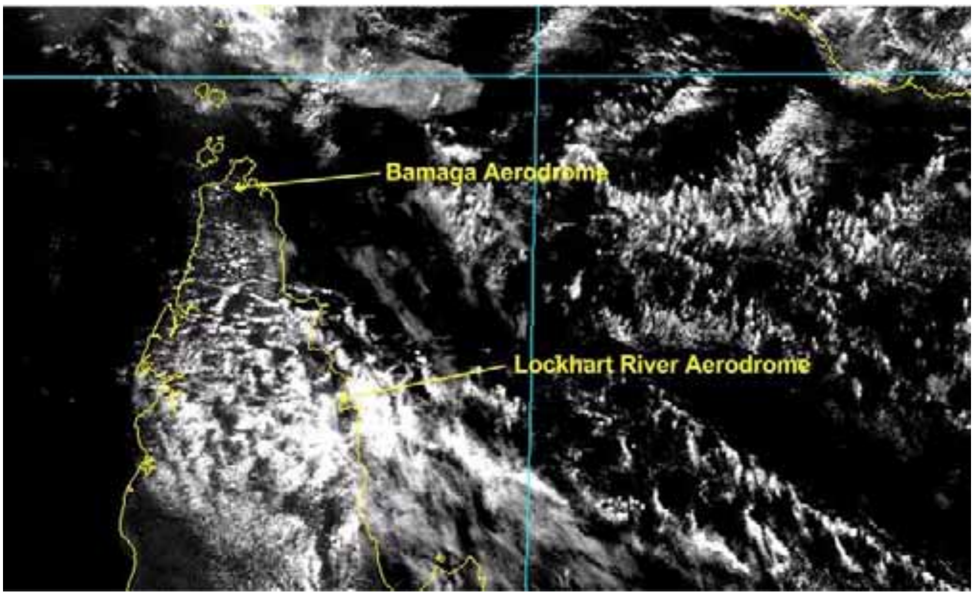
Satellite imagery

The visible satellite imagery covering the Cape York region at 1125 on the day of the accident is shown in Figure 16.

Bureau of Meteorology estimation of actual weather conditions

Based on the AWS recordings between 1100 and 1200, the 0900 observer's report and the visible satellite image at 1125, the BoM estimated that the weather conditions in the Lockhart River area at the time of the accident were overcast, with broken low cloud with a base between 500 ft and 1,000 ft AMSL. The wind was estimated to be from the south-east at between 10 and 15 kts, with occasional squally rain showers and intermittent drizzle. Those general conditions were confirmed by people at Lockhart River.

Figure 16: Satellite picture 1125, 7 May 2005



1.8 Aids to navigation

1.8.1 Global navigation satellite systems

Background

Global navigation satellite systems (GNSS) are capable of very accurate position fixing using a constellation of orbiting satellites. The first operational satellite system was the Global Positioning System (GPS) operated by the US Department of Defence. GPS uses a passive ranging method with the satellites being the active transmitters and the aircraft equipment being the passive receiver. The receiver calculates the position of the aircraft using the known position of four or more satellites and the times of arrival of the signals from each of those satellites. The GPS has been used in Australian aviation as a source of primary means navigation since December 1995 for en-route IFR navigation and since January 1998 for non-precision approaches.

System integrity

The integrity of the GNSS was based on its ability to provide warnings to flight crew if a GPS satellite was transmitting erroneous signals.

The availability of the aircraft GPS receiver RAIM function (see Section 1.6.12) was dependent on the number and geometry of satellites visible to the receiver. Airservices Australia[72] (Airservices) provided a RAIM Prediction Service for flight planning purposes for aerodromes with an approved RNAV (GNSS) approach. No RAIM outages were predicted for Lockhart River aerodrome on the day of the accident. The pilot of an aircraft engaged on an unrelated search and rescue mission approximately 200 NM east of Lockhart River aerodrome reported a 'RAIM failure' between 1120 and 1150, which lasted for between 10 and 50 seconds.

Examination of the recorded satellite data for the duration and route of the accident flight found that there were no system anomalies and that the satellite constellation provided adequate signals for navigation. There were ten satellites in view at Lockhart River at the time of the accident, all with an elevation greater than 5 degrees above the horizon.

An indicator of how close the GPS satellite constellation was to the optimum geometric relationship with the aircraft receiver was the Dilution of Precision (DOP) figure. The horizontal value of DOP (HDOP) indicated the level of accuracy of the latitude and longitude computations by the GPS receiver. A low value of HDOP indicated better constellation geometry and a lower error in position computations. The calculated HDOP at Lockhart River at the time of the accident was less than 1, and would have resulted in little effect on the accuracy of lateral navigation information being provided by the aircraft's GPS receiver.

Interference

The possibility that navigation information provided to the crew from the aircraft's GPS receiver was corrupted by on board use of portable electronic devices was examined. The investigation reviewed all mobile telephone activity at the Lockhart River base station. No telephone calls were recorded as being transmitted through this base station during the latter part of the accident flight.

RNAV (GNSS) approach procedure

The runway 12 RNAV (GNSS) approach to Lockhart River permitted a straight-in approach to the runway via a series of waypoints (see Figure 2 page 2). Due to the surrounding topography, the final approach track was offset by 5 degrees to the north of the extended runway centreline and had a steeper descent profile than the standard approaches. Additionally, the final leg was 7 NM in length, 2 NM longer than optimum. Each segment of the approach had a minimum safe altitude, however, the final segment of this approach had three altitude limiting steps due to the terrain. Each step within the final segment was defined by a distance to run to

72 Airservices Australia was the air traffic services provider.

the missed approach waypoint (MAPt)[73], and each had a progressively lower segment minimum safe altitude. Guidance in the form of a table showing altitude against distance to each waypoint provided a descent profile of 3.49 degrees to the runway threshold.

When conducting a non-precision instrument approach procedure, the lowest altitude to which pilots descend the aircraft was known as the minimum descent altitude (MDA).[74] The MDA was calculated to provide the aircraft with clearance from obstacles in the appropriate section of the approach. Most Australian instrument approach procedures had two MDAs. The higher MDA was to be used with the QNH obtained from weather forecasts. If an actual aerodrome QNH was obtained from an approved source, the pilot could use the lower MDA, which was normally 100 ft lower. Use of this lower MDA required that the pilot obtain an actual QNH prior to passing the initial approach fix of the instrument approach procedure.

Approved sources of actual QNH were: air traffic control; automatic terminal information service (ATIS); aerodrome weather information service (AWIS); and BoM-approved meteorological observers. A QNH obtained from an approved source was only valid for 15 minutes from the time of receipt. The two MDAs published for the Lockhart River Runway 12 RNAV (GNSS) approach procedure were 1,040 ft if using forecast aerodrome QNH, and 940 ft if using actual aerodrome QNH. As the crew of VH-TFU did not have an actual QNH within the previous 15 minutes, the applicable MDA was 1,040 ft.

There was also a runway 30 RNAV (GNSS) approach that permitted a straight in approach to the runway via a series of waypoints. The MDA for a straight in approach to runway 30, using the forecast aerodrome QNH, was 830 ft and 1,160 ft for a circling approach.

1.8.2 Ground-based navigation aids

Lockhart River aerodrome was serviced by a ground based non-directional beacon (NDB) for which an instrument approach procedure had been designed. There were no notices to airman (NOTAMs) issued by Airservices valid on the day of the accident indicating that there were any operational abnormalities with the NDB. There were no reports received to indicate any failure or malfunction of the NDB on the day of the accident.

The aircraft was equipped with an automatic direction finding (ADF) receiver that was able to display the bearing of the aircraft from the NDB. The *En-Route Supplement Australia*[75] indicated that the range of the NDB was 30 NM over land. A notice in the same section indicated that fluctuations in the bearing indication of up to 30 degrees could be expected from 8 NM in the sector approaching the NDB

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73 The missed approach waypoint was the point on the instrument approach procedure that signified where, if the required visual reference was not established, the flight crew had to immediately initiate the published missed approach procedure.

74 Minimum descent altitude (MDA) was the specified altitude on a non-precision approach or circling approach below which descent could not be made without the required visual reference. Minimum descent altitude was referenced to mean sea level.

75 The *En-Route Supplement Australia* was an Australian operational document published by Airservices and used by pilots.

of between 300 and 325 degrees magnetic. The track of the aircraft from Bamaga was outside that sector.

NDB approach procedure

A Runway 30 NDB instrument approach chart was published for Lockhart River. It described an instrument let-down procedure for aircraft equipped with an ADF, such as VH-TFU. The procedure was designed to permit descent from overhead the NDB on an easterly heading over the lower coastal terrain. The outbound leg was limited to a time interval of 3 minutes before a turn inbound to the NDB, for descent to the MDA. If a pilot made visual contact with the ground, a landing could be made on runway 30 or the aircraft could be circled to land on runway 12. The MDA for a circling approach was 1,160 ft, the same as the circling MDA for the RNAV (GNSS) approach. If a pilot did not make visual contact with the ground by the MDA, the aircraft was required to be tracked to the NDB and a missed approach conducted from overhead the NDB, while turning onto an easterly heading.

1.8.3 Instrument approach charts

Pilots employed by Transair were expected to use charts produced by Jeppesen and both pilots of VH-TFU held current subscriptions to the Jeppesen chart amendment service. Although those charts were produced by Jeppesen, they were developed from data published by Airservices Australia. Due to the impact damage and post-impact fire, the investigation was unable to conclusively determine whether both pilots were carrying and using the appropriate charts for the flight.

1.9 Communications

All communications between air traffic control (ATC) and the crew were recorded by ground-based automatic voice recording equipment for the duration of the flight. Radio transmissions made by the crew on the Lockhart River common traffic advisory frequency (CTAF) were recorded on the aerodrome automatic voice recording equipment (see Appendix E). The sound quality of the aircraft's recorded transmissions was generally good. A review of radio transmissions from the aircraft did not indicate any aircraft anomalies.

1.10 Aerodrome information

Lockhart River aerodrome was a licensed aerodrome. It was 77 ft above mean sea level and had a single runway that was aligned in the 12/30 (119 degrees/299 degrees magnetic) direction. The runway width was 30 m and the length was 1,500 m. The runway strip width was 90 m. The aerodrome had one windsock located on the northern side of the strip.

The aerodrome was located on a coastal plain 4.5 km west of the Lockhart River township. The Great Dividing Range was nearby with the terrain rising to over 800 ft to the south-west and west within about 8 km of the aerodrome (Figure 6). The highest terrain in the vicinity was Mount Tozer at 1,787 ft, which was located 11 km west-north-west of the aerodrome and about 4 km south of the accident site at South Pap. There was a valley between Mt Tozer and the accident site.

Many pilots who regularly flew into Lockhart River aerodrome reported that when flying approaches to runway 12, they regularly encountered moderate turbulence over the hills to the north-west of the aerodrome and windshear near the threshold of runway 12.

Lockhart River aerodrome was not served by an ATC tower, and it was outside of ATC radar coverage. The aerodrome did not have a Certified Air/Ground Service nor was this service required by the relevant aviation regulations.[76] The Lockhart River CTAF was not fitted with a frequency confirmation system nor was the system required under the aviation regulations.[77]

1.11 Flight recorders

1.11.1 Flight data recorder

Flight data recorder information

VH-TFU was required by CAO 20.18 to be fitted with a flight data recorder (FDR) system[78] that met the standards of CAO 103.19. These standards required that at least the first six parameters listed in Appendix 1 of CAO 103.19 were recorded. The FDR system fitted to VH-TFU exceeded the minimum regulatory requirements and recorded 19 parameters.

The FDR was a Loral Data Systems F1000 model. This model FDR compressed the flight data before it was stored in solid-state memory and as a result the recording duration exceeded the minimum requirement of retaining the most recent 25 hours. Examination of the FDR data recovered from VH-TFU showed that the recording duration was 100 hours, 2 minutes and 16 seconds. This period covered the accident flight and 59 previous flights.

Detailed information regarding the FDR readout and analysis is provided in Appendix A.

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76 Certified Air/Ground Radio Service (CA/GRS) was an aerodrome radio information service that provided operational information to aircraft, including: the preferred runway due to the wind direction, cloud base and visibility, wind direction and speed, present weather, temperature, QNH and runway surface conditions. The provision of CA/GRS was required by Civil Aviation Safety Regulation (CASR) 139.420 at an aerodrome during the arrival and departure of an aircraft with a maximum passenger seating capacity of more than 30 seats that was engaged in RPT or charter operations.

77 A frequency confirmation system sent a signal or message to an aircraft transmitting on the radio frequency, confirming that the transmission had been received. An aerodrome operator was required under CASR 139.385 to provide a frequency confirmation system if the aerodrome was used at least five times a week by an aircraft with a maximum seating capacity of more than nine passenger seats that was engaged in RPT or charter operations.

78 An FDR system comprises the recorder, aircraft sensors, cockpit fail indication and interconnecting wiring.

Recorded parameters

The FDR system installation in VH-TFU was designed to record the following parameters:

- Elapsed time
- Pressure altitude
- Indicated airspeed
- Vertical acceleration
- Magnetic heading
- Microphone keying – pilot in command
- Microphone keying – copilot
- Pitch attitude
- Roll attitude
- Horizontal stabiliser position
- Flap position
- Elevator position
- Rudder position
- Aileron position
- Right engine propeller RPM
- Left engine propeller RPM
- Right engine torque
- Left engine torque
- Longitudinal acceleration

Parameter serviceability and tolerances

The pitch attitude parameter was unserviceable during the accident flight and all the previous flights recorded by the FDR.

The pressure altitude and airspeed recording system, which included sensors in the FDR measuring static and pitot pressure from the copilot's systems, was out of calibration. Calibration equations were developed which corrected for this problem.

No anomalies were apparent for any of the other recorded parameters.

The accuracies for corrected pressure altitude and corrected indicated airspeed (IAS) are outlined in the table below.

Altitude	Accuracy
3,000 feet	± 100 feet
18,000 feet	± 300 feet
22,000 feet	± 400 feet

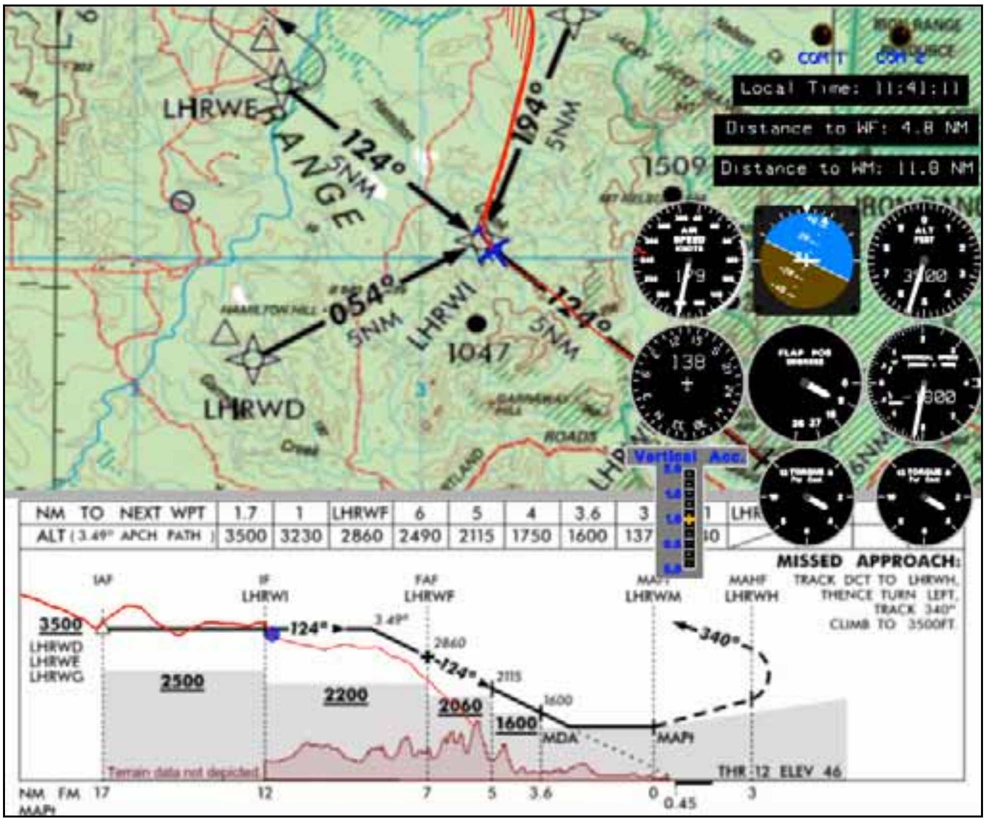
Indicated airspeed	Accuracy
60 kts – 150 kts	± 10 kts
> 150kts	± 15 kts

The resolution and sampling rate for each parameter are detailed in Appendix A.

1.11.2 Flight data for the accident flight

Section 1.1 and Appendix A provide details of the information obtained from the FDR. An approach track and altitude profile, derived from the FDR data, are shown in Figure 4. An animation of the incident was prepared using Insight Animation™ software and is part of this report. A file containing the animation in Insight View™ format (.isv) is available for download from the ATSB website.[79] A still screen capture of the FDR animation is shown at Figure 17.

Figure 17: Screen image of FDR animation



Engines and propellers

Recorded torque data for each engine was symmetrical and appropriate for the phase of flight. Propeller RPM parameters were also symmetrical and appropriate for the phase of flight. During the accident flight, the recorded data did not provide any evidence of a problem with either engine or propeller.

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79 This file requires the installation of an Insight Viewer that can be downloaded from <www.flightscape.com/products/view.php> at no charge.

Aircraft systems

Examination of the FDR data provided direct and indirect evidence concerning the serviceability of the following aircraft systems:

- electrical power
- hydraulic power
- flight controls
- pitot/static system.

This examination did not provide any evidence of problems with these systems during the accident flight.

Turbulence

Examination of recorded data showed that the turbulence encountered by the aircraft increased during the last 25 seconds of the accident flight. During this period the aircraft would have been under the increasing influence of mechanical turbulence from the South Pap ridge line.

Flight control inputs

The final 10 seconds of recorded data showed that small pitch and yaw control inputs were evident as small elevator and rudder position changes. Larger roll control inputs were evident as aileron position changes. The roll inputs were applied in the opposite sense to the aircraft bank angle showing that the aircraft attitude was being actively controlled by the handling pilot.

Elevator position data showed that no significant pitch control inputs were made during the corresponding period. A GPWS escape manoeuvre required that the pilot make a large nose-up pitch control input and apply maximum engine power. Recorded elevator position and engine torque parameters showed no evidence of such inputs by the flight crew.

Approach speed profile

The speed profile from the accident flight recovered from the FDR was compared with the maximum operating speeds defined in the *Transair Operations Manual* and the approach speeds specified in the *Aeronautical Information Publication* for aircraft performance Categories B and C (Figure 18).[80]

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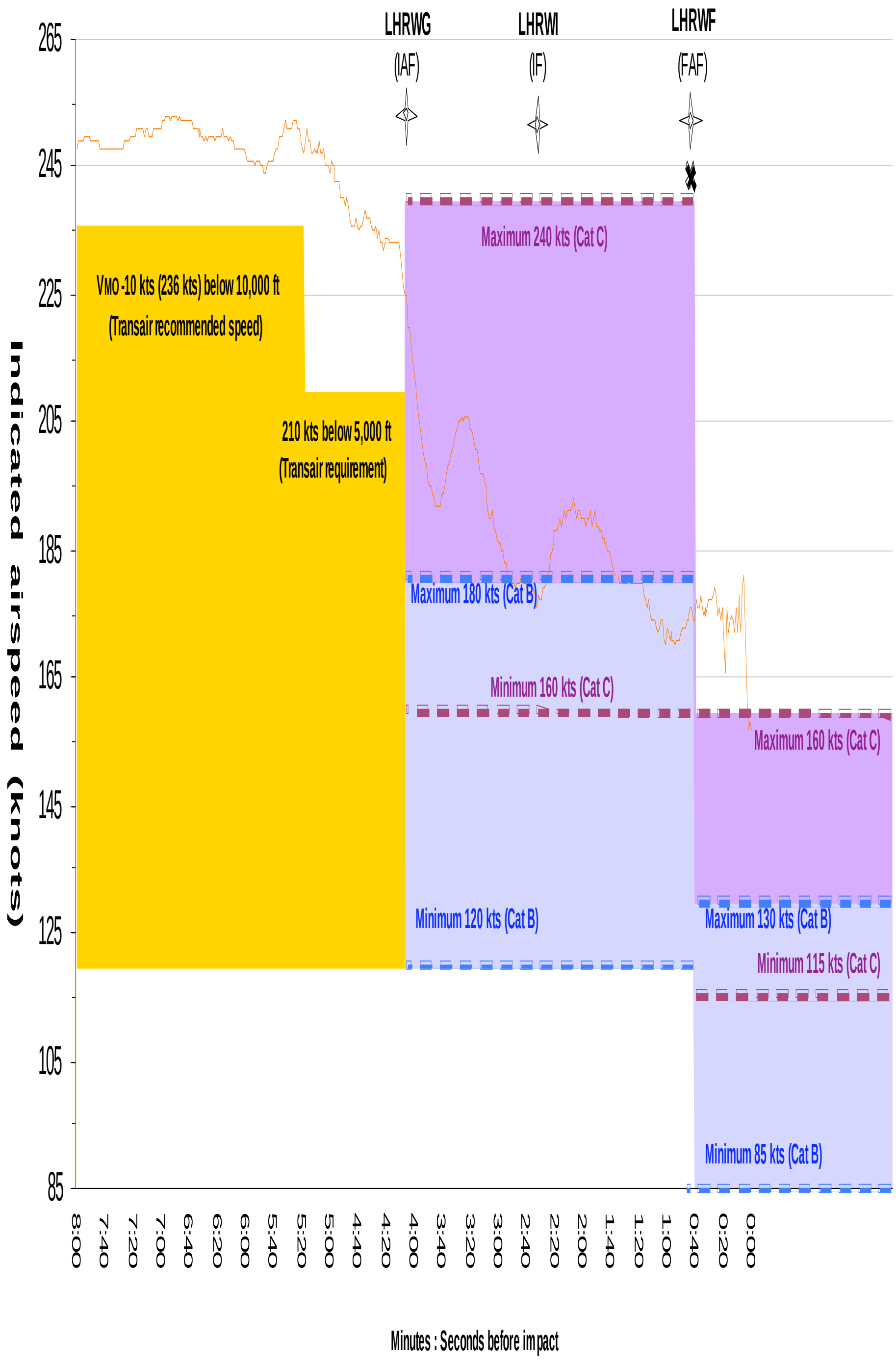
80 The *Transair Operations Manual* implied that VH-TFU was to be operated as a Category B aircraft (see Section 1.17.7). Category C speeds have been included for comparison.

Figure 18: Approach speed profile[81]



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81 V_{MO} refers to the maximum permitted operating speed under any condition.

1.11.3 Flight data for previous flights

Cairns to Lockhart River flight on 7 May 2005

The FDR data for northbound flight to Lockhart River on 7 May 2005 is shown below. The data indicated that the aircraft descended continuously from FL 180 until reaching 1,000 ft above aerodrome level (AAL). The average rate of descent was 1,640 ft/min while the maximum rate of descent was 2,390 ft/min between 6,600 ft and 5,200 ft AAL. During the descent, the aircraft was flown at or near V_{MO} (246 kts) between 14,900 ft and 5,000 ft AAL, a period of 5 minutes and 40 seconds.

An estimated ground track was derived from the FDR data. Using this estimate, the aircraft intercepted the runway 30 RNAV (GNSS) approach track at waypoint LHREI (the intermediate fix) and diverged from the approach track at waypoint LHREF (the final approach fix). The aircraft then tracked for a left downwind circuit leg for runway 12.

Position	**Time before touchdown (mm:ss)**	**Altitude (ft AAL)**	**Indicated airspeed (kts)**	**Flap**	**Engine torque (%)**
LHREI	05:01	3,840	237	Up	21
LHREF	03:51	2,350	205	1/4	8
500 ft AAL	00:48	500	150	1/2	41
Full flap selection	00:44	435	149	1/2	42
On runway heading	00:34	350	146	Full	25
Touchdown	00:00	0	130	Full	18

Lockhart River to Bamaga flight on 7 May 2005

The FDR data for the northbound flight to Bamaga on 7 May 2005 is shown below. The data indicated that the aircraft descended continuously from FL 180 until reaching 1,000 ft AAL. The average rate of descent was 1,730 ft/min, while the maximum rate of descent was 2,270 ft/min at an altitude of 7,300 ft AAL. During the descent, the aircraft was flown at or near V_{MO} (246 kts) between 15,800 ft and 1,500 ft AAL, a period of 8 minutes and 4 seconds.

The recorded data indicated that, from a northerly heading, the aircraft turned left continuously until it was on the Bamaga runway 13 heading. The track and altitude profile was not consistent with the published runway 13 RNAV (GNSS) approach.

Position	Time before touchdown (mm:ss)	Altitude (ft AAL)	Indicated airspeed (kts)	Flap	Engine torque (%)
Left turn onto final commenced	02:24	950	176	1/4	21
1/2 flap selection	02:16	930	174	1/2	24
On runway heading	01:17	630	157	1/2	37
Full flap selection	01:12	590	160	1/2	34
500 ft AAL	01:00	500	145	Full	16
Touchdown	00:00	0	118	Full	18

Other previous flights into Lockhart River

Data from nine previous flights to Lockhart River was retained by the FDR. Details of these flights are provided in the following table.

Flight sequence (before accident flight)	Sector	Date	Runway
2	Cairns – Lockhart River	7 May 2005	12
9	Cairns – Lockhart River	4 May 2005	12
17	Bamaga – Lockhart River	30 April 2005	12
19	Cairns – Lockhart River	30 April 2005	12
28	Bamaga – Lockhart River	27 April 2005	12
30	Cairns – Lockhart River	27 April 2005	12
34	Cairns – Lockhart River	25 April 2005	12
36	Bamaga – Lockhart River	23 April 2005	12
50	Cairns – Lockhart River	20 April 2005	12

The three Bamaga – Lockhart River flights were examined and on one flight, 27 April 2005, the track and altitude profile was consistent with the published runway 12 RNAV (GNSS) approach.

Bamaga to Lockhart River flight on 27 April 2005

The southbound flight to Lockhart River on 27 April 2005 was conducted with the same pilot in command as the accident flight on 7 May 2005 and a different copilot. A review of pilot logbooks indicated that the pilot in command was the non-handling pilot during this approach.

The FDR data for this flight is shown below. The data indicated that the aircraft descended continuously from FL 170 until reaching 5,700 ft AAL, where it levelled for a few seconds. The average rate of descent was 1,490 ft/min, while the maximum rate of descent was 1,930 ft/min descending through 15,200 ft AAL. During the descent, the aircraft was flown near V_{MO} (246 kts) between 15,590 ft and 7,890 ft AAL, a period of 5 minutes and 18 seconds.

An estimated ground track was derived assuming nil wind. Using this estimate, the aircraft intercepted the runway 12 RNAV (GNSS) approach track between waypoint LHRWE and LHRWI (see Figure 2). The aircraft then tracked directly for LHRWM.

Position	**Time before touchdown (mm:ss)**	**Altitude (ft AAL)**	**Indicated airspeed (kts)**	**Flap**	**Engine torque (%)**
1/4 flap selection	07:16	5,670	222	Up	19
Joining RNAV approach (between LHRWE & LHRWI)	05:22	3,390	193	1/4	12
LHRWI	04:23	2,490	186	1/4	25
LHRWF	02:48	1,900	177	1/4	30
1/2 flap selection	02:16	1,880	175	1/4	29
Full flap selection	01:06	760	164	1/2	23
LHRWM	00:19	130	150	Full	21
Touchdown	00:00	0	139	Full	6

Speed summary data from other flights

The FDR data was also examined to obtain speeds from other previous flights. The table below shows the average recorded speeds at 5,000 ft AAL, 1,000 ft AAL, 500 ft AAL, and touchdown for the 30 flights from 26 April to 6 May 2005. Minimum and maximum speeds are shown in brackets.

A calibration equation, derived specifically for the accident flight, was applied to all indicated airspeed data recorded by the FDR. This calibration equation was observed to produce reasonable results for previous flights back to the 26 April but was not necessarily valid for earlier flights. As a result these earlier flights were not considered in this analysis.

Based on a review of pilot logbooks, most of these flights would have been visual approaches. The handling pilots could not be determined for most of the flights. The flights on which the pilot in command was on board are shown in the table compared with flights where other pilots in command were on board. The flights when the pilot in command was on board had higher average speeds at 1,000 ft and 500 ft, and these differences were statistically significant.[82]

82 The statistical tests used were t-tests for independent samples. All statistical tests used an error rate of less than 0.001.

Pilot in command	Number of flights	5,000 ft AAL (IAS kts)	1,000 ft AAL	500 ft AAL	Touch-down (IAS kts)
Same as accident flight	10	239 (209-252)	169 (154-175)	161 (147-169)	133 (118-144)
Other	20	229 (155-250)	154 (140-175)	146 (129-165)	125 (106-139)

1.11.4 Cockpit voice recorder

Cockpit voice recorder information

Metro 23 aircraft were required by CAO 20.18 to be fitted with a cockpit voice recorder (CVR) system. VH-TFU was fitted with an L-3 Communications Aviation Recorders model A100 CVR unit and associated components that were capable of recording audio signals from each flight crew position and a remote mounted area microphone for a minimum of 30 minutes. The CVR installation also provided the crew with a test facility to check the serviceability of the system. A detailed report on the CVR is available at Appendix B.

Cockpit voice data for the accident flight

Examination of the 30-minute CVR tape indicated the following:

- The recording contained a mixture of electrical pulses and fragments of conversation.
- It is considered likely that the CVR unit developed a fault that may have been present in either the bias oscillator or the internal direct current power supply.
- The fault in the CVR had stopped the unit from functioning as intended, but had not been discovered or diagnosed by flight crew or maintenance personnel.
- The presence of conversation related to previous flights and the fragmented nature of the recorded audio indicated that the fault in the CVR unit had been present for some time.
- No audio recovered from the CVR recording could be confirmed as having been recorded during the accident flight.
- Fragments of conversations present on the CVR recording indicated flight crew performing appropriate communications within the cockpit, with ATC, and with other aircraft relating to the operation of VH-TFU not confined to the 30-minute period prior to the accident flight.
- Audio present on the CVR recording indicated operation of the GPWS fitted to VH-TFU through the recording of several GPWS generated aural alerts. Other aural alerts fitted, such as pitch trim activation, were also recorded, but could not be linked to the accident flight.

Technical advice was sought from the UK Air Accidents Investigation Branch, US National Transportation Safety Board and the CVR unit manufacturer. Recorder specialists from these organisations concurred with the above findings and they agreed that recovery of useable data relating to the accident flight from the CVR was not possible.

CVR serviceability checks and maintenance

CAO 103.20 required that a facility be provided for flight crew to monitor the CVR for proper operation as part of the flight deck pre-flight procedure. The CVR manufacturer provided this facility via a test button on the CVR control unit, which, in VH-TFU, was mounted on the instrument panel in front of the pilot in command. When the TEST button was pressed, and held for more than 5 seconds, a signal generated within the CVR unit was recorded on the tape. The test signal was recovered from the tape and displayed on a meter marked with a scale and green arc. The deflection of the indicator into the green arc indicated a serviceable CVR unit (see Appendix B for further information).

The CVR was inspected in accordance with the *Approved Airplane Flight Manual* serviceability check. The last inspection was carried out on 17 April 2005 during the scheduled phase inspection. An applicable CASA airworthiness directive relating to the CVR was carried out by the maintenance provider on 16 June 2004 and no system defects were recorded at that time.

Following the accident, Transair performed a pre-flight functional check on three other aircraft in the fleet that were fitted with CVR units. The tests detected two unserviceable CVR units.[83]

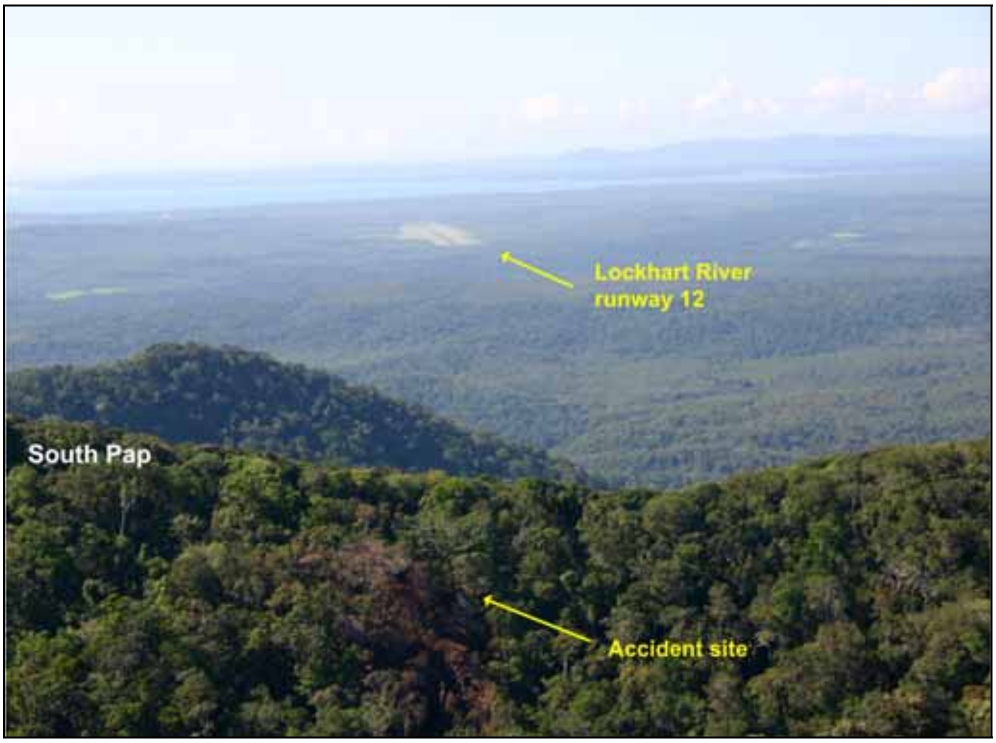
1.12 Wreckage and impact information

1.12.1 Accident site description

The accident site was located on the north-west side of South Pap, a ridge in the Iron Range National Park. The wreckage lay in dense tropical rainforest at an elevation of 1,190 ft (363 m) and a distance of about 11 km on a bearing of about 304 degrees magnetic from the threshold of runway 12 (Figure 19). The height of the initial impact with trees was 1,210 ft, which was about 90 ft below the crest of the ridge.

83 The Australian Transport Safety Bureau (ATSB) examined 40 A100 series cockpit voice recorders between 1995 and 2005. There was only one CVR which exhibited any type of internal failure. That CVR was the unit fitted to VH-TFU.

Figure 19: General view of the accident site looking toward the south-east



1.12.2 General wreckage description

Based on examination of the wreckage and the damage to trees, the investigation determined that the aircraft had entered the rainforest canopy in an approximately wings-level attitude at a flight path descent angle of about 4 degrees. The aircraft pitch attitude at the time of collision with the trees could not be determined. The aircraft began to break up immediately after entering the rainforest and destruction of the aircraft was consistent with successive impacts with trees and large boulders during the impact sequence (Figure 20). The wreckage trail was about 100 m in length and aligned on a track of about 101 degrees magnetic.

Figure 20: Wing section showing impact damage with a tree trunk or branch

As the aircraft flew through the crowns of the trees, the outboard sections of both wings and the blades of both propellers separated from the aircraft. The aircraft continued along a descending flight path, contacting tree trunks and branches. This resulted in further sections of both wings, the engines and sections of the horizontal stabiliser and elevators being torn off. The nose of the aircraft then impacted boulders and broke up. The remaining left wing structure then impacted a rock outcrop causing the fuselage to roll to the right approximately 50 degrees (Figure 21).

Figure 21: View along the direction of travel showing the rock outcrop and main wreckage in the background

The remaining wreckage then continued about 20 m up the steeply sloping ground before stopping. It was then consumed by an intense, fuel-fed, post-impact fire (Figure 22).

Figure 22: The rear fuselage section

1.12.3 Structure

The aircraft structural damage was consistent with the application of excessive structural loads during the impact sequence, and the effects of the subsequent fire. No pre-existing defects likely to have contributed to the aircraft break-up were found.

1.12.4 Flight controls

Although the flight control systems were severely damaged during the accident sequence, damage to the components that were able to be examined was consistent with them being intact prior to the impact. There was no evidence found that suggested there was any pre-existing defect or malfunction of any part of the flight control system.

Horizontal stabiliser

An on-site examination showed that the pitch trim actuator assembly of the horizontal stabiliser had sustained extensive impact, and post-impact fire damage. The actuator assembly had remained securely attached to the fuselage and tailplane attachment points. However, both of the pitch trim actuator's jackscrew shafts were severed during the impact. Comparison of the jackscrew shaft extension with that on a serviceable aircraft indicated that the horizontal stabiliser trim was within the normal operating range and not at either limit. Due to the mechanical nature of the jackscrew assembly, it was considered very unlikely that impact forces would have changed the setting.

1.12.5 Engines and propellers

Both engines and propellers sustained severe damage as a result of the impact. The left engine struck the trunk of a large tree prior to the fuselage impacting the terrain, resulting in destruction of the engine and gearbox. A section of the left engine mount and wiring harness were embedded in and tangled with the tree trunk. The right engine was located to the right side of the accident trail. It had been partially subjected to fire damage and also exhibited severe impact damage. Examination of the rotating components of both engines (compressor and turbine) found damage that was consistent with the engines rotating at impact.

The individual blades from both propellers had separated from their respective hubs. Several of the blades had broken into pieces and had round indentations in their leading edges. All but one of the left propeller blades was positively identified on site. A tip portion of a propeller blade was also found, but this could not be associated with the seven identified blades. The damage to the propeller blades was consistent with impacting solid round objects (probably tree branches) whilst rotating at high speed. The distribution of the propeller blades in the wreckage trail suggested that they separated from the hubs soon after entering the trees.

Examination of the engines and propellers did not find any evidence to suggest that the engines were not capable of normal operation prior to impact.

1.12.6 Landing gear

All three landing gear hydraulic actuators were found with their piston shafts bent in the extended position, indicating that the landing gear was extended at the time of impact.

1.12.7 Cockpit instruments and systems

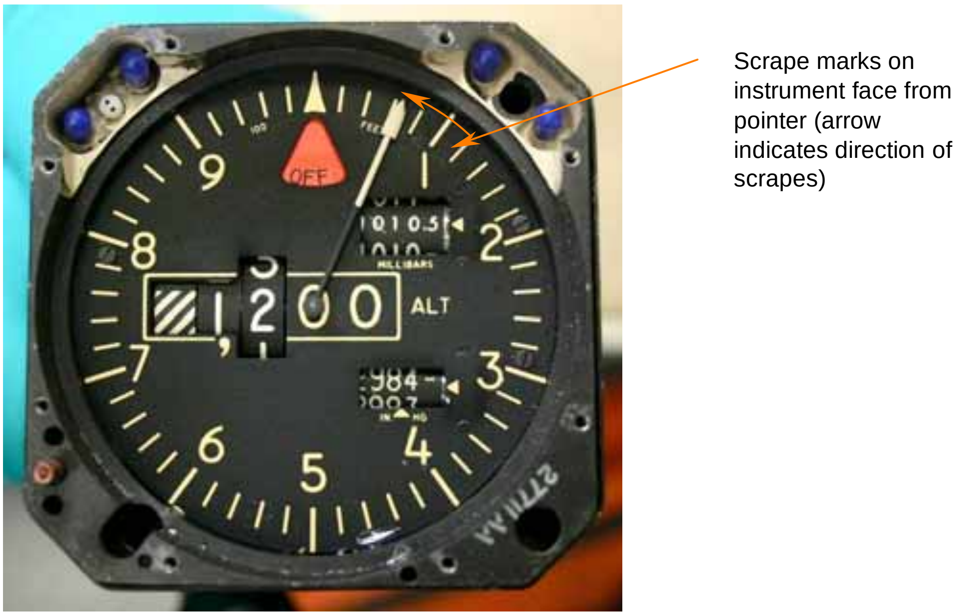
Impact and fire damage to the cockpit area resulted in most of the instruments and systems being destroyed. However, those systems of most interest to the investigation (see Sections 1.6.6 to 1.6.13) that were recoverable from the accident site, were examined at the Australian Transport Safety Bureau (ATSB) engineering laboratory.

Barometric altimeters

The pilot in command's altimeter was damaged by impact. The glass face was broken but remained attached to the unit. The counter drum scale indicated an altitude of 1,200 ft. However, examination of the instrument indicated that the drum freely moved between 1,100 and 1,200 ft. The pointer indicated 63 ft (Figure 23). There were scrape marks from the pointer on the face of the instrument running from 120 ft down to 60 ft, indicating that the pointer was at or above 120 ft at impact. Therefore, the altimeter was probably indicating 1,120 ft or more at impact.

The barometric pressure scale setting was 1010.5 hPa. Due to the nature of the damage sustained to the barometric scale mechanism, it was not considered likely that the post-accident setting had changed from the setting immediately prior to impact. Given that the AWS was recording 1013.1 hPa (see Section 1.7.3), the barometric pressure setting of the altimeter would result in it under-reading by about 70 ft (that is, the aircraft would actually have been about 70 ft above that indicated on the altimeter, and therefore about 1,190 ft at impact).

Figure 23: Pilot in command's encoding altimeter



The copilot's altimeter was severely damaged by the impact. The glass face was destroyed, the instrument face depressed inward, and the three pointers missing from the spindle. There were numerous marks on the face, none of which could be conclusively identified with imprints from the pointers. The barometric pressure scale setting was 1012 hPa. Evidence on the instrument indicated that this was the setting at impact.

Vertical speed indicators

Only the pilot in command's VSI was recovered from the accident site. The glass face was intact and the pointer was indicating a rate of descent of about 6,000 ft/min (see Figure 24). Due to internal damage from the impact, the indication was considered unreliable. There was no evidence to suggest that the instrument was not functioning prior to the impact and fire.

Figure 24: Vertical speed indicator (recovered from VH-TFU)

Radio altimeter system

The only component of the radio altimeter system recovered was the digital radio altitude indicator. The indicator unit had sustained impact and heat damage from the post-impact fire. Examination of the digital radio altitude indicator unit found that the decision height was set to 920 ft.

The warning flag was in the radio altimeter inoperative position (over the decision height display). A mark that corresponded to the end of the flag was found on the face of the decision height drum. It could not be determined if this mark was created at the initial impact, indicating that it was over the drum prior to impact, or if it was a result of the multiple impacts the unit was subjected to as the aircraft broke up.[84]

There was no conclusive evidence to indicate whether the decision height annunciator and circuit card light globes were illuminated at impact.[85]

The investigation could not determine if the radio altimeter system was functional prior to the impact.

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84 During examination of a functional system, it was noted that the appearance of the flag over the decision height display was almost instantaneous.

85 When light globes are illuminated, the filaments are at very high temperatures, their strength is reduced and the material becomes ductile. If they are then subjected to large accelerations (such as impacting the ground at high speed) the filament can stretch and remain stretched. This permanent stretch does not occur when the light globes are not illuminated, as the filament material is much stronger and brittle. Due to many factors (including the age of the light globe, the direction of acceleration and the stiffness of the globe mounting), not all globes that are illuminated in the same unit will exhibit the same stretching behaviour. Therefore, permanent stretching of the filament is a good indication that the globe was illuminated at impact, but a lack of permanent stretch does not necessarily indicate that it was not illuminated at impact.

Altitude alerting system

The altitude alerter was not identified in the wreckage and was probably destroyed by the impact and post-impact fire.

Ground proximity warning system

The ground proximity warning computer and the annunciators were not identified in the wreckage and were probably destroyed by the impact and post-impact fire.

Global positioning system

The GPS receiver display unit, which also contained the datacard, was not identified in the wreckage and was probably destroyed by the impact and post-impact fire.

Only the face plate and annunciator circuit board of the MD41 annunciation control unit were recovered. The two light globes corresponding to the AUTO annunciator displayed evidence that they were illuminated at impact. This indicated that the unit had power at impact and that the GPS was set to automatically sequence through the waypoints.

Cockpit annunciator panel

The cockpit annunciator panel had sustained significant impact and fire damage during the accident sequence. Examination of the damaged panel showed that bulbs from 12 of the segments had evidence that they were illuminated at impact (Figure 25).

Figure 25: Annunciator segments with evidence of illumination at impact (representative)

The warning (red) segments with evidence of illumination were:

- L OIL PRESS which indicated that the engine oil pressure had dropped below the allowable operation limit
- L HYD PRESS which indicated that the outlet pressure from the hydraulic pump on the left engine was below the allowable operation limit
- R HYD PRESS which indicated that the outlet pressure from the hydraulic pump on the right engine was below the allowable operation limit
- CARGO DOOR which indicated that the cargo door locks were not all properly engaged
- GEAR DOOR POSITION which indicated that one of the main landing gear doors was not latched closed. This system normally works only when the aircraft is on the ground.

The alert (yellow/amber) segments with evidence of illumination were:

- L CHIP DET which indicated that the chip detector in the left engine had sensed a metal chip
- L XFER PUMP which indicated that the left fuel transfer pump had failed to maintain the fuel level in the hopper tank
- L BATT DISC which indicated that the left battery relay was disconnected
- L GEN FAIL which indicated that the generator relay on the left engine was open
- L FUEL FILTER which indicated that the left fuel filter bypass was open.

The advisory (green) segments with evidence of illumination were:

- L W/S HT which indicated that the left windshield heating system was operating
- SAS DEICE which indicated that the stall avoidance system sensor deicing system was operating.

Seven of these annunciators were associated with the left engine and its associated systems, suggesting a major failure of the left engine. As other evidence indicated that both engines were producing power (see Section 1.12.5) and the break up of the wings and engines began when the aircraft entered the tree canopy, these indications very likely occurred immediately before the cockpit impacted the terrain[86] and did not indicate the status of the annunciator panel prior to the aircraft entering the tree canopy.

Emergency locator transmitter

The emergency locator transmitter was not identified in the wreckage. It is probable that the post-impact fire destroyed the unit.

1.13 Medical and pathological information

There were delays between the discovery of the aircraft wreckage, the recovery of the flight crew and the time of the post-mortem examinations. These delays placed constraints on the information that was collected during the examinations.

There was no evidence found during the post-mortem examination of each crew member of physiological factors that would have affected their performance.

Due to the nature of the samples recovered from the crew, toxicological examination for the detection of alcohol was not able to be reliably performed. Toxicological examination of tissue samples from both crew members did not reveal the presence of any drugs.

Within the limitations imposed on the samples because of their condition, there was no evidence of in-flight incapacitation of crew or passengers from either toxic fumes or fire.

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86 These light globes take only a few milliseconds to obtain full illumination.

1.14 Fire

Site examination indicated that the aircraft fuel tanks were disrupted during the impact sequence resulting in an intense post-impact fire that consumed most of the fuselage and cabin interior. The ignition of the fuel probably resulted from electrical arcing and/or contact with high-temperature engine components. There was no evidence of an in-flight fire.

1.15 Survival aspects

The accident was not considered to be survivable due to the severity of the impact forces.

1.16 Tests and research

1.16.1 Flight crew forensic speech analysis

Speech analysis is a technique that can be used for detecting changes in the psychological and/or physiological state of a speaker that may be associated with factors such as workload demand, emotional stress, hypoxia or alcohol impairment. A forensic phonetician was contracted by the investigation to conduct an analysis of each pilot's speech. The analysis was conducted to help establish whether either pilot was experiencing any non-normal condition that was affecting their speech, and may therefore have affected their ability to operate in the cockpit.

As there was no useable CVR data, the speech analysis used recordings from the Lockhart River CTAF, Cairns ATC tower frequency, and Brisbane ATC centre frequencies. The study compared voice samples from the accident flight with control samples from other flights on the day of the accident and other flights on previous days. Control samples involved flights with the same crew pairing as well as flights when each pilot was operating with a different pilot. The copilot speech analysis looked separately at speech recorded from the beginning of the accident flight and towards the end of the accident flight during the approach into Lockhart River. The analysis of the pilot in command's speech only had recordings from the beginning of the accident flight.

The analysis included two components: *auditory* analysis, which provided a qualitative assessment of observations of the pilot's voice; and *acoustic* analysis, which provided a quantitative assessment of the pilot's voice. The acoustic techniques comprised three perspectives: articulation rate (number of syllables uttered per second); fundamental frequency (rate at which the vocal cords open and close during speech, perceived as the pitch of a voice); and formant analysis (spectral characteristics and resonant frequencies of the sound waves).

None of the tests applied to the data were able to detect any significant differences in the speech or voice of either pilot when compared with the same auditory and acoustic properties in the control samples from several previous flights.

The same forensic phonetician was commissioned by the investigation to interpret the contents of the copilot's final CTAF transmission. The initial part of the transmission could be unambiguously determined as:

> Ah fairly dismal really, [a]bout nine hundred foot clear…

However, it was not possible using either auditory or acoustic techniques to unequivocally verify the ending of the final word, which could have been either *clearance* or *clearing*. The analysis was also unable to provide any evidence to suggest one interpretation was more likely than the other.

1.16.2 Assessment of ground proximity warning system operation

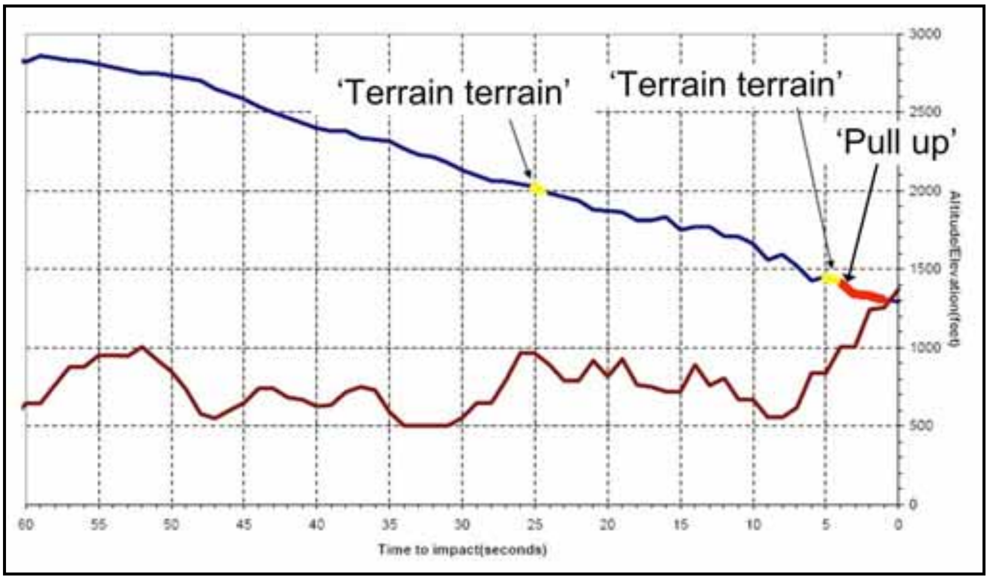
Accident flight simulation[87]

Data from the FDR was provided to the GPWS manufacturer, Honeywell, for assessment. Honeywell conducted a computer simulation of the final stages of the accident flight to determine what, if any, warning would have been provided by the GPWS if it was functioning as designed (see Appendix F).

The simulation assumed that the flaps were not in the landing position, the landing gear was down and the flap override switch was not activated. As radio altitude was not recorded by the FDR, Honeywell used an estimate of the radio altitude that was derived using the estimated flight path of the aircraft (position and altitude) and a digital elevation model (computer terrain database). As a result, Honeywell advised that the simulation must be used with caution as the actual radio altitude processed by the GPWS computer may have been different.

The simulation (Figure 26) indicated that the GPWS should have provided a single 'terrain terrain' alert of about 1-second duration at about 25 seconds before impact. This was followed by a second 'terrain terrain' alert and then a repetitive 'pull up' warning during the final 5 seconds of the flight.

Figure 26: Accident flight simulation showing GPWS alerts and warnings[88]



87 The results of the accident flight simulation differ from those included in previous ATSB interim factual and draft reports as Honeywell subsequently provided updated information to the investigation.

88 The blue line indicates FDR derived flight path, brown line depicts estimated terrain. The yellow line depicts the 'terrain terrain' alerts and the red line depicts the 'pull up' warnings.

Pilot response time to GPWS

One study examined FDR data of 19 GPWS-initiated incidents during approach in IMC.[89] The range of pilot reaction times varied from 1.2 to 13 seconds, with an average reaction time of 5.4 seconds. The US FAA stated that 'studies indicate that the combined pilot and aircraft reaction time to avoid a CFIT after warning is within the 12 to 15 second range'.[90]

Constant angle and step-down approach simulations

Honeywell also conducted Lockhart River Runway 12 RNAV (GNSS) approach simulations for the constant angle approach along the recommended 3.49 degree profile and a step–down approach[91] along the segment minimum safe altitudes. For the step-down approach, the aircraft was assumed to descend at 1,200 ft/min between the step-down altitudes.

Honeywell conducted the simulations using groundspeeds[92] typical of a Category B aircraft (130 kts) and Category C aircraft and the accident flight (160 kts). The simulations were conducted with the landing gear down and separate simulations with either approach flap throughout the simulation and landing flap extended at the final approach fix. Extension of landing flaps desensitised the GPWS to mode 2B, which had a reduced warning envelope (see Section 1.6.11 and Appendix C).

The simulations indicated that mode 2A alerts and warnings should be generated during both the constant angle and step-down approaches at both speeds when in the approach flap configuration. These alerts and warnings occurred in the vicinity of South Pap. Appendix F shows graphical representations of these simulations. When the simulations were conducted with the landing flap configuration, no mode 2B alerts or warnings were generated.

Bamaga to Lockhart River flight 27 April 2005 simulation

Data from the FDR of the only other Lockhart River Runway 12 RNAV (GNSS) approach apart from the accident flight was also provided to Honeywell for a GPWS simulation. The simulation indicated that the GPWS should have provided GPWS mode 2 alerts and warnings when the aircraft was in the vicinity of South Pap (Figure 27).

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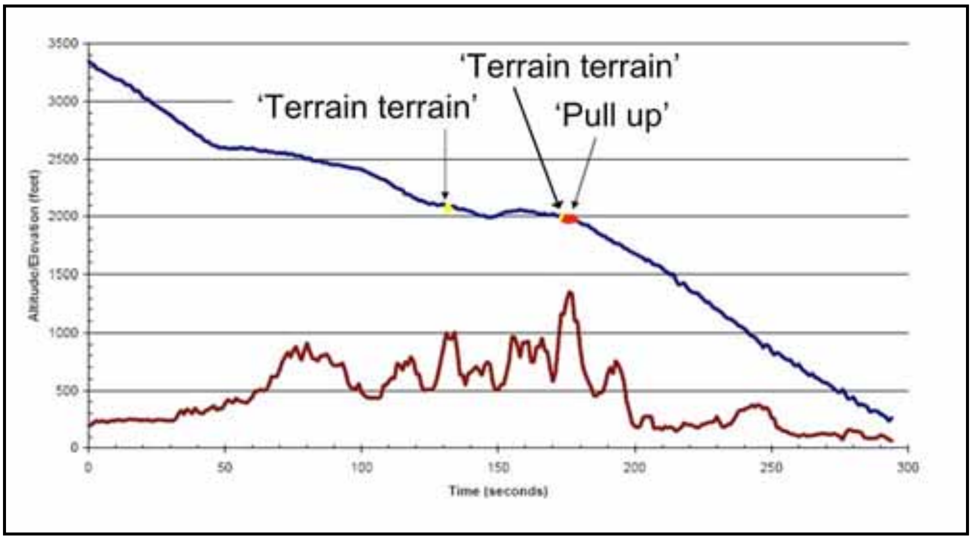
89 Gurevich, A. (1991). Pull up pull up - The when and how of GPWS pull-ups. *British Airways Flight Deck - Issue 1, Autumn 1991* (reprinted from *Boeing Airliner Magazine*).

90 US Department of Transportation (Federal Aviation Administration), *14 CFR Parts 91, 121, 135 Terrain Awareness and Warning System; Final Rule*. Federal Register / Vol. 65, No. 61 / Wednesday, March 29, 2000, Rules and Regulations, pages 16735-16756.

91 An approach where the aircraft was descended to the segment minimum safe altitude, then flown along that altitude until the next altitude step, where the process was repeated.

92 Groundspeed refers to the speed of the aircraft over the ground, which is influenced by the wind speed and direction, and differs from the aircraft's airspeed which is the speed of the aircraft through the air. A GPWS generated mode 2 alerts and warnings based on the closure rate with terrain. This depended on the aircraft's groundspeed, rate of descent, and the terrain profile.

Figure 27: Simulation for Bamaga to Lockhart River on 27 April 2005 showing GPWS alerts and warnings[88]



The copilot of this flight initially reported that he had not received any GPWS alerts or warnings when flying the Lockhart River Runway 12 RNAV (GNSS) approach in cloud, but 'had it go off when visual' (that is, flying the approach in visual conditions). Later in the investigation when asked about the flight on 27 April 2005, the copilot could not recall this particular flight.

Cockpit voice recordings of GPWS alerts and warnings

Due to the lack of CVR information (see Section 1.11.4), the investigation was unable to determine if the GPWS functioned as designed during the accident flight. However, several GPWS alerts and warnings were recorded on the CVR and indicated that at some stage prior to the accident, the GPWS was probably operational. These alerts and warnings were not mode 2 annunciations.

Transair pilot reports of GPWS operation at Lockhart River

There were no reports submitted by Transair to the ATSB about GPWS alerts, and no evidence of any reports of GPWS activation in the Transair safety management database. [93]

Apart from the copilot on the 27 April 2005 flight (see above), no other Transair pilots reported hearing GPWS alerts or warnings when conducting the Lockhart River Runway 12 RNAV (GNSS) approach. However, Transair had only operated RPT services from Bamaga to Cairns since August 2004. These flights were scheduled twice a week, but the sector from Bamaga to Lockhart River was not always flown. Most approaches by Transair pilots into Lockhart River were visual approaches, and visual approaches to runway 12 normally tracked along the extended runway centreline which was over a valley south of South Pap (see Section 1.19.3).

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93 The Transport Safety Investigation Regulations 2003 defined GPWS alerts as a routine reportable matter.

One pilot reported hearing a GPWS annunciation at Lockhart River while manoeuvring VH-TFU from the south to join the runway 12 circuit. Other pilots could not recall any GPWS alerts or warnings during approaches in VH-TFU.

Other pilot reports of GPWS operation at Lockhart River

A pilot from another operator recalled conducting a runway 12 RNAV (GNSS) approach soon after the procedure was published. He stated that the approach was flown with the autopilot coupled to the flight management system, which had calculated a constant angle approach path. The pilot reported that the GPWS did not generate any alerts or warnings.

Pilots from a different operator reported to the ATSB, following the accident involving VH-TFU, that:

> We cannot conduct the Lockhart River Runway 12 RNAV approach without the GPWS announcing ‘terrain terrain pull up pull up’. This happens in both [aircraft types, one was a Category B performance aircraft and the other Category C]. The occurrence is always after passing LHRWF inbound.

The pilots reported that the warnings had occurred while the aircraft was on the published constant angle approach path with the autopilot coupled to the flight management system, in the approach configuration, and within the appropriate approach speeds for the aircraft category.

The investigation interviewed a sample of 10 pilots from other operators who regularly operated into Lockhart River and regularly used RNAV (GNSS) approaches (see Section 1.19.3). None of the aircraft operated by these pilots into Lockhart River were fitted with GPWS, nor were they required by the relevant aviation regulations to be fitted with the system.

Terrain awareness and warning system simulation

To enable a comparison with a current terrain awareness and warning systems (TAWS) (see Section 1.6.20), Honeywell conducted simulations of the accident flight and the stabilised and step-down approaches, described above, in a computer simulator for their MK VI enhanced ground proximity warning system, a type of TAWS (Appendix F).

The simulation found that, for the accident flight path, TAWS should have provided a ‘caution terrain’ alert at about 32 seconds before impact, and a ‘terrain terrain’ alert followed by repetitive ‘pull up’ warnings during the final 28 seconds before impact. The system should also have provided a solid red area on the visual terrain display.

1.17 Organisational and management information

1.17.1 Air operator certificate holder responsibilities

In order for an aircraft operator to conduct commercial activities, including low capacity regular public transport (RPT) operations[94], permission was required from CASA and an Air Operator's Certificate (AOC) was required to be issued under the provisions of Section 27 of the *Civil Aviation Act 1988*.

The responsibilities of an AOC holder were listed in the Act. Section 28BD of the Act stated that:

> The holder of an AOC must comply with all requirements of this Act, the regulations and the Civil Aviation Orders that apply to the holder.

Section 28BE of the Act included the following provisions:

> (1) The holder of an AOC must at all times take all reasonable steps to ensure that every activity covered by the AOC, and everything done in connection with such an activity, is done with a reasonable degree of care and diligence.
>
> (2) If the holder is a body having legal personality, each of its directors must also take the steps specified in subsection (1).
>
> (3) It is evidence of a failure by a body and its directors to comply with this section if an act covered by this section is done without a reasonable degree of care and diligence mainly because of:
>
> (a) inadequate corporate management, control or supervision of the conduct of any of the body's directors, servants or agents; or
>
> (b) failure to provide adequate systems for communicating relevant information to relevant people in the body.

Section 28BF of the Act stated that:

> (1) The holder of an AOC must at all times maintain an appropriate organisation, with a sufficient number of appropriately qualified personnel and a sound and effective management structure, having regard to the nature of the operations covered by the AOC.
>
> (2) The holder must establish and maintain any supervisory positions in the organisation, or in any training and checking organisation established as part of it, that CASA directs, having regard to the nature of the operations covered by the AOC.

Transair held an AOC that authorised aerial work, charter and regular public transport (RPT) operations (see Section 1.18.2).

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94 Commercial activities were prescribed in the CAR 206 as, including 'the purpose of transporting persons generally, or transporting cargo for persons generally, for hire or reward in accordance with fixed schedules to and from fixed terminals over specific routes with or without intermediate stopping places between terminals'. CAR 2 termed that activity as regular public transport operations. CAO 82.0 defined high capacity aircraft as meaning an aircraft that was certified as having a maximum seating capacity exceeding 38 seats or a maximum payload exceeding 4,200 kg. Low capacity RPT operations were RPT operations conducted in aircraft other than high capacity aircraft.

1.17.2 Overview of Transair

History of operations

Transair was the trading name of Lessbrook Proprietary Limited, a company that was incorporated in Queensland on 29 September 1988. The Civil Aviation Authority (CAA)[95] issued an initial AOC to Transair on 17 May 1989 that authorised the company to conduct charter operations in Cessna Conquest, Mitsubishi MU2 and Rockwell 690 turbo-prop aircraft. The CAA subsequently varied Transair's AOC to authorise the operation of other types of aircraft and in July 1994 the AOC was varied so that Transair could operate the Fairchild SA226-TC Metro II and SA227-AC Metro III series turbo-prop aircraft.

Until October 1999, Transair was engaged in charter operations within Australia and on an international route between Australia and Papua New Guinea. On 29 October 1999, CASA authorised Transair to conduct RPT cargo-only operations between Australia and Papua New Guinea. CASA subsequently withdrew that authorisation on 15 December 1999 due to Transair using a Metro II aircraft, VH-TFQ, on the Papua New Guinea route. That aircraft was not approved for RPT operations (see Section 1.18.12). In September 2001, Transair was authorised to conduct RPT passenger operations between Christmas Island and Jakarta, Indonesia. The following month, CASA approved Transair to conduct RPT passenger operations within Australia on the Cairns – Bamaga route.

Transair's RPT passenger operations significantly increased during 2004 when the company was approved to expand its route structure to link Sydney with Inverell, Gunnedah, Coonabarabran, Cooma, Grafton and Taree in regional New South Wales. These services were operated on behalf of an affiliated company, Big Sky Express Proprietary Limited (see below). In 2004 CASA also approved Transair to operate on the Inverell – Brisbane route and to include Lockhart River on the Cairns – Bamaga route. The RPT operations in Queensland and New South Wales were conducted using Metro aircraft, except for the Coonabarabran – Gunnedah route, which utilised a Beech Baron aircraft.

Organisational structure

Transair's main base and head office was at Brisbane airport with other ancillary bases at Cairns, Inverell and Grafton aerodromes, and a helicopter base at an amusement park near the Gold Coast, Queensland.

Apart from the chief pilot, at the time of the accident there were about 21 pilots employed on a full-time basis and three pilots employed on a casual basis. Five of the full-time pilots held the role of base manager and reported to the chief pilot (Figure 28).

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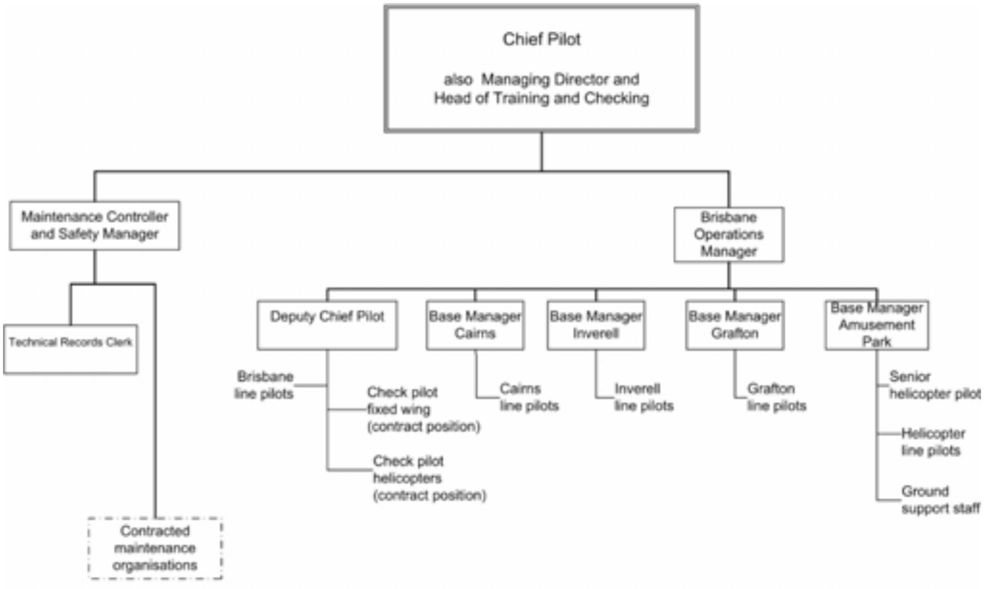
95 On 1 July 1988 the Civil Aviation Authority assumed responsibility for the regulation of the Australian civil aviation industry until it was split into the Civil Aviation Safety Authority and Airservices Australia on 6 July 1995.

Figure 28: Transair organisational structure as at 7 May 2005



Affiliated organisations

Transair entered into a commercial arrangement with Aero-Tropics in September 2001 to operate RPT services between Cairns and Bamaga (see Section 1.17.5). Transair provided all personnel and aircraft for this service from its Cairns base. This arrangement was extended in 2004 to include RPT services to Lockhart River.

In January 2004 Big Sky Express commenced RPT services in regional New South Wales. Big Sky Express was a 'community based airline' owned by Transair, various shire councils, business organisations and private investors. Transair provided the flight crew and aircraft for the Big Sky Express operation from ancillary bases at Inverell and Grafton.

Transair's chief pilot reported that he was also a shareholder and director of Trans Air Limited operating in Papua New Guinea (Trans Air PNG). That company held a Papua New Guinea Air Services Licence that authorised aerial work and charter operations using Metro II and Cessna Citation aircraft.

Cairns base

Transair commenced operations at an ancillary base at Cairns in 1996. At the time of the accident, the base operated two Metro aircraft, one on a passenger service to Bamaga and the other on a regular freight service to Port Moresby. The base had five pilots, consisting of two first officers and three captains. The pilot in command of the accident flight was also the Cairns base manager and had held that position since August 2003.

Fleet

At the time of the accident, Transair's AOC listed five Metro turbo-prop aircraft that were authorised for RPT operations. In addition to VH-TFU, there were four SA227-AC aircraft: VH-TGD, VH-TFG, VH-TGQ and VH-UUN. The AOC also authorised a Beech Baron piston engine aircraft for RPT operations. In addition, Transair operated a SA226-TC Metro II aircraft (VH-TFQ), a Cessna Conquest turbo-prop aircraft, a Cessna Citation turbo-fan aircraft, and a helicopter.

The Transair chief pilot reported that Transair's five RPT approved Metro aircraft were located at various bases; two at Cairns, two at Brisbane and the fifth at Inverell. Other evidence indicated that a sixth Metro aircraft was based at Grafton. The Conquest, Citation and Baron aircraft were based at Brisbane.

There was evidence that Transair was operating the Metro VH-TFQ, which was not approved for RPT operations, on Big Sky Express RPT services. This evidence included the aircraft being involved in two incidents reported internally by Transair pilots on flights with a Transair RPT flight numbers, and a notification of an occurrence by Airservices Australia with an RPT flight number. In addition, CASA audit files showed that CASA inspectors had conducted en route inspections of Transair operations on this aircraft on RPT flights in August 2004 and February 2005 (see also Section 1.18.12).

There was also evidence that Transair operated another Metro aircraft (VH-IAW) on Big Sky Express RPT services. This evidence included the aircraft being involved in two incidents reported internally by Transair pilots on flights with Transair RPT flight numbers. VH-IAW was not listed on Transair's AOC, and there was no other evidence that CASA had authorised Transair to operate VH-IAW as an RPT aircraft.

1.17.3 Chief pilot

Responsibilities of a chief pilot

The position of chief pilot was defined in Section 28(3) of the *Civil Aviation Act 1988* as being a key position within an AOC holder's organisational structure. CASA considered the position as one requiring:

> … a focus on regulatory compliance and is a critical link between the AOC holder and CASA. To be effective in the role, Chief Pilots must have the knowledge, experience and strength of character to balance the sometimes conflicting demands of safety and commercial considerations.[96]

CAO 82.0 Appendix 1 outlined the responsibilities of a chief pilot. Those included ensuring that flight operations were conducted in compliance with the legislation, arranging flight crew rosters, maintaining a record of licences and qualifications, maintaining a record of flight crew flight and duty times, ensuring compliance with loading procedures, monitoring operational standards, supervising the training and checking of flight crew, and maintaining a complete and up-to-date reference library of operational documents.

Roles in Transair

CASA records indicated that the chief pilot had been approved to hold that position when the company was initially issued with an AOC in 1989. He had about 13,000 hours total aeronautical experience and about 1,500 hours on the Metro aircraft. He did not have previous industry experience in an airline environment.

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96 Civil Aviation Safety Authority, *Chief Pilot Guide*, March 1999.

The chief pilot was also the managing director of Transair[97], and controlled the day-to-day management of the company as well as supervising the organisation's flight operations. In addition, he filled the position of head of training and checking, and acted as a check pilot for all fixed wing aircraft types in the Transair fleet. He therefore performed three of the four positions listed in Section 28(3) of the *Civil Aviation Act 1988* as being key personnel within an AOC holder's organisation: that is, the chief executive officer; the head of the flying operations (chief pilot); and the head of the training and checking. The fourth key position was the head of aircraft airworthiness and maintenance control (maintenance controller).

Involvement with Trans Air Limited Papua New Guinea

Trans Air PNG had its own chief pilot, except for a period during 1998 and 1999 when the chief pilot of Transair (Australia) was also the chief pilot of Trans Air PNG. The Transair chief pilot reported that some pilots operating for Trans Air PNG were endorsed by the chief pilot from the Brisbane base and were paid by Lessbrook Proprietary Limited.

Pilots who had worked for Trans Air PNG stated that the chief pilot of Transair (Australia) was involved in the 'day-to-day' management of Trans Air PNG, and would visit Papua New Guinea 12 times a year for periods of 2 to 7 days each. The chief pilot reported that he was not involved in the 'day-to-day running' of Trans Air PNG, and that he would only visit Papua New Guinea up to six times a year.

Pilots operating for Trans Air PNG often conducted operations for Transair (Australia) from the Cairns base, including as operating crew on RPT flights on the Bamaga route. Trans Air PNG pilots also submitted incident reports to the Transair safety manager.

Other flying activities

The chief pilot reported that he did a 'reasonable amount of endorsements', estimated to be up to one a month. Other Transair personnel estimated that the number of endorsements was higher than this figure. Some of these endorsements were for non-Transair employees. The chief pilot also occasionally did flight training for other operators.

1.17.4 Other key personnel

Deputy chief pilot

As of October 2000, the *Transair Operations Manual* required that the operator establish and maintain the position of deputy chief pilot. The manual stated that the deputy chief pilot was responsible for performing the duties of the chief pilot when the chief pilot was absent. The duties outlined for the position included also being responsible to the chief pilot for the content and revision of the company's operations manual, as well as the management of the company's training and checking organisation (see Section 1.17.8).

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97 The Transair chief pilot was one of two directors of Lessbrook Proprietary Limited when the company was incorporated in 1988.

There was no regulatory requirement for the position of deputy chief pilot. However, CASA indicated to Transair on a number of occasions from 1998 that a pilot should be nominated and approved to act as chief pilot while the Transair chief pilot was away on other duties. The chief pilot reported that Transair usually had someone operating in the position of deputy chief pilot. There was no record on CASA files of anyone being approved to act as chief pilot in the chief pilot's absence during the period from January 1998 until December 2002.

A review of Transair pilot files found a letter from the chief pilot to CASA in January 2000 which stated that a contractor check pilot had accepted the position of deputy chief pilot. The contractor check pilot reported that he could not recall accepting the position or ever acting in that position. There was no record on CASA files of the notification letter, or that the contractor check pilot had been interviewed for the position of acting chief pilot in the event of the chief pilot's absence.

In March 2001, Transair nominated a supervisory pilot for the position of deputy chief pilot, and therefore to act as the chief pilot in the chief pilot's absence, but he was found to be unsuitable by CASA at interview at that time. In December 2002, that supervisory pilot was approved by CASA to act in the role of chief pilot during the incumbent's absences on other duties.[98] The deputy chief pilot reported that he was not aware of most of the checking and training duties associated with the position of deputy chief pilot (see Section 1.17.8).

Maintenance controller

The maintenance controller was responsible for controlling all maintenance carried out on Transair (Australia) and Trans Air PNG aircraft. He had been employed in that position since February 2000. At the time of the accident, he was approved as the maintenance controller for six Metro aircraft (VH-TFU, VH-TGD, VH-TFG, VH-TGQ, VH-UUN and VH-TFQ), a Beechcraft Baron and a Cessna Citation.

The maintenance controller also held the position of safety manager from late 2001. The responsibilities of the safety manager position are discussed in Section 1.17.10. Although the controller was assisted by a technical records clerk, the controller reported that he felt 'a bit stretched' in terms of the workload associated with the two positions.

Training and checking pilots

Transair had two training and checking pilots for the Metro aircraft. These were the chief pilot, and a contractor check pilot. The contractor reported that he was employed on a consultation basis and did minimal work for Transair. The responsibilities of training and checking pilots are discussed in Section 1.17.8.

Base managers

The base managers were pilots. The *Transair Operations Manual* stated that the base managers were responsible to the chief pilot for a number of administration

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98 CASA reported that a finding of unsuitability on one occasion did not preclude the possibility that the same candidate could be found to be suitable on a subsequent assessment, especially with increased knowledge and experience in the interim.

and operational tasks, including ensuring operations were conducted in accordance with the *Transair Operations Manual*, supervising line pilots, attending flight standards meetings as required by the chief pilot, and reporting all safety issues.

Operations manager

Transair employed a full-time operations manager, who provided administrative support to the chief pilot. The person employed in this position did not operate as a pilot for Transair. The *Transair Operations Manual* stated that the duties associated with the position included the administration of flight crew duty times and training records.

1.17.5 The Cairns – Lockhart River – Bamaga route

Relationship between Transair and Aero-Tropics

Aero-Tropics was a low capacity RPT and charter operation based in Cairns. Following the cessation of operations in September 2001 by a regional airline affiliated with the Ansett Airlines group, the managing director of Aero-Tropics reached a verbal agreement with Transair's chief pilot to conduct an RPT service between Cairns and Bamaga. Under the agreement, Aero-Tropics would provide ground handling, pilot briefing facilities and marketing services at both aerodromes and Transair would provide the aircraft and crews to conduct the RPT service. The agreement provided for Transair to be paid a fixed sum for each flight undertaken. The advertised schedule on the Aero-Tropics internet site and passenger boarding passes indicated that the service was operated by Transair.

Aero-Tropics reported that it did not conduct internal audits on Transair operations. Meetings were held a number of times between the Transair safety manager and Aero-Tropics check-in and loading staff. The Transair chief pilot stated that the safety manager visited each port twice a year to review ground operations. He also reported that the safety manager visited Bamaga approximately 5 weeks prior to the accident.

Transair pilots reported that they did not consider there was any commercial pressure from Aero-Tropics or Transair to keep to the published schedule for the RPT services.

Cairns – Bamaga route

CASA authorised Transair to conduct RPT operations in Metro aircraft between Cairns and Bamaga on 5 October 2001. Before this date, Transair's AOC only authorised RPT passenger-carrying operations between Christmas Island and Jakarta, Indonesia (see Section 1.18.5). Aero-Tropics held an AOC which authorised RPT operations between Cairns, Bamaga, and Lockhart River. The aircraft specified on the Aero-Tropics AOC to be used for RPT operations were all piston engine aircraft with seating capacity of less than nine passengers, and therefore did not include Metro aircraft.

An article in *The Cairns Post* newspaper dated 22 September 2001 reported that 'Aero-Tropics restored flights between Cairns and Bamaga on Monday [17 September] four days after Ansett ceased its services'. The newspaper also published a fixed schedule for Aero-Tropics flights on the Cairns-Bamaga route for

22 September, with flight number HC171 departing Cairns at 1100 and flight number HC172 arriving back into Cairns at 1515.[99] The same flight numbers and times were published in the newspaper on subsequent days, including from 24 September to at least 11 October 2001.[100]

Data from Airservices Customer Billing System (AvCharges) showed that from 17 September to 4 October 2001, Transair operated a Metro on the Cairns-Bamaga-Cairns route on 14 days. One return trip was conducted each day except Sundays, Tuesday 18 September and Saturday 22 September. Two return trips were conducted on Friday 21 September. Most of the flights landed at Bamaga between 1240 and 1310, and arrived back at Cairns between 1500 and 1540. During the period from 5 October to 31 October 2001, flights on the Cairns – Bamaga – Cairns route occurred every day except Sundays, and most flights landed at Bamaga between 1240 and 1300 and arrived back at Cairns between 1500 and 1520. Transair's chief pilot reported that the initial three flights between Cairns and Bamaga were conducted in the charter category of operation.

Cairns – Lockhart River – Bamaga route

Transair received authorisation to conduct RPT operations to Lockhart River on 5 October 2004 (see Section 1.18.5). At the time of the accident, the scheduled services between Cairns and Bamaga consisted of nine return services a week, using Transair's Metro, VH-TFU. Two of those services included scheduled landings at Lockhart River (Wednesdays and Saturdays).

An article in *The Cairns Post* newspaper dated 20 August 2004 reported that Aero-Tropics 'has included a twice-weekly return stop-over at Lockhart River on its main service from Cairns to Bamaga, starting August 28'. These flights were to operate on Wednesdays and Saturdays.

Data from AvCharges showed that from 28 August to 1 October 2004, Transair operated VH-TFU into Lockhart River on 14 days (involving 22 landings). A review of landing times and a comparison with Transair's flight schedule indicated that, on at least 11 of these days (17 landings), these trips occurred while the aircraft was conducting the RPT service on the Cairns – Bamaga – Cairns route. Seven of these trips occurred on Wednesdays and Saturdays. During the period from 5 October to 31 October 2004, VH-TFU operated into Lockhart River every Wednesday and Saturday while the aircraft was conducting the RPT service on the Cairns – Bamaga – Cairns route.

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99 CAR 210 stated: 'A person must not give a public notice, by newspaper advertisement, broadcast statement or any other means of public announcement, to the effect that a person is willing to undertake by use of an Australian aircraft any commercial operations if the last-mentioned person has not obtained an Air Operator's Certificate authorising the conduct of those operations.'

100 The published departure time from Cairns on Monday 1 October 2001 and Monday 8 October was 1245.

1.17.6 The *Transair Operations Manual*

Regulatory requirements

CAR 215 required an operator to provide an operations manual for the use and guidance of its personnel. The operations manual was to contain information, procedures and instructions with respect to the flight operations of all types of aircraft operated by the operator to ensure the safe conduct of flight operations. Any information that was contained in other documents that were required to be carried in the aircraft was not required to be reproduced in the operations manual. This requirement was restated in CAO 82.3 - *Conditions on Air Operators' Certificates authorising regular public transport operations in other than high capacity aircraft.*

CAR 215 (9) stated:

> Each member of the operations personnel of an operator shall comply with all instructions contained in the operations manual in so far as they relate to his or her duties or activities.

To assist operators in compiling an operations manual, CASA produced a Civil Aviation Advisory Publication (CAAP) 215-1 (0) *Guide to the preparation of operations manuals* (September 1997). The CAAP stated:

> As part of its methodology for the safety regulation of industry, CASA will place increasing emphasis on operators to use safety systems in the oversight of their operations. An operations manual itself is a safety system and it will contain many sub-systems.

CAAP 215 provided a suggested format for an operations manual, which included, among others, the following topics: instrument approach recency; operations at specific locations; crew coordination; and visual and instrument departure and approach procedures.

The CAAP indicated that an independent contractor could be utilised to produce an operations manual, but advised that:

> …the operator's lack of direct involvement frequently leads to an inadequate awareness of what is exactly required by the text of his or her own manual.

Hierarchy of documentation

Two manuals provided information regarding the operation of Transair's aircraft. These were, in order of precedence:

- the CASA-approved flight manual for the aircraft
- the *Transair Operations Manual*.

The CASA-approved flight manual consisted of the FAA *Approved Airplane Flight Manual*, which contained sections on operating limitations, normal procedures, emergency procedures, abnormal procedures, performance data, weight and balance, manufacturer's data on selected systems and components, and a number of supplements relating to the aircraft.

Compilation of the Transair Operations Manual

Following a CASA surveillance audit in December 1999 and the follow-up meeting with the chief pilot (see Appendix H), CASA noted that Transair's manuals were written by a contractor and that they were 'totally unacceptable in their current format and need to be completely re-written'. The chief pilot agreed to rewrite the *Transair Operations Manual*, and he was advised by CASA at the time to write the manual in the format proposed by draft Civil Aviation Safety Regulation (CASR) Part 119 format.[101] Transair submitted a revised operations manual in August 2000.

Content of the Transair Operations Manual

The *Transair Operations Manual* was divided into four parts:

- Part A contained administrative information and general operating procedures
- Part B contained specific aircraft operating procedures
- Part C contained route and aerodrome requirements
- Part D contained the training and checking manual.

The content of the *Transair Operations Manual* generally followed the recommended framework outlined in CAAP 215. However, the specific aircraft operating procedures for all types of fixed-wing and rotary-wing aircraft were combined in Part B rather than being differentiated by aircraft type.

Format of the Transair Operations Manual

The *Transair Operations Manual* was provided to pilots on a CD-ROM. After September 2003, pilots did not receive a paper version of the manual, and the newer pilots, including the copilot, had only ever received a CD-ROM version. The chief pilot reported that the change to the CD-ROM format was driven by feedback from CASA during audits. The CASA Brisbane airline office manager reported that there had not been any pressure applied to Transair to produce the manual in electronic format.

The CD-ROM issued to pilots contained the four parts of the manual separated into 181 files spread across five electronic folders. There was no central index or an index for each manual part. Rather, there were many index files within each part that dealt with the contents of only one section of the part. These indexes were in separate files to the contents, and there were no hyperlinks between indexes and contents. Transair's electronic operations manual did not use any automatic indexing and hyperlink functionality to assist in the useability of the CD-ROM.

Some Transair pilots commented that they did not like the CD-ROM format and, as a result, did not read the *Transair Operations Manual* and were unfamiliar with its contents. It was reported that the manual was difficult to use, and that it was not

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101 In May 2000, CASA issued a discussion paper with supporting documentation regarding the proposed CASR Part 119. CASR Part 119 was intended to incorporate into one document, all regulatory provisions relating to obtaining and retaining an AOC that authorised the holder to conduct commercial air transport operations. As at the date of this investigation report CASR Part 119 had not been implemented.

uncommon for pilots in the Cairns base to wait until other pilots came on duty to ask them about specific information that would normally be found in the manual. A CASA inspector stated that, following the accident, he found the CD-ROM format of the *Transair Operations Manual* to be not useable and, in order to review it, that he had to first print a paper copy comprising about 700 pages.

Transair's document control

ICAO Document 9376-AN/914 *Preparation of an Operations Manual* contained information on the structure and organisation of an operations manual. The document provided advice on how to process amendments to an operations manual. Section 2.3.7 stated:

> Amendments to the operations manual must be produced as new or replacement pages. Handwritten amendments to an operations manual are generally not acceptable. The new or replacement pages must include a page identification number and a date of issue. A letter or covering sheet must identify the reason for the amendment and provide a checklist of the amendment to be made. This is particularly necessary when an amendment is made to any safety-related information.

Transair's Cairns base was required to keep a paper copy of the *Transair Operations Manual* in the pilot briefing room, but it was reported that this copy of the manual was not kept up to date. In the week following the accident, the ATSB investigation identified in the Cairns pilot briefing room the *Transair Operations Manual* Cairns Base Copy No.9 including the most recent signature sheets completed up to 28 May 2004, and a record of revision sheet completed up to amendment number 3, which was dated April 2002.

When a new CD-ROM was issued, Transair did not indicate which sections had been changed. Each page of the *Transair Operations Manual* had a date included on it, and often the dates on the pages did not match any of the saved dates on the electronic files. For example, Section A0 of the manual contained a 'list of effective pages'. In this list, Section A8-1 Annex 1 was listed as having an effective date of 10/2000. Examination of the electronic file listing revealed that the file was last modified and saved on 10/2/2005. No pages in this section had effective dates other than 10/2000, nor were there any pages that had an effective date of 10/2/2005. This process was replicated in other sections of the manual. This meant that to ensure that a pilot had the latest paper copy of the manual, they had to reprint the entire manual every time a new CD-ROM was received.

1.17.7 Transair's descent and approach procedures

Descent and approach procedures were specified in the flight procedures, standard operating procedures, and the route and aerodrome sections of the *Transair Operations Manual*. The procedures are discussed below and the relevant sections of the manual are provided in Appendix G. The *Approved Airplane Flight Manual* did not contain any procedures or guidance relating to approach profiles, configurations and speeds.

Before descent procedures

The descent and approach briefing requirements were located in two separate areas of the *Transair Operations Manual*. The instrument approach briefing content was discussed in the standard operating procedures section of Part B, and stated that the 'crew briefing' was to be completed prior to commencing descent. Procedures to be followed before initiating a RNAV (GNSS) approach were described in Part A of the manual.

Descent procedures

The *Transair Operations Manual* provided guidance for the descent in the standard operating procedures section of Part B. The manual did not list separate descent procedures for different aircraft.

The *Transair Operations Manual* stated that the descent point was calculated by multiplying the number of thousands of feet above destination airfield elevation by two. The chief pilot reported that this reference was only appropriate for Citation aircraft, and that the Metro descent profile involved multiplying the number of thousands of feet above the airfield elevation by three.

Several Transair pilots reported that they normally calculated the descent point by multiplying the number of thousands of feet above the airfield elevation by three.[102] Other Metro operators reported that they also multiplied the number of thousands of feet above the elevation by three.

The *Transair Operations Manual* stated in Part B that:

> Descent will normally be made at Vmo –10 [*sic* V_{MO}-10] kts. In Class G airspace [outside controlled airspace] reduce to 210 kts below 5,000 ft.

Altimeter setting procedures

The altimeter setting procedures were found in Part A of the *Transair Operations Manual*. The procedures required crews, when operating below the transition level (FL 110 in Australian airspace), to set the altimeters to the latest QNH altimeter setting for the destination aerodrome. Outside controlled airspace (OCTA), the QNH was to be obtained from the current aerodrome terminal area forecast (TAF).

Turbulence penetration procedure

Part A of the *Transair Operations Manual* provided the following guidance regarding crew actions on encountering turbulence:

> Pilots encountering moderate to severe turbulence are to fly company aircraft at the turbulence penetration speed where nominated for the specific aircraft. Where this speed is not nominated the maneuvering [*sic*] speed Va [V_A][103] was to be used.

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102 For example, 17,000 ft multiplied by 3 resulted in a descent point that was 51 NM from Lockhart River aerodrome.

103 V_A (design manoeuvring speed) is the maximum speed in the cruise configuration at which the application of full available aerodynamic control will not overstress the aircraft. V_A for VH-TFU on approach to Lockhart River was 173 kts based on its estimated weight of 6,699 kg.

Altitude alerting system procedures

The guidance provided in Part A of the *Transair Operations Manual* stated that on descent OCTA, the lowest safe altitude (LSALT) or minimum safe altitude (MSA) was to be set. On commencement of an instrument approach, or after leaving the initial approach fix, the altitude alerting system was to be set to the published missed approach altitude.

In Part B of the manual, guidance was provided for standard crew calls relating to altitude alerting procedures. The relevant calls for the instrument approach procedure required the non-handling pilot to advise the handling pilot when leaving the commencement altitude and at 200 ft above the minimum descent altitude (MDA).

Standard approach calls

There was limited guidance provided throughout the *Transair Operations Manual* as to how to accomplish standard operating procedures and calls in a multi-crew environment. The terms ‘pilot not flying’ (or ‘PNF’) and ‘non-flying pilot’ (‘NFP’) were used in the manual to refer to the non-handling pilot, and the terms ‘pilot flying’ (‘PF’) and ‘flying pilot’ (‘FP’) was used to refer to the handling pilot. The guidance provided in the manual included:

Occurrence	**PNF**	**PF**
Commencing instrument approach	“Left....for....”	“Check”
Final approach on instrument approach	“200 ft to minima”	“Check”

> ….
>
> During 2 crew operations, the NFP shall assist the FP in any way necessary to allow the FP to concentrate on physically flying the aircraft. …
>
> The 2 crew checklists are designed as the challenge and response type. …

The manual stated that, during an instrument or visual approach, the non-handling pilot shall monitor the handling pilot and advise him of various deviations in tracking, altitude, airspeed and rate of descent performance (see also *Instrument approach procedures* below).

Approach speeds

The approach speeds referred to in Part A of the *Transair Operations Manual* directed crews to the table of handling speeds published in the *Aeronautical Information Publication* (AIP), which was also reproduced in the *Transair Operations Manual*. The table gave a range of speeds for each aircraft performance category.[104] The *Transair Operations Manual* did not specify the appropriate

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104 ICAO Doc 8168-OPS/611 Volume 1 *Procedures for Air Navigation Services Aircraft Operations* (PANS-OPS) stated: ‘Aircraft performance has a direct effect on the airspace and visibility needed to perform the various manoeuvres associated with the conduct of instrument approach procedures. The most significant performance factor is aircraft speed. Accordingly, …. five categories of typical aircraft have been established based on 1.3 times stall speed in the landing configuration at maximum certificated landing mass, to provide a standardized basis for relating aircraft manoeuvrability to specific instrument approach procedures.’

performance category applicable to the aircraft type. The *Transair Operations Manual* stated:

> The following table shall be used by all Company pilots for aircraft performance category. The V_{at}/V_{ref} speeds for each Company aeroplane is at Part B.

Aircraft Performance Categories[105]

Category	V_{at}	Initial Approach	Final Approach	Circling	Missed Approach
A	<91	90 – 150 (*110)	70 – 100	100	110
B	91 – 120	120 – 180 (*140)	85 – 130	135	150
C	121 – 140	160 – 240	115 – 160	180	240

> …
>
> During instrument approaches and circling approaches, Company aircraft shall use the above speed profiles according to the Performance Category of the particular aircraft type.

Aircraft performance categories were based on an indicated airspeed at the threshold (V_{AT}).[106] Part B of the *Transair Operations Manual* did not state the value of V_{AT}/V_{REF} for the Metro 23, however, the approved *Airplane Flight Manual* stated that at maximum landing weight the aircraft had an approach speed (which equated to V_{AT}) of 117 kts. Although the aircraft performance category was not specified in the *Transair Operations Manual*, the above speed meant that the Metro 23 was a performance Category B aircraft.

Several Transair pilots were asked about the speeds and configurations used during straight-in instrument approaches. Most reported that the speed at the initial approach fix would be about 180 kts, with some pilots reporting 180 to 200 kts. Most pilots reported that the speed at the final approach fix would be about 140 kts or slightly higher. One pilot reported a speed of 120 to 140 kts (though faster if the weather was better), and another pilot reported that he aimed for a speed of V_{REF}+10 kts (about 125 kts). The Transair chief pilot reported that he would expect a speed of about 140 kts at the initial approach fix and 125 to 130 kts at the final approach fix.

The Transair chief pilot reported that all fixed-wing aircraft in the Transair fleet were operated as Category B. Of the other Transair pilots who were asked about the performance category used in operations, two reported that it was a Category B aircraft, another reported it was operated as Category B aircraft in fine weather but operated as Category C if they needed to keep the speed up due to weather, one pilot reported that it was operated as Category C, and another pilot could not recall. The contractor check pilot also reported that the Metro should be operated as a Category B aircraft.

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105 Speeds denoted by asterisks in the table referred to the maximum speeds for operation during a procedural reversal turn.

106 V_{AT} is the indicated airspeed at the threshold which is equal to the stalling speed with landing gear extended and flaps in the landing position (V_{so}) multiplied by 1.3 or the stalling speed under 1g vertical (normal) acceleration with flaps and landing gear retracted (V_{s1g}) multiplied by 1.23.

The flight plan lodged with Airservices for the accident flight indicated that the aircraft was nominated to be operated as a Category B aircraft.

The AIP Enroute Section 1.5, *Holding, Approach and Departure Procedures* stated that:

> 1.2.2 An aircraft must fit into and be operated in accordance with the requirements of only one category. An aircraft:
>
> a. may not reduce category because of reduced operating weight, but
>
> b. must increase category when actual handling speeds are in excess of those for category (based on Vat) detailed at Sub-section 1.15.
>
> 1.2.3 Provided an aircraft can be operated within the limits of the handling speeds (detailed at Sub-section 1.15) for a lower category than the category determined by V_{at}, and subject to approval by CASA, an operator whose crew(s) operate under a CAR 217 training and checking organisation may operate that aircraft type at the lower category. When such an approval is granted, all company operations of the aircraft type must be in accordance with the requirements of the revised category.

Approach configuration

There was variation in the point at which Transair pilots reported that they changed configuration during the approach. Some pilots reported that they selected ½ flap and gear down prior to or at the initial approach fix, and some others reported selecting ½ flap and gear down at about the intermediate fix or later.

Stabilised approach

The Flight Safety Foundation recommended criteria for stabilised approach procedures, including a maximum speed of V_{REF} +20 kts, or 134 kts for the accident flight, and a maximum rate of descent of 1,000 ft/minute at 1,000 ft above aerodrome level (AAL) (see Section 1.21.3). ICAO also provided guidance to include stabilised approach procedures in an operations manual (see Section 1.18.8).

The *Transair Operations Manual* did not contain information about the concept of a stabilised approach. The criteria for a stabilised approach were not defined, but that information was indirectly provided to crews in the section relating to monitoring instrument approaches (see *Instrument approach procedures* below). Transair pilots reported that they were not aware of any specific stabilised approach criteria for Transair operations.

The Transair chief pilot reported that he was aware that the *Transair Operations Manual* did not include stabilised approach criteria, as this deficiency had been drawn to his attention during an audit by a potential customer organisation. He also reported that he had discussed stabilised approach criteria with a CASA inspector, who had advised him that this information was not required in an operations manual for Metro aircraft. Other CASA inspectors reported that they believed it was important to include stabilised approach criteria in an operations manual.

Comparison with other Metro operators

The investigation sampled five Australian Metro operators about approach procedures. Three operated the Metro as a Category B aircraft, while two (operator

#1 and operator #4 in the table below) operated them as Category C aircraft. The approach speeds, approach configuration and stabilised approach speeds and rates of descent used by each operator are presented in the table below.

	Initial approach fix	**Final approach fix**	**Stabilised approach speeds/rate of descent**
Operator #1	160 – 180 kts Flaps – quarter Gear – up	140 – 160 kts Flaps – half Gear – down	1000 ft Speed < V_{REF} + 20 RoD < 1,000 ft/min
Operator #2	170 +/- 10 kts Flaps – half Gear – up	130 kts Flaps – half Gear – down	1000 ft Speed: < V_{REF} + 10 RoD not > 500 ft/min
Operator #3	135 – 150 kts Flaps – half Gear – down	135 kts Flaps – half Gear – down	200 ft Speed V_{REF} to V_{REF} + 5 RoD < 1,000 ft/min
Operator #4[107]	200 kts Flaps – up Gear – up	160 kts Flaps – half Gear – down	300 ft Speed V_{REF} + 20 RoD not > 1,000 ft/min
Operator #5	< 180 kts Flaps – half Gear – up	130 kts Flaps – half Gear – down	300 ft Speed < V_{REF} + 10 RoD < 1,000 ft/min
Transair chief pilot	140 kts Flaps - quarter Gear - up	125 – 130 kts Flaps - half Gear - down	None
Transair Operations Manual	120 – 180 kts configuration not specified	85 – 130 kts configuration not specified	None
Accident flight	229 kts Flaps – up Gear – probably up	177 kts Flaps - half Gear – probably down	

Instrument approach procedures

Part B of the *Transair Operations Manual* provided guidance to crews for the conduct of an instrument approach. The pilot in command was responsible for ensuring that a 'crew briefing' was conducted prior to commencing the approach. The briefing called for the handling pilot to review the approach chart for the procedure to be flown and to nominate the tuning and identification of the required navigation aids.

The non-handling pilot was tasked with monitoring the approach and calling any deviations, including:

- altitude errors in excess of 100 ft;
- deviations in excess of 10 kts from the nominated airspeed;
- a rate of descent on final approach in excess of 1,000 ft/min;

107 This operator utilised a Metro 3 flight simulator with both visual and motion systems to conduct most of its endorsement training and proficiency checks.

- approaching any instrument approach altitude restriction; and
- altitudes of 500 ft, 200 ft, and 100 ft above the minimum descent altitude (MDA) in IMC.

The non-handling pilot was also required to advise the handling pilot of tracking errors for the NDB and VOR approaches and tracking and glidepath errors for an ILS approach. The manual did not specify any requirements in relation to a RNAV (GNSS) approach.

The landing checklist was required to be completed no later than the outer marker[108] or in VMC by 1,000 ft AGL. At 400 ft AGL the non-handling pilot was to call the check for confirmation that the landing gear was down and locked, flaps set and that the runway was clear.

The procedures did not make reference to using the distance/altitude table included on instrument approach charts during the approach.

RNAV (GNSS) instrument approach procedures

RNAV (GNSS) approach procedures were located in Part A of the *Transair Operations Manual*. Information relating to the RNAV (GNSS) approach procedure was generic and directed crews to the receiver manufacturer's operational documentation carried in the aircraft.

The manual stated that, when the aircraft was operated by two pilots, all GPS switching was carried out by the non-handling pilot on confirmation from the handling pilot. Other actions relating to the operation of the GPS were setting the GPS approach switch to the 'arm' position at 30 NM from the destination aerodrome and entering the altimeter setting of the destination aerodrome.

Missed approach

The *Transair Operations Manual* did not specify that a missed approach should be initiated if the approach became unstable, nor did it specify the pitch attitude and configuration of the aircraft required for the missed approach manoeuvre. The *Approved Airplane Flight Manual* specified a target speed and the configuration for the missed approach manoeuvre.

108 The outer marker refers to a beacon about 4.5 NM from the runway threshold, which is part of an instrument landing system.

Ground proximity warning system procedures

The procedures in the *Transair Operations Manual* for responding to GPWS warnings during flight at night or in IMC by the handling pilot was as follows.

Position	Warning	Action
Instrument approach	'SINK RATE' or 'BELOW G/S	Check approach profile and prepare for missed approach
Final approach	'MINIMA'	If visual land, if not visual complete the missed approach procedure
Descent	'SINK RATE' or 'PULL UP'	Immediately apply go-around power and set the go-around attitude

The *Transair Operations Manual* did not make reference to the mode 2 alert 'terrain terrain'.

The *Approved Airplane Flight Manual* supplement for the GPWS installed in VH-TFU provided the following procedure if a mode 2 warning was encountered in IMC or at night:

a) Level wings and simultaneously pitch up at a rotation rate of 2 to 3 degrees per second to the best angle of climb attitude (approx. 15 deg.).

b) Apply maximum power.

c) Monitor radio altimeter for trend toward terrain contact and adjust pitch attitude accordingly upwards as necessary, honoring pre-stall buffet/warning.

d) Continue maximum climb straight ahead until visual and aural warnings cease.

The chief pilot reported that the *Honeywell GPWS Mark VI Warning System - Ground Proximity Warning System Pilots Guide* was kept in the aircraft and many photocopies were made.

Route and aerodrome requirements

Part C of the *Transair Operations Manual* contained information relating to route and aerodrome requirements. For the Cairns – Bamaga route, a note stated that the last route segment was to be flown in VMC. The last route segment was 122 NM, ending at Bamaga aerodrome. The chief pilot reported that this requirement was included in the manual because he was not in favour of the RNAV (GNSS) approach. For the Cairns – Lockhart River – Bamaga section, no similar note was included.

Other issues

A review of the *Transair Operations Manual* also noted that it did not contain the following information:

- any information or guidance on the requirements or use of the radio altimeter;
- any guidance on crosswind limits;

- any company guidance on the use of weather radar during descent or the instrument approach; and
- any standard phraseology that could be used by crew members to challenge the other crew member when errors were detected and not corrected.

Other aspects noted were:

- elements of the descent and approach standard operating procedures were distributed throughout the *Transair Operations Manual* as suggested by CAAP 215 framework, and there was no consolidation of standard operating procedures in Part B of the manual;
- there was little guidance provided in the *Transair Operations Manual* as to how to accomplish standard operating procedures in a multi-crew environment;
- the manual stated that 'the NFP shall assist the FP in any way necessary to allow the FP to concentrate on physically flying the aircraft' was open to interpretation and would have been difficult for company check pilots to enforce that standard operating procedure; and
- the *Transair Operations Manual* specified when deviations in tracking, airspeed, rate of descent and altitude limitations were to be announced by the non-handling pilot, but there was no standard phraseology provided that could be used by the crew members to announce these deviations during an instrument approach or to determine the possibility of pilot incapacitation during the approach.

1.17.8 Transair's flight crew training and checking processes

Regulatory requirements

CAR 217 stated:

> (1) An operator of a regular public transport service, an operator of any aircraft the maximum take-off weight of which exceeds 5,700 kilograms and any other operator that CASA specifies shall provide a training and checking organisation so as to ensure that members of the operator's operating crews maintain their competency.
>
> (2) The operator must ensure that the training and checking organisation includes provision for the making in each calendar year, but not at intervals of less than four months, of two checks of a nature sufficient to test the competency of each member of the operator's operating crews.
>
> (3) The training and checking organisation and the tests and checks provided for therein shall be subject to the approval of CASA.
>
> (4) A pilot may conduct tests or checks for the purposes of an approved training and checking organisation without being the holder of a flight instructor rating.

CAO 82.3 provided further requirements in relation to the training and checking organisation of an operator of RPT services in low capacity aircraft. It stated:

> Each operator must ensure that a person does not act as an operating crew member on a scheduled revenue service unless that person has satisfactorily completed all necessary training programs and proficiency checks and has been certified by a check pilot as being competent to act as an operating crew member.

Appendix 2 of CAO 82.3 included further regulatory requirements, including:

> The operator must appoint sufficient personnel to ensure that all training programs, examinations and proficiency checks can be undertaken to the satisfaction of CASA.

Appendix 2 to CAO 82.3 also required the operator to provide a training and checking manual. The CAO stated that the manual must include, among other things, the duties, responsibilities and proficiency requirements of training and checking personnel, and course outlines and syllabuses for each flight training program.

CAO 82.3 required the operator to maintain up-to-date records showing the recent experience status of each flight crew member, the currency of licences and the ratings and endorsements held by each crew member.

Transair's training and checking organisation

CASA originally issued an approval for Transair to operate a check and training organisation under CAR 217 in August 1995. This approval was subsequently reissued in August 2001.

The chief pilot was the head of Transair's CAR 217 approved training and checking organisation. CASA approval of the position of head of training and checking was not required when this position was held by the chief pilot and the chief pilot was a CASA-approved check pilot authorised to conduct proficiency checks on pilots working for that operator.

The *Transair Operations Manual* indicated that the chief pilot was responsible for the overall monitoring of operational standards and supervising the checking and training of all company pilots. The chief pilot was also to ensure that there were sufficient check pilots to carry out the check and training functions of the company. The *Transair Operations Manual* required that the number of check pilots be ascertained by the conduct of a task analysis which was to be carried out by the chief pilot. No record of any task analysis carried out by the Transair chief pilot was found by or provided to the investigation.

The *Transair Operations Manual* indicated that the position of deputy chief pilot was part of the check and training organisation and was responsible to the chief pilot for managing Transair's training and checking program, with specified duties including scheduling all training and checking requirements for flight crew, and monitoring the progress of flight crew undergoing training. The deputy chief pilot reported that he was not aware of these requirements. He only held supervisory pilot approval within Transair's training and checking organisation (see below) and reported that the chief pilot conducted most of the responsibilities relating to training and checking outlined in the *Transair Operations Manual*. The deputy chief pilot also reported that, because his roster duties mainly consisted of night flying, he rarely went into the Brisbane office during normal business hours.

There were additional positions nominated within Transair's training and checking organisation that were responsible for the operating standards and competency assessment of Transair's flight crew. These personnel were nominated in the positions of check pilot, training pilot or supervisory pilot.

Check pilots

A check pilot was a person approved by CASA under CAO 82.0 to conduct proficiency checks within a CAR 217 organisation. CASA also routinely provided check pilots with delegations that enabled them to conduct the flight test for the renewal of an instrument rating (CAR 5.19) and issue the rating in a pilot's logbook (CAR 5.14).

The then CAA had indicated in a letter to the Transair chief pilot in July 1990 that:

> Check pilots are responsible for ensuring that flying operations are conducted in accordance with, and meet the standards defined by the Civil Aviation Regulations and their supporting legislation, and the company Operations Manual.

The *Transair Operations Manual* defined the responsibilities of a check pilot as including the conduct of proficiency checks, instrument rating renewals and endorsement training. The manual also stated that check pilots for turbine aircraft had to hold or have held a Grade 1 or 2 multi-engine flight instructor rating or have held a previous multi-engine check or training approval.

The *Transair Operations Manual* also stated that there were two check pilots approved for Metro operations: the chief pilot and a contractor check pilot. Most of the proficiency checks conducted on Transair's Metro pilots were carried out by the chief pilot.

Both the chief pilot and the contractor check pilot held appropriate check pilot approvals from CASA. The CASA flight crew licensing database recorded that the chief pilot's approval as a check pilot expired on 11 November 1997. CASA reported that this approval had never been cancelled, and there was no documentation on CASA files that indicated that the approval had been cancelled.[109]

As far as could be determined, the Transair chief pilot's delegation under CAR 5.19 was first issued in May 1994. From May 1994 until April 2003, there was a condition on the delegation that required the chief pilot to hold a Grade 1 flight instructor (aeroplane) rating.[110] The chief pilot had never held a flight instructor rating. This condition was removed from his delegations in April 2003.

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109 The CASA database also recorded that the Transair chief pilot had a check pilot approval for a different operator commencing on 12 November 1997. This approval, and the cancellation of the Transair approval, were both entered in the CASA database at about the same time on 15 January 1998. Accordingly, the database entry showing that his Transair approval had been cancelled appeared to be a data entry error. This error had remained undetected from January 1998 until March 2007.

110 CASA inspectors reported that this condition was sometimes inadvertently included on CAR 5.19 instruments of delegation, but were not applicable for check and training pilots under a CAR 217 organisation.

Training pilots

A training pilot was a person approved by CASA under CAO 82.0 to conduct endorsement training and other flight training within a CAR 217 organisation. CASA routinely provided training pilots with an approval under CAR 5.21 to conduct endorsement training and a delegation to issue the endorsement in a pilot's logbook (CAR 5.23).

According to the *Transair Operations Manual*, the responsibilities of training pilots included endorsement training. The required qualifications outlined in the manual for a training pilot were the same as those for a check pilot.

Both the chief pilot and the contractor check pilot held appropriate training pilot approvals from CASA.[111] Most of the endorsement training for Transair Metro pilots was conducted by the chief pilot.

Supervisory pilots

Supervisory pilots were not required to be approved by CASA.

The *Transair Operations Manual* stated that supervisory pilots were responsible for the 'supervision of endorsed pilots acting in command under supervision (ICUS)'. The Transair chief pilot reported that supervisory pilots also flew with new copilots. The manual stated that the required qualifications of a supervisory pilot were at least 200 hours on type and at least 12 months experience with the company.

According to the *Transair Operations Manual*, prior to conducting supervisory pilot duties, a pilot had to complete a line proficiency check from the right seat[112] over at least two sectors, and a ground briefing session on the 'preparation of flight', 'flight planning' and 'captaincy' items on the company's proficiency line check form. There was no regulatory requirement or requirement in the *Transair Operations Manual* to have completed any training on the principles and methods of instruction.[113] One Transair supervisory pilot reported that he was not provided with any guidance as to how to conduct the duties relating to this role.

The *Transair Operations Manual* listed the person who held the deputy chief pilot position as being the only supervisory pilot for the Metro fleet. However, other pilots had been approved by the chief pilot as supervisory pilots. These included the pilot in command of VH-TFU and one other pilot based in Cairns. The pilot in command had no previous training or instructing experience.

Endorsement training

The *Transair Operations Manual* contained a section dealing with endorsement training on aircraft. All pilots required to undergo conversion training or requiring endorsement on particular aircraft types would have to complete the training

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111 The CASA flight crew licensing database did not list a CAR 5.21 approval for the chief pilot in respect of pilots employed by Transair. However, the investigation identified a valid instrument of approval dated 4 September 1995 on archived CASA files.

112 The right seat is normally the operating position for the pilot performing copilot duties.

113 CASA's *Air Operator Certification Manual* (AOC Manual) (see Section 1.18.2) stated that supervisory pilots should have training in the principles and methods of instructions.

outlined in *Annex 4* of Part D2 of the manual. *Annex 4* indicated that the content of initial training on a company turbine aircraft would consist of a 4-day ground school on the aircraft, its operating systems, the *Transair Operations Manual* and a performance examination. The flight training for the aircraft would consist of two in-flight exercises, one covering general aircraft operations and the other covering circuit operations.

Training in multi-crew procedures was not included as part of the endorsement. As with the crew of the accident flight, most pilots starting with Transair had no previous multi-crew experience. There was no regulatory requirement in Australia for flight crew undergoing a type rating on a multi-crew aircraft to be trained in procedures for crew incapacitation and crew coordination, including allocation of pilot tasks, crew cooperation and use of checklists. Although this was required from July 1988 under the ICAO's Annex 1 *Personnel Licensing,* eighth edition, CASA had notified ICAO in 2000 of a 'difference' with respect to paragraph 2.1.5.2a of this standard.[114]

The Transair chief pilot reported that he did not always follow the syllabus of training listed in the *Transair Operations Manual*. He tailored the training to the knowledge and experience of the person undergoing the endorsement training. Where previous knowledge was evident, he spent less time explaining the systems and moved on in the course. These comments were supported by a senior CASA flying operations inspector who underwent Metro endorsement training conducted by the chief pilot in 2001. This inspector had considerable experience operating turbine aircraft and had come from a heavy-jet airline background. He reported that the ground school conducted during his endorsement by the chief pilot was of 3 days duration, was conducted on a one-to-one basis, and covered all the systems and performance calculations.

Several Transair pilots who underwent ground school training with the Transair chief pilot reported that they were not given any formal classroom training during the ground school, instead they were provided with a copy of the *FlightSafety International SA-227 Pilot Training Manual* and the engineering examination and told to return the examination when it had been completed (see also Section 1.5.2). This was the case even for pilots who had no previous turbine aircraft endorsements or multi-crew experience. Other Transair pilots, who completed the Metro ground school with a Transair supervisory pilot, reported that they were provided with formal classroom training.

The pilot in command's pilot file did not contain any document recording the completion of a Metro ground school, but the file included an undated engineering examination. A family member reported that the copilot was provided with a training manual to study and was not given any formal classroom training during his ground school.

The contractor check pilot occasionally used by Transair displayed a different approach to the conduct of endorsement training, reporting that he spent 5 days delivering the ground school; 3 days covering the systems on board the aircraft, 1 day on aircraft performance calculations and 1 day on multi-crew operation procedures. This check pilot also commented that the endorsement training

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114 CASA reported that the notification of a difference with ICAO was legitimate and commonly used by all nations. In respect of this particular standard, the following countries had filed a difference: Australia, Bulgaria, France, New Zealand, Saudi Arabia, Spain and Zambia.

provided by Transair was basic, the standard of endorsed pilots was barely adequate, and no consolidation training was provided following the endorsement (see also Section 1.17.9).

A Transair supervisory pilot reported that it was common for both he and the pilot in command to spend additional time training new copilots when they arrived at Cairns as they were not sufficiently trained during the endorsement process to carry out the role and functions of a copilot. He reported that the level of systems knowledge displayed by newly-arrived copilots was ‘poor’. This supervisory pilot also reported that he and the pilot in command had both expressed their concerns about the level of training provided to pilots during their endorsement to the Transair chief pilot on a number of occasions.

Issuing of endorsements – pressurisation system

CAR 5.167(1) required that:

> …an air transport pilot (aeroplane) licence does not authorise the holder of the licence to fly an aeroplane as pilot in command, or co-pilot, unless the holder also holds:
> (a) a type endorsement or class endorsement; and
> (b) if the aeroplane has a special design feature—a special design feature endorsement;
>
> that authorises the holder to fly the aeroplane in that capacity.

CAR 5.06 outlined a similar requirement for pilots holding a commercial pilot (aeroplane) licence, regardless of whether they operated as pilot in command or copilot. According to CAR 5.01, special design features included a pressurisation system. No special design feature endorsement for the pressurisation system was entered in the pilot in command’s or copilot’s logbook when they were issued with their Metro endorsements, and their logbooks showed that all the aircraft types flown previously by them were non-pressurised aircraft types.

A review of a sample of other Transair pilot files[115] showed that most of them also had not been issued with a special design feature endorsement for the pressurisation system when they received their Metro endorsements. The Transair chief pilot reported that he provided training on the pressurisation system during endorsement training. Consequently, the absence of the special design feature endorsement in the pilots’ logbooks appeared to be an administrative error.

Post-endorsement training and clearance to line operations

The *Transair Operations Manual* required post-endorsement training to be completed by all pilots following initial endorsement and before operating as a crew member in RPT, charter or aerial work operations. The manual stated that this training shall include the following subject areas: flight planning, loading, systems, performance, check lists, flight procedures, navigation and route knowledge. The manual required that all post-endorsement training be recorded on the appropriate form and kept on the pilot’s file.

The manual also specified minimum flight time on type before pilots could operate as crew members on flights for Transair. A pilot in command on RPT, charter or

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115 Pilot files sampled for this investigation were those of some training pilots, the pilots based in Cairns at the time of the accident, and some other pilots who had previously operated at Cairns.

aerial work operations was required to have a minimum of 50 hours on type before being authorised to conduct line operations.[116] For a copilot on RPT or charter operations, the manual required a minimum of 10 hours and a minimum of three sectors before the pilot could be 'cleared to line'. The chief pilot reported that his understanding was that the 10-hour requirement in the *Transair Operations Manual* for copilots could be completed with a supervisory pilot during revenue operations.

The *Transair Operations Manual* stated that, before being 'cleared to line', pilots in command and copilots were required to undertake a proficiency route check over at least two sectors with a check pilot. CAO 82.3 also stated:

> Each operator must ensure that a person does not act as an operating crew member on a scheduled revenue service unless that person has satisfactorily completed all necessary training programs and proficiency checks and has been certified by a check pilot as being competent to act as an operating crew member.

Both the pilot in command and copilot of the accident flight had completed a flight proficiency base check as part of their endorsement training. The pilot in command's pilot file showed that he had then undergone 50 hours in command under supervision flying with a supervisory pilot. However, he had not been cleared to line by a check pilot. Following the copilot's endorsement (4.2 hours), the copilot conducted his next flight on a freight charter flight with a supervisory pilot (see also Section 1.5.2). He was not cleared to line by a check pilot. A review of a sample of Transair pilot files found that most had not been cleared to line by a check pilot.

Induction and recurrent training

The *Transair Operations Manual* indicated that all personnel associated with flight operations would 'as soon as practicable' undergo instruction on the company, its operations and dangerous goods manuals and its safety program.

The induction training required by the *Transair Operations Manual* also indicated that pilots would have to undergo additional training. The additional training included:

> c. Where required, a pilot shall complete the 'GPS under the IFR' as per Annex 1, prior to being 'cleared to line'
>
> e. All new pilots shall complete the Human Factors Management (HFM) induction course, as per Annex 2, within 6 months of joining the company.

In addition to the initial induction training, the *Transair Operations Manual* also required that pilots complete a recurrent human factors management course every 15 months training (see below). The manual specified no other recurrent flight training requirements. Pilots reported that they had received no recurrent flight training of any form while employed at Transair.

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116 CAO 82.3 Appendix 4 listed the qualifications required for pilots of an aeroplane with a MTOW greater than 5,700 kg engaged in RPT operations. A pilot in command was required to have, among other things, 50 hours in command or in command under supervision on the aircraft type. There was no requirement for the copilot to have any experience on the aeroplane type other than holding an endorsement.

Human factors management training

Transair flight crew operating the Metro aircraft performed the roles of handling and non-handling pilot on alternate sectors in a multi-crew environment. Human factors management courses (generally known as crew resource management or CRM training[117]) are designed to teach flight crew the non-technical skills essential for operating in a multi-pilot team in a complex time-critical environment (see Section 1.20).

Transair's human factors management courses, as outlined in the *Transair Operations Manual*, were an extension of the air transport pilot licence (ATPL) syllabus and revolved around classroom-based awareness training. The manual also specified that discussions after a check flight between the check pilot and pilot under assessment should cover 'technique, safety, and human factors matters' on a discussion rather than an instructional basis.

No record could be located to indicate that the pilot in command had completed the Human Factors Management Induction Course or any Human Factors Management recurrent training course, either before or after commencing employment with Transair in 2001. There was also no record of the copilot having completed the Human Factors Management Induction Course since his appointment in February 2005. However, he was still within the initial 6 months period of his employment as specified in the *Transair Operations Manual*. None of the other Cairns-based pilots reported that they had completed any human factors management training.

A Transair supervisory pilot had provided instruction in CRM to the Trans Air PNG pilots while working for that operator. The Transair chief pilot had completed a CRM course with that instructor in August 2002. He reported that some other Transair pilots had also completed CRM training about this time. The chief pilot reported that he had stopped CRM training at Transair after this time as he had been using two different instructors who were not consistent with each other.

RNAV (GNSS)[118] approach training

CAO 40.2.1 paragraph 13.3.4 stated:

> For the purposes of regulation 5.16[119], it is a condition of each instrument rating that the holder of the rating must use only the types of navigation aids or procedures endorsed in the holder's personal log book when exercising the authority given by the rating.

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117 There were no specific regulatory requirements in Australia for operators to provide CRM training (see Section 1.20.7). However, by including a requirement for CRM training in the *Transair Operations Manual*, the provision of that training to Transair pilots was mandatory and subject to regulatory enforcement. CAR 215(9) stated that 'Each member of the operations personnel of an operator shall comply with all instructions contained in the operations manual in so far as they relate to his or her duties or activities'.

118 GPS/NPA refers to global positioning system non-precision approaches, referred to as RNAV (GNSS) approaches in this report.

119 CAR 5.16(1) stated 'CASA may issue, or renew, a flight crew rating, or grade of flight crew rating, subject to any condition that is necessary in the interests of the safety of air navigation'.

CAO 40.2.1 paragraph 13.4A further stated:

> For regulation 5.16, a person who has a RNAV(GNSS) endorsement must not conduct a RNAV(GNSS) approach in I.M.C. as pilot in command of an aircraft unless he or she has carried out at least 3 RNAV(GNSS) approaches in flight, or in a synthetic flight trainer, using a GNSS receiver:
>
> (a) which is the same as that fitted in the aircraft; or
>
> (b) which CASA has determined in writing is to be taken as being the same as that fitted in the aircraft.

CASA reported that the intent of the CAO was to require, for multi-crew aircraft, that both flight crew be endorsed on a particular instrument approach in order to conduct that instrument approach. However, many pilots interpreted the CAO as requiring only the pilot in command to be endorsed on the particular approach.

The chief pilot stated that it was a company policy that both pilots of a multi-crew aircraft had to hold an RNAV (GNSS) approach endorsement in order to conduct that type of approach. The *Transair Operations Manual* included the following crew requirements that related to the use of RNAV (GNSS) approaches:

> Flight crew are to:
>
> - hold endorsements for GPS Primary means navigation and GPS/NPA
>
> - have been assessed as proficient
>
> - meet the GPS recency requirements.

Transair pilots reported that it was common knowledge that both pilots were to be RNAV (GNSS) endorsed for the crew to conduct an RNAV (GNSS) approach. A supervisory pilot reported that the pilot in command was also aware of this requirement. All of the Cairns-based pilots, including the pilot in command, were aware that the copilot was not RNAV (GNSS) endorsed.

The Transair chief pilot reported that it was a requirement for Transair pilots to have an NDB approach endorsement on their instrument rating, but it was not a requirement for them to hold an RNAV (GNSS) endorsement. He stated that if they had the endorsement, he 'would not stop them' using it to do approaches. The chief pilot stated that, even though he held an endorsement, he was not comfortable with the nature of RNAV (GNSS) approaches. He believed they were more complex than NDB approaches, and he also did not like the fact that distance was indicated to the next waypoint rather than to the point of landing (see Section 1.19.4).

The *Transair Operations Manual* contained a training syllabus for GPS training, covering 'Primary means En route Navigation' and 'GPS Non Precision Approaches'. Transair pilots reported that they had to arrange their own RNAV (GNSS) endorsement training as the company did not provide this training. Transair also did not track pilot recency for RNAV (GNSS) approaches.

Two Transair supervisory pilots reported that they, and the pilot in command, had frequently complained to the chief pilot that not all of the pilots based in Cairns had a RNAV (GNSS) approach endorsement. They believed such an endorsement was necessary, because the only available instrument approach for Bamaga was an RNAV (GNSS) approach.

In addition to the copilot of the accident flight, one of the other four pilots based in Cairns (a pilot in command) at the time of the accident had not obtained an RNAV

(GNSS) approach endorsement. Another Transair pilot in command, who was occasionally based in Cairns to provide roster relief, also did not hold an RNAV (GNSS) approach endorsement.

In an email to family and friends in April 2005, the copilot described a situation where he was part of a crew operating an RPT flight to Bamaga with another pilot in command who was also not RNAV (GNSS) endorsed. The crew initially could not make visual contact with the ground at the lowest safe altitude, but eventually found a hole in the cloud and descended to 500 ft in rain showers. The crew then made several attempts to visually locate the aerodrome before they succeeded.

Ground proximity warning system training program

In a letter dated 24 September 1999, Transair indicated to CASA that it would be equipping its aircraft with predictive GPWS (or TAWS) and nominated four turbine aircraft as the first aircraft to receive the systems. They also indicated that flight crew would undergo ‘controlled flight into terrain awareness’ training by viewing a video, and that the *Transair Operations Manual* would be amended to include this training requirement.

The *Transair Operations Manual* provided brief guidance on procedures to use in the event of various types of warnings (see Section 1.17.7). There was no training syllabus for the GPWS in the training and checking part of the manual. In addition, there was no mention in the manual of the ‘controlled flight into terrain awareness’ video as outlined in the letter to CASA.

The *Approved Airplane Flight Manual* for each aircraft contained a GPWS supplement. However, this manual was required to be on board the aircraft at all times during operation and therefore presented limited opportunities to be used as a reference or training document.

The Transair chief pilot reported that he expected pilots to respond to the GPWS warnings by using common sense and initiating a climbing manoeuvre, and that this information was repeated in the *Transair Operations Manual*. He reported that when endorsing pilots, he would have covered the GPWS, but from a technical side. He also reported that the ground school did not cover what to do from an operational perspective.

No record of either the pilot in command or the copilot having undergone GPWS training or ‘controlled flight into terrain awareness’ training could be located by the investigation. A review of a sample of Transair pilot files found that most had not received training in GPWS awareness, and most pilots reported not receiving such training from Transair. None of the Cairns-based pilots had received any training in this area.

Route checks

CAR 218 required that:

> (1) A pilot is qualified to act in the capacity of pilot in command of an aircraft engaged in a regular public transport service if the pilot is qualified for the particular route to be flown in accordance with the following requirements:
>
> (a) the pilot shall have been certified as competent for the particular route by a pilot who is qualified for that route;

> (b) the pilot shall have made at least one trip over that route within the preceding 12 months as a pilot member of the operating crew of an aircraft engaged in any class of operation; ...

The *Transair Operations Manual* also required that a competency certification had to be completed by a check pilot for each aerodrome and route to be flown and to be kept on the pilot's file.

The Transair chief pilot reported that he would have conducted some of these route checks himself. However, a review of a sample of Transair pilot files found no evidence of completed competency forms for any routes. This included the pilot in command.

A review of the pilot in command's logbook showed that he first operated into Bamaga on 19 September 2001. Although this was prior to Transair being approved to conduct RPT operations on the Cairns – Bamaga – Cairns route, the flight was part of a regular series of flights on that route starting on 17 September 2001 (see Section 1.17.5). The other pilot on this flight was a line copilot.

The pilot in command's logbook also showed that he first operated into Lockhart River on 23 February 2002 on a charter flight with a line copilot. Prior to Transair operating regular flights into Lockhart River starting 28 August 2004, the pilot in command operated into Lockhart River on six other occasions. Most of these appeared to be additional flights following the regular Cairns – Bamaga – Cairns RPT service each day. All were with line copilots.

Another pilot in command reported that the first occasion he operated into Lockhart River was as a pilot in command on an RPT flight without being route checked.

Proficiency checks

CAR 217(2) required that an operator provide two checks of pilot competency each year (see above). In relation to these checks, CASA's *Air Operator's Certificate Manual* (see Section 1.18.2) stated the following:

> The competency checks required by CAR 217 form part of the approval process of the organisation. All operating crew require two complete checks of the competency annually.
>
> In RPT operations, an organisation's pilots are required to meet additional regulatory requirements – the flight proficiency checks required by CAO 40.1.5.
>
> The CAR 2 definition of "aeroplane proficiency check" ties the proficiency check to the CAR 217 competency requirement. For CASA to be satisfied with an applicant's proposed tests and checks, a CAO 40.1.5 proficiency check, appropriate to the aircraft type and the type of operation, should be regarded as the minimum standard for a competency check for the purposes of CAR 217.

CAO 40.1.5 contained the contents of the aeroplane proficiency check which included various components that had to be demonstrated to complete the proficiency check. These components included a general flying segment, an instrument flying segment, a twin-engine aircraft emergency manoeuvres section, bad weather circuit segment, a night flying segment and a general emergency procedures segment. CAR 249 prohibited the practice of emergency procedures while passengers were carried on board the aircraft.

In summary, an RPT operator was required to conduct two checks of a pilot's competency each year as per CAR 217(2), and each check needed to be sufficient to meet the pilot proficiency check requirements of CAO 40.1.5.

The *Transair Operations Manual* stated the following:

> In accordance with the requirements of CAR 217(2), each Company pilot shall complete 2 flight checks in each calendar year at intervals of not less than 4 months. Each flight check shall consist of a proficiency base check and a proficiency line check.

A whiteboard in the Transair Brisbane office, which was used to track pilot recency (see below), listed base checks and line checks as each having a 1-year recency requirement.[120]

The base check required the demonstration of proficiency in the conduct of emergency procedures and was meant to be flown without passengers on board the aircraft. The line check could be flown with passengers as part of normal revenue operations because no emergency procedures were required to be carried out. The *Transair Operations Manual* nominated that a check pilot had to be the pilot in command and that flights had to be over a 'reasonable length' and be of a minimum of two sectors. The proficiency base check could also be used to assess the pilot for the renewal of an instrument rating.

The Transair chief pilot reported that he thought the requirements of CAR 217(2) were ambiguous, and that he believed only one base check and one line check per year were sufficient to meet the requirements of the regulation. He also reported that the contractor check pilot had asked for clarification from CASA regarding the required frequency of proficiency checks. The response from a CASA inspector was:

> The interpretation that you will read from the regulation is that two checks are required in a year.
>
> I have tried to read four into it, but can't. So the minimum is two.

The contractor check pilot and the CASA inspector both reported that the two checks required each year had to meet the requirements of a base check or an instrument rating renewal. They also reported that a line check was not sufficient to meet the requirements of one of the two proficiency checks specified by CAR 217(2). Two other CASA inspectors supported this interpretation of the regulation. Another CASA inspector reported that he believed that one base check and one line check per year may be sufficient.

An examination of a sample of Transair pilot files revealed that only one flight proficiency base check and generally one flight proficiency line check had been conducted per year. Almost all of the base checks were conducted by the chief pilot. The contractor check pilot was used to conduct the base checks on the chief pilot, but performed few other proficiency checks (see also Section 1.17.9). The chief pilot had conducted about half of the line checks. The other line checks were conducted by supervisory pilots, who were not approved to conduct such checks.

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120 In another section of the *Transair Operations Manual* discussing types of records, it was stated that the 'flight proficiency base check' form was to be completed after each 12-monthly base check, and the 'flight proficiency line check form' was to be completed after each 12-monthly line check.

As outlined in Section 1.5.1, the pilot in command had undergone such base checks and line checks about once per year since joining the company in 2001. The copilot had only been with the company for less than 3 months, so no recurrent proficiency checks were required.

Pilots reported that some supervisory pilots would provide briefings prior to check and line training flights, and debriefings following such flights. However, when the Transair chief pilot or the pilot in command conducted the check or training flights, little briefing or debriefing was conducted.

1.17.9 Supervision of flight operations

Cairns base

The Transair chief pilot stated that he would visit the Cairns base about every 3 months to conduct checks and have meetings with the base pilots. He reported that these meetings were 'quite extensive' about the operation and Aero-Tropics. Cairns-based pilots reported that the chief pilot did not use his visits to proactively discuss operational standards with the pilots, and flight standards meetings were not convened.

A review of the training and checking records for a sample of Cairns base pilots indicated that the chief pilot conducted about half of the base checks on these pilots in Brisbane. The chief pilot reported that he conducted 'two or three trips' of line flying from the Cairns base per year. A review of some of the Cairns-based pilot files revealed that the chief pilot conducted some line checks of these pilots from Cairns. A review of the pilot in command's logbook showed that the chief pilot operated with the pilot in command from Cairns on three occasions, including two line checks. The contractor check pilot reported that he never conducted line operations at the Cairns base.

The *Transair Operations Manual* did not specify required qualifications for the position of a base manager. The chief pilot stated that he chose the pilot in command for the role of Cairns base manager primarily on the basis of time on the job. The chief pilot stated that he did not conduct any on-going assessments of the pilot in command in this role, relying on feedback from CASA audits.[121]

On 27 April 2004, the pilot in command of the accident flight wrote a letter to the chief pilot requesting a pay rise. In the letter he stated that '…you have been quite satisfied with the operation here in Cairns to which I oversee and that it takes very little involvement on your behalf'. An email from the pilot in command to the Transair chief pilot on 25 August 2004 stated '…once again communication has been lacking between you and us, as I was only to find out in reading the Cairns Post last Friday [20 August 2004] that we were now conducting RPT services out of Lockhart River'. As noted in Section 1.17.5, these flights commenced on 28 August 2004. The pilot in command operated into Lockhart River on the 28 August 2004 flight.

121 CASA records show that the September 2001 and February 2005 audits of Transair included en route inspection flights from the Cairns base. Neither of these flights involved the pilot in command of the accident flight.

The *Transair Operations Manual* stated that one of the duties of the base manager was to attend flight standards meetings as required. There was no evidence that any such meetings had taken place. The chief pilot reported that there had been no meetings of check, training and supervisory pilots to discuss standards.

Cairns-based pilots reported that the pilot in command, in his role as base manager, was effective at ensuring maintenance concerns were promptly resolved. However, a number of Cairns based pilots reported that other supervisory pilots, rather than the base manager, actively encouraged a culture of pilots following company procedures.

Pilots at the Cairns base reported that they were responsible for keeping track of their instrument approach and night recency on an ongoing basis. Each month they were required to pass recency data on to the base manager, who was required to forward the information to the main office in Brisbane. The chief pilot reported that the data would then be placed on a whiteboard in the Brisbane office. An examination of the whiteboard 6 days after the accident showed that instrument approach recency was listed for NDB and ILS approaches, but RNAV (GNSS) approach recency was not listed. The whiteboard did not include two Cairns pilots who had joined in early 2005.

Other bases

The contractor check pilot reported that the chief pilot had asked him to conduct some line flights with pilots from Transair's Big Sky Express operation based at Inverell and review the standard of flight operations. The check pilot submitted a report to the chief pilot in September 2004 regarding his observations. His assessments included the following issues.

- The operation was not up to RPT standard.
- The pilots in command were not consistently following standard operating procedures.
- The pilots had 'a bare bones endorsement' and 'no follow up training', and their systems knowledge was 'poor'.
- The operation was in its infancy and urgently needed direction.

The contractor check pilot recommended that the pilots be provided with CRM training and ground school training on systems and performance. The contractor check pilot reported that he did not receive a response from the chief pilot regarding his report. The chief pilot reported that he could not recall receiving a report.

1.17.10 Transair's safety management processes

Overview

CASA defined a safety management system[122] as

> … an integrated set of work practices, beliefs and procedures for monitoring and improving the safety and health of all aspects of your operation. It recognises the potential for errors and establishes robust defences to ensure that errors do not result on incidents or accidents.

In April 1998, CASA published the *Aviation Safety Management – An operator's guide*, which contained suggested practices for general aviation charter operators and low capacity RPT operators for implementing a safety program. The guide stated:

> The ultimate responsibility for safety rests with the directors and management of the company. The whole ethos of a company's attitude to safety – the company's safety culture – is established from the outset by the extent to which senior management accepts responsibility for safe operations, particularly the proactive management of risk.

Regulatory requirements

The Civil Aviation Regulations 1988 did not require AOC holders to have a safety management system in place.[123] However, CASA provided guidance material to the industry in the form of the *Aviation Safety Management* guide and replacement guidance material on safety management systems in July 2002. CASA also published several educational articles on the topic in its *Flight Safety Australia* magazine. CASA advised that its safety management system materials had been used by other countries overseas, and that it had contributed significantly to ICAO developments in this area.

Section 28BE of the *Civil Aviation Act 1988* placed the main responsibility for the safety of operations on the AOC holder and any company directors associated with the AOC. The CASA *Aviation Safety Management* guide suggested that:

> One proven way of improving safety – and meeting legal requirements of Section 28BE of the Act – is for operators to take a leadership role in building a safety program.

Overview of Transair's aviation safety program

In December 1999, CASA conducted its first safety systems-based audit of Transair. This audit found among other things (see Appendix H), that Transair had 'inadequate systems of corporate management, control and communication'. At a meeting with CASA on 14 January 2000, Transair's chief pilot agreed to a number

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122 CASA 2002 *Safety Management Systems, What's in it for you.*

123 In May 2000, CASA issued a discussion paper with supporting documentation regarding the proposed CASR Part 119. CASR Part 119 was intended to incorporate into one document, all regulatory provisions relating to obtaining and retaining an AOC that authorised the holder to conduct commercial air transport operations. Sub-part 119.E of the proposed CASR required an operator to establish and maintain a safety management system. As at the date of this investigation report CASR Part 119 had not been implemented.

of undertakings, including establishing the position of a quality manager who would be responsible for the introduction and managing ‘a comprehensive safety system within the organisation’. This safety system was to be based on the CASA *Aviation Safety Management* guide.

Transair’s aviation safety program was documented in the *Transair Aviation Safety Manual*, which was initially issued in September 2003 and amended in November 2004. The safety manual contained the information about the responsibilities of the aviation safety manager, a hazard and risk management database, and procedures regarding accident/incident reporting, accident investigation, audits, safety information distribution and staff training on the safety program. The intended scope of the safety program was to involve all sections of Transair operations, including flight operations, ground support operations, and maintenance operations.

The safety manual stated that:

> Transair intends to provide a safe and healthy working environment for all staff and the highest possible standards of safety for all its customers by the elimination of all recognised risks. To achieve these goals, Transair will maintain an active Aviation Safety Manual and all staff are expected to support the programme and to take an active role in the identification, reduction and elimination of risks in our operations.

Safety manager

The maintenance controller was appointed to the additional position of aviation safety manager[124] in late 2001 and tasked to implement and manage the safety program. The safety manager carried out all safety program-related activities undertaken for Transair, mostly involving dealing with hazard and incident reports, investigations, safety audits, and safety meetings. The safety manager had previous experience in implementing a quality management system in a large maintenance organisation. Both the safety manager and chief pilot attended a safety management system workshop held by CASA around 2001. The chief pilot was reported to have had limited day to day involvement in the safety program.

Safety management committee

The chief pilot, safety manager, and operations manager formed a ‘safety management committee’. All employees were invited to the safety committee meetings, but remoteness of the ancillary bases and flying duties made this impractical for line pilots to attend. Although the deputy chief pilot was listed in the safety manual as a permanent member of the safety committee, his attendance was reported as being only occasional. The function of this committee was stated in the safety manual as:

- to review the status of current accidents and incidents and any actions taken
- to review the status of current hazard reports and any actions taken
- to review any aviation safety audit or inspection reports and actions taken

124 There was no regulatory requirement for an operator to have a position of safety manager or quality manager.

- to review and resolve any aviation safety matters brought before the Safety Management Committee
- to provide feedback to company staff.

The committee met informally on an irregular basis averaging about every 3 months. It was reported that minutes of these meetings were kept and distributed to the permanent committee members. Although the investigation sought copies of these minutes on multiple occasions, Transair did not provide any minutes for meetings which occurred prior to the accident.

Hazard and incident reporting

The *Transair Aviation Safety Manual* encouraged employees observing a hazardous situation that could affect aviation safety to report it to the safety manager. The manual also stated that any member of staff who became aware of an accident/incident involving Transair was required to report the matter to Transair's Brisbane office as soon as practical, followed by a written air safety incident or accident report by the pilot in command. The manager receiving the form was required to make copies available to the chief pilot, maintenance controller and the ATSB.

It was reported that there had been about 17 written hazard/incident reports entered into Transair's computer database each year since November 2001. The majority of these were reported to have been airworthiness issues rather than flight operational issues. Only written reports were entered into the database.

The investigation identified 24 reports from line pilots received by Transair management between 8 May 2002 and 7 May 2005 that were required to be reported to the ATSB under the regulatory requirements[125], but were not forwarded to the ATSB. Seven of these that occurred after 1 July 2003 were 'immediately reportable' matters under the *Transport Safety Investigation Act 2003* and Regulations. The safety manager had a limited understanding of what operational incidents were required to be reported to the ATSB.

Safety audits

Transair's safety manual stated:

> Each base will receive a safety audit at least annually. The Aviation Safety Manager using other specialist team members as appropriate will conduct the audits.

The safety manager reported that these safety audits were conducted by himself in conjunction with the scheduled maintenance audits. The audits covered issues such as passenger loading, ground procedures, and passenger briefings. They did not cover flight operational areas. The safety manager stated that a report was written for each audit and was discussed at the safety management committee meetings.

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125 Until 30 June 2003 the relevant legislation was the *Air Navigation Act 1920*. After that date the regulatory requirements were contained in the *Transport Safety Investigation Act 2003* and Transport Safety Investigations Regulations 2003.

Hazard identification and risk management

Reported hazards/incidents were entered into a computer database and likelihood and consequence ratings were assigned by the safety manager to produce a risk rating. The circumstances of these hazards and incidents were reviewed where necessary by the safety manager, and they were discussed at the safety management committee meetings.

The safety manual did not require that additional risk assessments be conducted for changes to existing operations or the introduction of new operations. Transair management also reported that formal risk assessments had not been conducted for these situations. For example, Cairns-based pilots reported that the chief pilot had been informed on numerous occasions that all pilots needed RNAV (GNSS) approach endorsements as this was the only instrument approach available into Bamaga. There was no evidence that this issue was ever risk-assessed in a formal way. Similarly, the chief pilot reported that there was no risk assessment for the introduction of RPT services into Lockhart River.[126]

Other safety program issues

It was reported that the chief pilot could be contacted by any of the line pilots if they had any concerns regarding operations. However, several Cairns base pilots reported that they had told the chief pilot about various operational concerns, such as pilots conducting RNAV (GNSS) approaches into Bamaga without being appropriately endorsed, but nothing was done about these issues. The chief pilot reported that he could not recall any such complaints. Two pilots stated that they did not bother reporting flight operational hazards because they learnt through experience that nothing would change as a result.

The safety manager reported that pilots were given awareness training about the safety program when they started with Transair and then every two years. Flight crew records indicated that pilots received 'Aviation Safety Manual familiarisation' as part of their 'Company Maintenance Authority' training.

1.17.11 Transair's aircraft maintenance control processes

Transair's maintenance controller was responsible for the control of all scheduled and unscheduled maintenance for Transair's fleet of aircraft. The maintenance controller was an appropriately licensed aircraft maintenance engineer with lead auditor qualifications and had the necessary CASA approval.

The maintenance work on the aircraft was performed by two separate external maintenance providers at Archerfield and Cairns aerodromes. The *Transair Maintenance Control Manual* detailed the requirements for maintaining the fleet and specified the functions and responsibilities of the maintenance controller and the external maintenance providers.

A review of Transair's maintenance documentation indicated that VH-TFU was maintained in accordance with the approved system of maintenance and regulatory requirements. The review found that there were a number of deficiencies in Transair's maintenance control processes that included poor documentation

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126 Prior to the introduction of services to Lockhart River, Transair contracted a consultant to provide appropriate take-off performance charts to the satisfaction of CASA.

control, the lack of detail on avionic inspection procedures, the absence of a deferred maintenance procedure and incomplete records of on-aircraft components. A number of deficiencies were also identified and commented on by CASA during audits (see also Section 1.18.13).

1.18 Regulatory oversight of Transair and Aero-Tropics

1.18.1 The function of the Civil Aviation Safety Authority

CASA was responsible, under the provisions of Section 9 of the *Civil Aviation Act 1988*, for the regulation of aviation safety in Australia. Section 9 of the Act included the following:

> (1) CASA has the function of conducting the safety regulation of the following, in accordance with this Act and the regulations:
>
> (a) civil air operations in Australian territory;
>
> (b) the operation of Australian aircraft outside Australian territory;
>
> by means that include the following:
>
> (c) developing and promulgating appropriate, clear and concise aviation safety standards;
>
> (d) developing effective enforcement strategies to secure compliance with aviation safety standards;
>
> (e) issuing certificates, licences, registrations and permits;
>
> (f) conducting comprehensive aviation industry surveillance, including assessment of safety-related decisions taken by industry management at all levels for their impact on aviation safety;
>
> (g) conducting regular reviews of the system of civil aviation safety in order to monitor the safety performance of the aviation industry, to identify safety — related trends and risk factors and to promote the development and improvement of the system;
>
> (h) conducting regular and timely assessment of international safety developments.

The two primary means of oversighting an operator's aviation activities were assessing applications for the issue of or variations to its Air Operator's Certificate (AOC) and associated approvals (including key personnel and training and checking organisation), and conducting surveillance of its activities on a regular basis.

1.18.2 Processes for assessing variations to an AOC

Regulatory requirements

CASA was required by the *Civil Aviation Act 1988* to satisfy itself about various matters when processing an application for the issue of, or variation to, an AOC. Section 28(1) of the Act stated that:

> (1) If a person applies to CASA for an AOC, CASA must issue the AOC if, and only if:
>
> (a) CASA is satisfied that the applicant has complied with, or is capable of complying with, the provisions of this Act, the regulations and the Civil Aviation Orders, that relate to safety, including provisions about the competence of persons to do anything that would be covered by the AOC; and
>
> (b) CASA is satisfied about the following matters in relation to the applicant's organisation:
>
> (i) the organisation is suitable to ensure that the AOC operations can be conducted or carried out safely, having regard to the nature of the AOC operations;
>
> (ii) the organisation's chain of command is appropriate to ensure that the AOC operations can be conducted or carried out safely;
>
> (iii) the organisation has a sufficient number of suitably qualified and competent employees to conduct or carry out the AOC operations safely;
>
> (iv) key personnel in the organisation have appropriate experience in air operations to conduct or to carry out the AOC operations safely;
>
> (v) the facilities of the organisation are sufficient to enable the AOC operations to be conducted or carried out safely;
>
> (vi) the organisation has suitable procedures and practices to control the organisation and ensure that the AOC operations can be conducted or carried out safely;
>
> (vii) if CASA requires particulars of licences held by flight crew members of the organisation—the authorisations conferred by the licences are appropriate, having regard to the nature of the AOC operations…

Section 28(2) of the Act stated that:

> The financial position of the applicant is one of the matters that CASA may take into account in forming a view for the purposes of paragraph 1(a).

Additional regulatory requirements when authorising low capacity RPT operations

A charter operator seeking authorisation to conduct low capacity RPT operations had to satisfy a number of additional regulatory requirements before their AOC could be varied to include RPT operations. The additional requirements were specified in the CARs and CAOs[127] and related to flight crew qualification and training, the type of aircraft to be used, the maintenance of those aircraft and the use of licensed aerodromes. More specifically:

- The flight crew requirements included license type and experience levels, route qualifications, training and proficiency checking. If the operator did not have an existing training and checking organisation under CAR 217, this was also required for RPT operations (see Section 1.17.8).
- The aircraft to be used on RPT operations had to be in the normal, commuter or transport category depending on the aircraft weight.[128] They had to be maintained as Class A aircraft[129] using an approved system of maintenance, which had to be documented. The operator was required to appoint a maintenance controller who was responsible for control of maintenance of the aircraft.
- The aerodromes to be used on RPT operations had to meet certain requirements and, if not controlled by ATC, a radio communication confirmation system was required. The operator also had to include certain information in the operations manual about the aerodromes to be used on RPT operations.

Assessment process

The procedures for assessing an application for the issue of, or variation to, an AOC were contained in the CASA *Air Operator Certification Manual* (AOC Manual). It contained checklists and explanatory notes to assist CASA inspectors during the assessment process.[130] The manual was publicly available.

The AOC assessment process was divided into a series of phases that required CASA flying operations and airworthiness inspectors[131] to carry out a number of tasks, including:

- evaluation of the operator’s manuals and other documents required by the legislation;

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127 For example, CAR 39, 42ZV, 42ZW, 42ZY, 92A, 217 and 218, and CAO 20.18 and 82.3.

128 The term *Commuter Category* was defined in FAR 23 Subpart A – General as being ‘limited to propeller-driven, multiengine airplanes that have a seating configuration, excluding pilot seats, of 19 or less, and a maximum certificated takeoff weight of 19,000 pounds [8,618 kg] or less’. Commuter Category aircraft had additional design and performance requirements to those specified in FAR 23 for Normal Category aircraft.

129 CAR 2(1) defined the term Class A aircraft to mean ‘… an Australian aircraft, other than a balloon, that satisfies either or both of the following paragraphs:
(a) the aircraft is certificated as a transport category aircraft;
(b) the aircraft is being used, or is to be used, by the holder of an Air Operator’s Certificate which authorises the use of that aircraft for the commercial purpose.’

130 The AOC Manual contained procedures and guidance in two parts: ‘High Capacity RPT Operations’, and ‘Other than High Capacity RPT Operations’. The material in this report is based on the content of the ‘other than high-capacity RPT’, which was applicable to Transair. However, much of the content in the two parts was similar.

131 The term ‘inspector’ is used in this report to refer to staff employed at CASA as either inspectors or auditors.

- inspection of the operator’s organisational structure and staffing, and the proposed operations, facilities, aircraft and aerodromes, including the conduct of proving flights; and
- certification of various personnel, and the approval of the training and checking organisation.

These evaluations, inspections and certifications were supported by a series of checklists. The AOC Manual required that completed checklists were to be placed on a certification file ‘as a consolidated record for the basis of certification’. CASA management reported that the absence of a completed form relating to an assessment activity did not mean that the activity was not conducted. CASA inspectors reported that it was their normal practice to place completed checklists on the certification file.

Document evaluation

The document evaluation phase of the AOC assessment process required CASA inspectors to conduct a detailed study of the manuals and other documents required by the *Civil Aviation Act 1988* and the Civil Aviation Regulations. An evaluation of the operations manual was included in this process, and the AOC Manual indicated that the assessment of the acceptability of the operations manual was likely to be the most time consuming task in the certification process (see Section 1.18.8).

Inspections

The AOC Manual stated that the inspection phase of the assessment process was required ‘to verify the information in the documentation and assess the practical acceptability of the applicant’s written instructions, facilities, services and equipment’. The inspections included an assessment of the applicant’s management structure, including the organisation having a sufficient number of suitably qualified and competent employees, the adequacy of the applicant’s administrative facilities, the appropriateness of systems to control records such as operational documentation, the adequacy of training facilities and staff, and whether the applicant’s aircraft met the required technical and operational standards.

As part of the assessment process, CASA personnel were required to inspect facilities at all aerodromes used by the applicant, whether used as a base or an RPT destination. These operating port inspections were intended to verify the accuracy of the aerodrome information in the operations manual, the suitability of the aerodrome for the type of aircraft operated by the applicant, and the adequacy of other facilities including passenger and baggage/cargo handling, and refuelling arrangements.

CASA also had to decide during the inspection phase whether the applicant needed to conduct a ‘proving flight’ to demonstrate that its systems, facilities and procedures were capable of working to produce a safe operation that complied with the legislative requirements.[132]

Certification of personnel and training and checking organisation

The certification phase included the granting of exemptions, approvals or permissions by CASA, and the approval of the applicant's key personnel. Exemptions, approvals or permissions were granted where, for example, the applicant proposed an alternative course of action in meeting the intent of the regulatory requirement. The applicant's key personnel approved during this phase included the chief pilot and the head of aircraft airworthiness and maintenance control (maintenance controller).

The certification phase also involved the approval of the applicant's training and checking organisation if that organisation was required under the proposed AOC; for example if the applicant was seeking authorisation to conduct RPT operations and did not already have a training and checking organisation in place. The approval included the head of training and checking, the training and checking manual, training facilities, training pilots, check pilots and other training staff.

1.18.3 Processes for conducting surveillance

CASA's approach to surveillance

In order to fulfil the function prescribed in Section 9 of the *Civil Aviation Act 1988*, CASA developed a surveillance program to determine whether aircraft operators, maintenance organisations and other organisations were meeting the regulatory requirements. The CASA *Surveillance Procedures Manual* defined surveillance as:

> … the mechanism by which CASA monitors the on-going safety health and maturity of permission holders undertaking aviation endeavours. Surveillance comprises scheduled audits, special audits and spot checks. It is the examination and testing of systems including sampling of products, and gathering of evidence, data, information and intelligence.

The surveillance program was documented in various CASA manuals. From 1994 until 1999, the program was known as the Aviation Safety Surveillance Program (ASSP), and the ASSP Manual was issued to staff with responsibilities for planning and conducting surveillance activities. During 2000 and 2001, the ASSP Manual was progressively replaced by Compliance Management Instructions (CMIs) as CASA reviewed its surveillance planning activities and changed the focus of its airline operator surveillance activities from product-based to systems-based auditing.

From November 2003, CASA used the *Surveillance Procedures Manual*, which contained procedures and checklists to assist staff in the planning, preparation, conduct, and reporting of surveillance activities. In a section on surveillance philosophy, this manual stated:

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132 Section 27AD(1) of the *Civil Aviation Act 1988* stated:

CASA may give a written notice to an applicant for an AOC, requiring the applicant:

(a) to conduct proving flights; or

(b) to carry out other aircraft tests or demonstrations of procedures;

to assess whether the applicant can safely conduct the operations covered by the application.

> CASA will discharge the obligations accepted by Australia, under the Chicago Convention and the Civil Aviation Act, by deploying appropriately experienced and trained teams of Auditors to conduct comprehensive surveillance.
>
> The minimum compliance standards required to be met and continually maintained by Certificate/Permission holders are those that exist during the issuance of the authorisation at entry and any subsequent authorised changes or variations to the authorisation. These are articulated in the relevant entry control manuals. Where civil aviation authorisation holders manuals and operational plans are submitted to CASA for acceptance or processing an approval then those accepted standards are the standards against which compliance is measured, subject to legislative requirements requiring the authorisation holder to update their manuals as the result of changes in the Certificate/Permission holder's operations, aircraft or equipment, or in the light of experience.
>
> CASA will encourage the aviation industry to take on standards higher than the minimum required by regulations and those standards will be assessed during surveillance.

Most of the surveillance activities conducted for airline operators were scheduled audits. Some additional activities, such as special audits and spot checks, were conducted based on an assessment of risk (see also Section 1.18.15).

Scheduled audits

Scheduled audits utilised the systems-based approach that examined the management systems used by an operator to comply with the regulatory requirements. CASA began introducing the systems-based approach in 1999 to replace the product-based approach that had been previously used. Whereas the product-based approach was a quality control function that focussed on an inspection of the end products of the operator's activities, the systems-based auditing approach sought to:

> …assess an Auditee's management system and its ability to keep operational risks as low as reasonably practicable. To achieve this, safety-related processes are audited to assess if they are operating in accordance with the Auditee's documentation and Civil Aviation Legislation.[133]

CASA also stated in the explanatory notes of its audit reports that a systems-based audit:

> … is a sampling exercise and does not purport to be a total systems review. The sampling provides a snap shot of the system and any deficiencies detected could point to a systemic problem, requiring a total systems review by the operator. Deficiencies and problems identified in the audit findings must be addressed by the operator …

CASA personnel reported that systems-based audits were intended to be conducted by multidisciplinary teams of inspectors. CASA management reported that a single inspector may have been appropriate for certain types of surveillance activities – for example, en route flight inspections or dangerous goods inspections.

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133 CASA *Surveillance Procedures Manual*, version 1.3 30 April 2005.

CASA adopted a 'management system model' as the underlying basis for evaluating the processes implemented by an AOC holder. The model consisted of four system attributes:

- management responsibility, which included safety policy, internal communication and consultation, review of safety management, hazard identification and risk management, and change management;
- infrastructure, which included facilities and equipment, information, and training;
- process in practice, including line operations, load control, rostering, routes and ports, and maintenance control; and
- monitoring and improvement, which included internal audit, incident and accident recording and investigation, and remedial, corrective and preventive action.

Based on the model, lists of elements were developed for different types of organisations. The list for AOC holders contained 39 elements. Audits were planned by identifying a subset of the list of elements, and then examining those elements within an operator. All elements of the model were intended to be examined over each 3-year period. However, in the initial stages of implementing systems-based surveillance, inspectors were tasked to focus on the infrastructure and process in practice elements, as this was where they had previous experience in assessing operators.

At the end of 2003, the management system model was no longer used to provide the list of elements to be examined during an audit. An alternative list of elements was used, based on a list developed by the US FAA as part of its Air Transportation Oversight System (ATOS). This list was termed the CASA Regulatory Oversight System (CROS). Elements for airline surveillance were grouped under the following categories:

- aircraft configuration control
- manuals
- flight operations
- personnel training and qualifications
- route structures
- aircrew and crew flight, rest and duty time
- technical administration (including key personnel, such as chief pilot, and safety program).

About 80 of the CROS elements were relevant to AOC holders. The management system model was still used in the *Surveillance Procedures Manual* to provide general guidance for examining these elements.

CASA reported that CROS provided a more detailed list of elements which described an airline operation, and therefore had the potential to allow surveillance data to be more easily compared across surveillance activities and across operators. Inspectors from the Brisbane airline office reported that the terminology in CROS did not translate well to Australian operations, even though there had been attempts to modify the list of elements to better suit Australian operations. Some inspectors also reported that the list of elements did not effectively describe the things they looked at during audits, and they had difficulty determining which elements they should record audit findings against. Some inspectors reported that they did not think that the CROS elements integrated well with the management systems model.

The *Surveillance Procedures Manual* stated that:

> When deficiencies are identified continue to ask 'why' until the probable root cause is identified. Determine what systems and or processes have failed and continue in that direction irrespective of what was previously prepared on the Audit Worksheet and scope.

Between September 2001 and February 2002 the Australian National Audit Office (ANAO) conducted an aviation safety compliance follow-up audit on CASA.[134] The ANAO audit report noted that:

> Although operators are required to have systems that operate safely, they are not yet required under legislation to have in place 'safety management systems'. However, in the longer term, CASA desires that operators have comprehensive safety management systems and sound safety management cultures. This would allow CASA to obtain the greatest benefit from its systems-based auditing approach.

Special audits

Special audits were an additional method of evaluating an operator and were conducted in response to an assessment of an operator's risk profile using the CASA safety trend indicator (STI) questionnaires (see Section 1.18.15) and other safety intelligence, such as incident reports. The *Surveillance Procedures Manual* stated:

> A Special Audit may be planned for the following reasons:
>
> - STI score indicates certificate holder to be a high risk. Certificate holders rise to the top of the priority list according to their STI score and other information gained;
> - Follow-up of RCAs and Safety Alerts, where there is potentially a high impact on safety if the corrective action is not implemented effectively within the time given;
> - To address information received from any source that points to an increased risk;

The manual also stated that special audits did not necessarily mean that the operator was 'unfit to remain in the aviation industry; however, there may be reasons for the additional scrutiny'.

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134 Australian National Audit Office, *Aviation Safety Compliance Follow-up Audit Civil Aviation Safety Authority*, Audit Report no. 66 2001-2002, June 2002.

Spot checks

Spot checks were described in the *Surveillance Procedures Manual* as:

> … random checks carried out to observe processes, and/or inspect aircraft, documents, and records. They may also be undertaken for monitoring compliance with special airspace/operating procedures introduced for special events where a higher than normal air activity takes place. Spot checks may be undertaken independently of scheduled or special audits, or used for product verification or verification of the end result of a process in support of audits.

The manual also stated that spot checks could include 'ramp' checks of crew and aircraft at a particular aerodrome, port inspections, en route inspections and checks carried out on CAR 217 training and checking personnel.

Frequency of surveillance activities

The *Surveillance Procedures Manual* stated that the holder of an AOC authorising low capacity RPT airline operations required a scheduled audit every 6 months. The manual also stated that special audits and spot checks were to be carried out 'as required', with planning of special audits being 'planned monthly based on assessed risk'.

CASA's systems-based approach to surveillance was intended to be complemented by product-based surveillance activities. In early 2005, CASA decided to change from two scheduled audits a year to one scheduled audit per year for airline operator surveillance, and to increase product-based 'operational surveillance'. These changes took effect during 2005.

Reporting of surveillance activities to operators

The results of audits were recorded in a formal report, which included an index of findings and the actions to be taken by the operator in response to the findings. Those actions could be presented to the operator as either a request for corrective action (RCA), safety alert, or aircraft survey report (ASR).

- An RCA was issued when there was a failure to comply with the regulatory requirements, and necessitated the operator to take corrective and preventive action to address deficiencies in its policy and/or procedures. [135] If an RCA was issued, the operator had to address the deficiency and provide CASA with details of the corrective and remedial action by an agreed date. The *Surveillance Procedures Manual* stated that 'The aim of issuing an RCA is to highlight process or system deficiencies and not to provide consultancy and tell the Auditee what to do. It is the Auditee's responsibility to investigate and identify the root cause and take corrective action to address the root cause.'
- A safety alert was a type of RCA that was issued to an operator to raise a safety concern of a serious breach of the regulatory requirements. A safety alert required immediate action by the operator to rectify the problem.

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135 Prior to the introduction of systems-based audits, findings and required actions relating to failures to comply with regulatory requirements were presented to operators as Non Compliance Notices (NCN).

- An ASR was used to advise of non-compliance to regulatory requirements relating to an aircraft or its maintenance documentation.

CASA inspectors could also include audit observations (AO) in the report to draw the operator's attention to latent conditions or minor deficiencies in the operator's systems or processes that could not be attributed to current regulatory requirements. The intention of the AO was to raise awareness with a view to avoiding problems in the future. An operator was not required to submit a response to an audit observation. However, the *Surveillance Procedures Manual* stated that if the operator provided a response, this may be an indicator that it had a mature safety system.

Reporting of surveillance activities to CASA management

The *Surveillance Procedures Manual* stated that the lead auditor was responsible for collating the audit information and ensuring the production of the audit report. The relevant team leader (flying operations or airworthiness) would then review and recommend approval of reports. The manager of the airline office was responsible for approving the report. Inspectors from the Brisbane airline office stated that audit reports were not routinely sent to CASA management outside of the airline office.

1.18.4 Guidance, training and resources for conducting oversight activities

Guidance material for inspectors

The AOC Manual was the primary guidance material provided to CASA inspectors responsible for assessing applications to issue or vary an AOC. The *Surveillance Procedures Manual* (and its predecessors) provided the primary guidance material to inspectors responsible for conducting surveillance activities. CASA inspectors in the Brisbane airline office reported that they received little other guidance material to assist with systems-based surveillance activities.

Prior to the *Surveillance Procedures Manual*, guidance to inspectors on systems-based surveillance was provided in Compliance Management Instructions (CMI). An external audit commissioned by CASA reported its findings in June 2002 and noted that the CMIs were not a comprehensive guide to performing a systems-based audit and led to significant variations in approach between offices.

The *Surveillance Procedures Manual*, when it was first introduced in November 2003, provided a brief review of the components of the management systems model, and an appendix titled 'Reviewing Documents Using the Four System Attributes'. The appendix consisted of a small set of general questions to consider when evaluating some management system components.

A CASA manager reported that, with the introduction of CROS, CASA inspectors were encouraged to review the ATOS material on the FAA website. Inspectors in the Brisbane airline office reported that they had received little guidance on CROS, or that they had not consulted the FAA website.

Some CASA inspectors in the Brisbane airline office reported that, in the absence of detailed guidance information for conducting systems-based audits, they used the draft regulations Part 119 and Part 121 to develop lists of items to consider during an audit. The inspectors also reported that the delay in enacting the new systems-based regulations caused significant difficulties in conducting oversight activities using a systems-based approach, as it was difficult to use RCAs to facilitate changes in an operator's management systems or processes.

The AOC Manual contained only one reference to CASA's management system model, and few references to safety management systems. Overall there was minimal overlap in the concepts covered in the AOC Manual and the *Surveillance Procedures Manual*. CASA inspectors from the Brisbane airline office reported that the lack of overlap and consistency in the concepts caused difficulties when conducting their activities and entering the outcomes of oversight activities into databases. They believed that the requirements an operator had to meet during initial issue or variation of an AOC should be the same as the requirements that were examined during surveillance activities.

Training of inspectors

In 2000, CASA reported to the ATSB[136] that it would take up to a couple of years for the new systems-based audit processes and skills of their audit personnel to mature. It also reported that it would develop guidance material for its staff on each of the audit elements associated with its management systems model. CASA noted that there was no intention to recruit experts in management systems to assist with audits, but instead it would train its staff to be better able to examine system issues.

In 2001, the ATSB issued the following safety recommendation:

> Safety Recommendation R20000238
>
> The ATSB recommends that CASA consider widening its existing skill-base within the Compliance Branch to ensure that CASA audit teams have expertise in all relevant areas, including human factors and management processes.

In its response to the recommendation, CASA stated that its use of multidisciplinary audit teams (such as flying operations, airworthiness, cabin safety and dangerous goods inspectors), and courses such as its introductory course on human factors, would be sufficient to meet the intent of the recommendation.

CASA reported that in the early years of systems-based auditing, it also introduced a system of peer evaluation of audit reports. The evaluation process was intended to ensure that a consistent approach to auditing was established throughout CASA on a national basis.

CASA inspectors received a 5-day introductory training course on human factors, which included some content on system safety concepts. CASA also provided its inspectors with a 5-day course in auditing processes. Although this auditing course was designed to be tailored to the requirements of CASA personnel, CASA inspectors reported that it was still generic in nature. They also reported that it did not provide detailed guidance on conducting audits of system safety issues. A review of the course notes provided during the training found that these notes were consistent with the inspectors' impressions.

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136 ATSB Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok, Thailand, 23 September 1999. Published April 2001.

With the introduction of the *Surveillance Procedures Manual*, inspectors were provided with a 2-day course on material associated with the manual. Some inspectors received a 1-day course. An internal review of the introduction of the *Surveillance Procedures Manual* noted that there were some difficulties with the initial training courses in 2003 before the material was finalised. Subsequent training courses were evaluated as being much more successful. The report noted that absence of training data for the airlines branch made it difficult to evaluate the overall effectiveness of the training for the airlines branch inspectors.

CASA inspectors from the Brisbane airline office reported that much of their training was provided on-the-job with more experienced personnel rather than through formal training courses. Most of the inspectors considered that they had not received sufficient training or guidance material to conduct assessments of system safety issues, such as organisational structure and resources, risk management processes and safety management systems. Two inspectors reported that they made assessments on these issues based on ‘gut feeling’ rather than any structured or formal process. Another inspector reported that he found making assessments in these areas difficult. One inspector stated that he believed he had received sufficient training and guidance in these areas, but that he primarily focused on conducting product inspections when doing audits.

In the period May to July 2004, internal audits were conducted of CASA surveillance activities at several of its offices, including the Brisbane, Sydney and Melbourne airline offices and several general aviation offices. These audits confirmed that inspectors were generally following the requirements of the *Surveillance Procedures Manual*. However, a common finding was that some inspectors had difficulty understanding the management systems model. The report on the Brisbane airline office audit noted that inspectors were uncertain about the use of CROS when scoping, planning and preparing for audits.

During the investigation, CASA management stated that its inspectors were employed on the basis of significant aviation industry experience and ability. They reported that sufficient guidance was provided to its inspectors, with the AOC Manual and *Surveillance Procedures Manual*, formal training courses, on the job training, and other short courses.

In November 2004, CASA announced to its staff that there would be a new focus on staff who could ‘analyse management systems, particularly in large aviation organisations’. Selected CASA staff were to be developed to look at the ‘quality of safety related decisions taken by management as well as the management systems themselves’. In 2006, CASA started recruiting system safety specialists to perform these functions.

In February 2007, the CASA chief executive officer stated[137]:

> …whilst our auditing processes were carried out by technically competent people who looked at specific technical areas, in some cases they lacked the breadth of management and system experience to be able to look at an operation and the issues that were found and…join the dots and determine a system problem. In my view, that deficiency had been existent in the CASA surveillance system for some time.

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137 Australia, Senate 2007, *Standing Committee on Rural and Regional Affairs and Transport*, 1 February 2007, pp. 6-7.

The CASA chief executive officer stated that this was a view he formed in early 2005. He also stated that ‘systems knowledge and management experience’ were skills that had been missing in the past.

Resources for oversight activities

CASA inspectors from the Brisbane airline office reported that they experienced high workloads meeting the requirements of conducting two scheduled audits per year per airline, as well as the other oversight activities associated with these operators. Inspectors reported that they did not think these resource limitations affected the extent to which they examined applications to vary an AOC. However, at times they may have affected the extent to which inspectors could prepare for audits. They also reported that, because of resource constraints, on-the-job training did not always occur prior to new inspectors conducting audits.

The inspectors reported that these concerns had been expressed to CASA management from their office, and that similar concerns were provided by other airline offices. CASA management reported that they were aware of concerns regarding resource levels. They also reported that their assessments of the resourcing levels in the airline offices did not identify any concerns. The move from two audits per year to one audit per year with increased operational surveillance activities between audits was intended to reduce time spent on administrative tasks and increase the amount of contact time with operators. CASA management advised that increased record keeping requirements as a result of recommendations from ANAO audits had a negative effect on the amount of surveillance activity that was conducted, and therefore may have had a perverse effect on safety.

1.18.5 Regulatory oversight of Transair

Overview of variations to Transair’s AOC

Between September 1999 and August 2004, Transair submitted 11 applications for variations to its AOC to permit RPT operations on specific routes, as summarised in the following table. The applications reflected the significant growth of Transair’s operations as the company commenced RPT operations in north Queensland and then expanded its route structure into regional New South Wales.

Application date	Approval date	RPT Route
3 Sep 1999	29 Oct 1999	Cairns, Townsville – Port Moresby (cargo operations only; authorisation later withdrawn)
Unknown	17 Sep 2001	Christmas Island – Jakarta (initial RPT passenger operation)
7 Jun 2001	17 Sep 2001	Cairns – Port Moresby, Gurney (cargo operations only)
2 Oct 2001	5 Oct 2001	Cairns – Bamaga (initial RPT passenger operation within Australia)
1 Jul 2003	1 Aug 2003	Cairns – Kowanyama – Pormpuraaw
19 Nov 2003	9 Jan 2004	Inverell – Gunnedah – Sydney
27 Jan 2004	27 Feb 2004	Coonabarabran – Gunnedah
31 Mar 2004	8 Apr 2004	Brisbane – Inverell
26 May 2004	13 Jul 2004	Inverell – Sydney – Cooma
13 Jul 2004	23 Jul 2004	Inverell – Grafton – Taree – Sydney
23 Aug 2004	5 Oct 2004	Cairns – Lockhart River – Bamaga

Appendix H provides further details of these applications and approvals by CASA, as well as other events associated with CASA's regulatory oversight of Transair from 1998 to 2005. Some aspects of the applications and approvals are also discussed in Sections 1.18.6 to 1.18.13.

A review of the CASA files associated with the applications and approvals identified that most of the approval processes were conducted in accordance with the requirements of the AOC Manual. Some discrepancies are discussed in Sections 1.18.6 to 1.18.13.

Overview of CASA surveillance of Transair

Between December 1999 and February 2005, CASA conducted 11 scheduled audits of Transair, as summarised in the following table. The table also shows the number of RCAs (or NCNs) and AOs raised in each audit. No safety alerts were issued.

Audit date	Manage-ment	Flying operations	Mainten-ance	Cabin safety	Other[138]
Dec 1999	3 NCN 6 AO	16 NCN 3 AO	3 NCN 8 AO		
Jun 2000	3 AO		3 ASR 1 AO		6 RCA 7 AO
Mar 2001		5 AO	2 RCA 3 AO		
Sep 2001		2 RCA 3 AO	7 AO		
Nov 2001		3 RCA 2 AO	1 RCA 4 AO		
Oct 2002	1 RCA	4 RCA 3 AO	1 RCA		1 RCA
Feb 2003			1 AO		
Aug 2003	2 AO	1 AO			
Feb 2004		1 RCA			
Aug 2004	1 RCA 2 AO	2 RCA 4 AO	6 RCA 5 AO	4 RCA 5 AO	
Feb 2005		1 RCA 1 AO	4 RCA 3 AO	1 RCA 1 AO	3 RCA

Appendix H provides further details of these audits, as well as other events associated with CASA's regulatory oversight of Transair. Some aspects of the audits are also discussed in Sections 1.18.6 to 1.18.15.

A review of the CASA files associated with the audits from December 1999 to February 2005 noted the following.

- There were no special audits or spot checks conducted on Transair during the period from 20 December 1999 until the accident.
- Transair responded to almost all the NCNs or RCAs within the required time period. Most of the responses from Transair were acquitted by CASA in a timely manner.
- There was no indication on CASA files that Transair responded to any of the audit observations provided in CASA's audit reports. As noted in Section 1.18.3, an operator was not required to provide a response to an audit observation. The Transair chief pilot reported that CASA did not follow up audit observations with him.
- The audits on February 2003, August 2003 and February 2004 were conducted by a single flying operations inspector, and the audit on March 2001 was conducted by a single airworthiness inspector. The remaining audits were conducted with a team of two or more inspectors.
- The September 2001 and February 2005 audits included en route inspections of operations at Transair's Cairns base. The June 2000 audit focused on Transair's Christmas Island operation, and the October 2002 audit focused on Transair's helicopter operations based near the Gold Coast. The February 2004, August 2004 and February 2005 audits focused on Transair's Big Sky Express operations in New South Wales.

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138 This column includes dangerous goods, ground handling and other areas not covered by the other columns.

- The audit files often did not contain sufficient detail to fully ascertain what aspects of each audit element were examined, particularly for flight operations elements. There was also insufficient detail on files to determine whether the 'root causes' of identified deficiencies were searched for, particularly for flight operations elements.
- On a number of occasions following audits, CASA issued RCAs for similar, and in two cases, identical breaches of the regulations and orders. Examples include pilots not conducting passenger emergency briefings prior to takeoff and the stowage of cabin baggage (August 2004 and February 2005 audits), and not ensuring that operating personnel had copies of the *Transair Operations Manual* (December 1999 and November 2001).

1.18.6 Evaluation of Transair's organisational structure and staff resources

Processes for evaluating organisational structure and staffing

The AOC Manual provided some general guidance statements for assessing an organisation's structure. In a section titled 'Organisational Structure and Staffing', the manual stated:

> For a sound and effective management structure, essential for the achievement of safe air operations, the following organisational structure and conditions must be met:
>
> - The operational and maintenance managers must have appropriate status within the organisation, and they should report to the chief executive officer unless the applicant justifies otherwise.
> - The duties and responsibilities of the managers and their executives must be clearly defined and the chains of responsibility clearly established. The number and nature of managerial appointments will vary with the size and complexity of the organisation. The reporting chain for all those within sub-organisations must lead to the respective head of that organisation.
> - CASA must be satisfied that the management organisation is adequate and properly matched to the operating network and scope of the operation (paragraph 28(1)(b) of the Act).
> - Flying hours of crewmembers that hold managerial positions should be reviewed to ensure that there is a balance between routine flying duties and the adequate performance of designated managerial duties.

In other sections of the manual were the following statements:

> Chief pilots are responsible for holding and carrying out the duties of one, and in many cases two, of the four "key personnel" positions listed in the Act – namely, the "head of the flying operations part of the organisation" and "the head of the training and checking part (if any) of the organisation".

> In current practice, particularly in smaller operations, the Chief Pilot commonly holds both the head of flying operations and the head of training key personnel positions. However, where economies of scale permit, the trend is towards CASA's preferred position of two complementary individuals holding these appointments.

The manual also gave guidance on the structure for training and checking organisations. This included the use of supervisory, training and check pilots.

The CASA *Flying Operations AOC Checklist* contained an item titled 'Organisational structure and staffing'. The AOC Manual also included a checklist titled *Flying Operations Organisational Structure and Staffing*. The one-page checklist contained the following items under the title 'Organisational Structure':

- Organisation suitable with regard to the size and scope of the proposed operation
- Chain of command appropriate to ensure safety of operations
- Numbers of management positions not excessive
- Flying/administrative tasks balanced for Flight Crew Managers.

Under the title 'Qualified and Competent Employees', the checklist asked inspectors to consider whether the organisation had sufficient number of suitably qualified and competent employees of various types, such as flight crew, training and checking, and operations control. The AOC Manual also contained a similar checklist for maintenance organisational structure and staffing.

The *Surveillance Procedures Manual* contained prompts for inspectors to assess whether there was sufficient staff in the organisation. It did not provide guidance on the nature of an appropriate organisation.

CASA's advisory material on safety management systems provided some guidance on the placement of a safety officer within an operator. It discussed some options, and stated that the preferred option was to have a safety officer report direct to the chief executive with a formal communication line to the chief pilot.

Neither the AOC Manual nor the *Surveillance Procedures Manual* provided guidelines on how to evaluate whether an organisation had a sufficient number of staff. Similarly, there was no guidance in the manuals on how to evaluate whether the workload of any of the organisation's key personnel was excessive. The ATSB has previously noted limitations with the guidelines provided to CASA inspectors for assessing staffing levels and the workload of key personnel in maintenance organisations.[139]

Some CASA inspectors reported that making assessments of whether an organisation had a suitable number of personnel of different types was a subjective and difficult judgement.

Evaluating Transair's organisational structure and staffing

The AOC assessments during the period 1999 to 2004 did not identify any problems associated with the organisation's structure. All of the entries on the

139 ATSB Aviation Safety Investigation 200105618, Beech Aircraft Corporation C90, VH-LQH, Toowoomba Qld, 27 November 2001. Published June 2004.

Flying Operations AOC Checklist for each assessment for the item on organisational structure either stated 'nil change' or 'satisfactory' or 'not required'. There was no evidence that a *Flying Operations Organisational Structure and Staffing* checklist was completed during this period.

Transair was initially approved to conduct RPT (cargo only) operations to Papua New Guinea in October 1999. CASA subsequently withdrew this authorisation on 15 December 1999 due to Transair using an aircraft on the route that was not approved for RPT operations (see Appendix H). Shortly after the withdrawal of the authorisation to conduct RPT operations, CASA conducted its first systems-based audit of Transair. The audit found numerous deficiencies associated with the operator, and concluded that Transair had 'inadequate systems of corporate management, control and communication'. It noted that 'the evidence indicates that the company lacks proper documentation and supervision' and recommended that the chief pilot 'be asked to show cause why his approval should not be cancelled'. Following the audit, a CASA manager noted on file that the chief pilot's problems resulted from him 'attempting to personally do too much'. In response to the audit, the chief pilot advised that he had appointed various pilots as base managers, employed a maintenance controller, and that he intended to appoint a deputy chief pilot and a pilot as a 'Safety Officer'.

The nominee for the position of acting chief pilot was not found suitable at an interview with a CASA inspector in March 2001. During the October 2002 audit, CASA noted that there had been problems with record keeping due to the chief pilot conducting activities in Papua New Guinea for 'a considerable period'. CASA issued an RCA requiring a deputy chief pilot to be nominated to act as chief pilot when the chief pilot was absent. In December 2002, the same nominee as March 2001 was assessed as meeting the requirements of a chief pilot, and therefore was approved to act as a chief pilot when the Transair chief pilot was absent (see Section 1.17.4).

There were no other concerns about the chief pilot's workload expressed during surveillance activities, or the fact that he was carrying the duties of three key personnel (chief executive officer, chief pilot and head of training and checking). During the investigation, some CASA inspectors from the Brisbane airline office reported they had concerns regarding the chief pilot's workload and the large geographical spread of his operations. CASA reported that it was aware that the chief pilot was conducting most of the training and checking duties.

Several CASA inspectors from the Brisbane airline office reported that they were not aware of any other RPT operators who had the same person perform the roles of chief executive, chief pilot and head of training and checking. Another inspector reported that he was only aware of one other operator in recent times where the one person performed the above three roles.[140]

Information on CASA's assessment of Transair's maintenance resources is provided in Section 1.18.13.

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140 That operator ceased operations following a fatal accident at Toowoomba in November 2001. See footnote 139.

1.18.7 Evaluation of Transair's chief pilot

Processes for evaluating the suitability of a chief pilot

The AOC Manual provided guidance on how inspectors should assess the suitability of a candidate for a chief pilot position.

CAO 82.0 Appendix 1 outlined the qualifications of a chief pilot. The appendix stated that the pilot must hold certain minimum qualifications, in terms of total flying time on relevant aircraft types and duration of experience in commercial aviation, with the amounts varying depending on the number and complexity of an operator's aircraft fleet.

CASA did not specify competencies for a chief pilot in terms of managerial ability or knowledge of safety system concepts, nor was this required by aviation regulations. It did provide general guidance material for chief pilots in the CASA *Chief Pilot Guide*, published in March 1999.

The AOC Manual provided guidance on assessing the suitability of a chief pilot. This included the following:

- The quality of the chief pilot was critical to the safety of the flying operations of the operator, and therefore the assessment of the nominee was equally important.
- In addition to aeronautical knowledge, leadership and credibility were also vital.
- An ability to manage 'the system' was more important than manipulative skill. An appointment '…should only be approved if the nominee shows the capability to manage the operator's objectives within the boundaries imposed by aviation safety legislation'.

The interview component of the assessment process was to consist of: an oral examination; a written flight planning, loading and performance examination; a flight check (optional); and a briefing. The oral examination was to include a list of questions developed by a CASA inspector to suit the situation, including 'some that are relevant to management situations and some that relate to the proposed operation'. Those included questions on the operator's AOC authorisations, CAO 82.0 and the operator's operations manual.

The briefing was to be conducted by the inspector after the candidate was assessed as being suitable. It was to include aspects such as particular responsibilities or regulatory aspects requiring emphasis, the chief pilot's role in the chain of regulatory responsibility, and CASA surveillance.

The AOC Manual also contained a checklist to be used by the inspector during the chief pilot approval process. That checklist contained items reflecting the nature of the guidance material.

In February 1999, the then Bureau of Air Safety Investigation[141] issued recommendation R19980277 to CASA that stated, in part 'that CASA develop a process to assess the ability of a chief pilot applicant to administer and manage regulatory and safety compliance'. CASA responded in February 2000 that it

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141 The Bureau of Air Safety Investigation (BASI) became part of the newly formed multi-modal Australian Transport Safety Bureau (ATSB) on 1 July 1999.

agreed with the recommendation, and would amend the AOC Manual to 'more adequately address system safety management'.

In May 2001, a fifth component was introduced in the interview stage of the assessment process. That component, titled 'system management assessment' stated:

> A chief pilot elect is to be assessed for managerial ability for the various essential systems that make up a sound, well managed flying operation. The Chief Pilot should be able to clearly demonstrate an ability to implement, manage and audit systems which will enable compliance with those responsibilities defined in Appendix 1, CAO 82.0.
>
> An effective method of ensuring a base skill level in this area is to have the applicant brief the FOI [flying operations inspector] on the systems in place in the company. In this way, a check can be made on their completeness. Particular attention should be paid to areas of high operational importance…

In 2001, CASA management personnel advised the ATSB that[142]:

- In recent years, CASA inspectors were provided training on safety systems and related concepts, and therefore understood the importance of a chief pilot being familiar with such concepts.
- Specific competencies for chief pilots in terms of management and safety systems/awareness had not yet been defined by CASA.
- CASA inspectors could not enforce requirements in terms of chief pilot qualifications that had not specifically been required in the legislation.
- The overall suitability of an applicant's qualifications was assessed in light of the type of operation under consideration, with more managerial experience and skills required for a large airline versus a single pilot aerial work operation.

In October 2002, the ATSB made the following recommendation to CASA:

> Safety Recommendation R20020194
>
> The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the required qualifications and/or competencies for chief pilots, with particular reference to management and system safety issues.

In December 2002, CASA advised:

> CASA acknowledges the intent of this Recommendation. It is intended, under the proposed CASR Part 119 to introduce a Safety Management System, among other issues, for air transport operators. Essentially these proposals provide for training and checking for crews flying with small operators and a greater regulatory emphasis on the responsibilities of key personnel in a company, including the head of flying operations.

Draft CASR Part 119 proposed that chief pilots would be required to have certain qualifications and experience, although the nature of these requirements did not vary greatly from the existing requirements.

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142 ATSB Air Safety Investigation 200100348, Cessna C310R, VH-HCP, 3 km E Newman Aerodrome, 26 January 2001. Published October 2002.

Processes for re-evaluating chief pilot following upgrade to operations

CAO 82.0 provided that the position of chief pilot had to be approved by CASA. The approval was not time limited, and remained in force provided that the chief pilot continued to be employed by the operator. There was no requirement or guidance in the AOC Manual to conduct a reassessment of a chief pilot's suitability following changes to the AOC holder's class of operations (for example, from charter to RPT). There was also no requirement or guidance to conduct a reassessment of other key personnel – that is, chief executive officer, head of training and checking, and head of airworthiness and maintenance control.

CASA advised that, although not specifically stated, it was implied in the AOC Manual that when a significant change to operations was made, a reassessment interview should be conducted.

Problems associated with a chief pilot's performance could be identified during surveillance activities. If the problems were deemed to be of sufficient magnitude, then the approval could be suspended or cancelled.

Assessment of Transair's chief pilot

The Transair chief pilot was originally appointed in 1989. There was no evidence on CASA files that the suitability of the chief pilot was reassessed when the operator upgraded to RPT operations in 1999. None of the AOC assessments during the period from 1999 to 2004 identified any problems associated with the chief pilot. All of the entries on the *Flying Operations AOC Checklist* for each assessment for the item on the chief pilot either stated 'not applicable' or 'no change'. CASA advised that the fundamental nature of Transair's operations changed very gradually, and so reassessment of the chief pilot at every change was not considered necessary.

As discussed in Section 1.18.6, in the December 1999 audit, concerns were raised regarding the suitability of the chief pilot. Other than during that period, there was no evidence on subsequent surveillance files that CASA had any concerns regarding the chief pilot's suitability.

The chief pilot's approval was reissued in August 2001 as a result of the form of approval changing. No assessment of the suitability of the chief pilot was required or conducted.

A CASA inspector reported that the Brisbane airline office had a good opinion of the chief pilot and considered that he was a competent pilot and very competent instructor.

1.18.8 Evaluation of the *Transair Operations Manual*

Processes for evaluating an operations manual

The AOC Manual stated that:

> The *Operations Manual* must not just paraphrase regulatory requirements. It must be used, and seen, as the primary means of communicating and detailing the company processes and procedures that are to be followed by operations personnel in the conduct of their business.

This statement was supported in the ICAO publication *Preparation of an Operations Manual Doc 9376-AN/914*, which stated:

> This manual stresses the supervision of operations. Approval of the operations manual is a fundamental step in the approval of an operator and the issue of an air operator certificate.

CASA inspectors assessing an operations manual were required to use Civil Aviation Advisory Publication (CAAP) 215-1 (0) *Guide to the preparation of operations manuals* as a guide. The AOC Manual procedures required the inspectors to:

> … ensure that the [operations] manual addresses all items necessary to ensure that the operations can be conducted safely, that it complies with the various legislative requirements and does not conflict with material in the *Flight Manual* [*Approved Airplane Flight Manual*]. In other words, not only has the form and content to be assessed, but the meaning also has to be evaluated.

The AOC Manual also noted that:

> The quality of an *Operations Manual* must be entirely satisfactory at the time of issue of the AOC, as the manual will become the benchmark for future regulation. Experience has demonstrated that operators will resist expending further resources on *Operations Manual* amendments **after** AOC issue [emphasis in original document].

CASA could direct, under the provisions of CAR 215(3), that particular information, procedures and instructions be included in an operations manual. The AOC Manual stated that:

> It should be noted that, although the regulation [CAR 215] gives power to CASA to direct material to be included in a manual, it does not require that the manual be approved by CASA.[143]

The *Surveillance Procedures Manual* provided general guidance for reviewing documentation. It provided no specific guidance for the review of an operations manual. CROS elements included 'manual currency', 'content consistent across manuals', 'distribution', 'availability' and 'supplemental ops manual requirements'.

As noted in Section 1.18.3, the *Surveillance Procedures Manual* stated that when an operator's manuals are 'submitted to CASA for acceptance or processing an approval then those accepted standards are the standards against which compliance is measured'. Some CASA inspectors reported that if an audit identified that an operator was not complying with requirements in its operations manual, then the matter should be addressed in the audit through a RCA or CAR 215(3) direction, even if the operator's requirements were additional to the regulatory requirements. Other CASA staff reported that in such a case, issuing a RCA could lead to the operator simply removing the requirements from its operations manuals. They also reported that instead of issuing sanctions, operators should be encouraged to include requirements in their operations manual that exceeded the regulatory requirements.

143 Prior to 1 October 1998, CAO 82.0 contained references to the operations manual. Subsection 3.3 of the CAO required that an applicant for a certificate must (in part) 'provide to the Authority for its approval an operations manual'. That wording was subsequently removed from CAO 82.0.

Format of operations manuals

The ICAO publication *Preparation of an Operations Manual* stated:

> In selecting a format for the operations manual, the primary criterion is that the manual be easily used and understood.

The ICAO publication did not refer to operations manuals in electronic format. This was due in part to the rapid growth of technology and the publication not being updated to maintain an awareness of current and emerging electronic technologies.

The AOC Manual and CAAP 215-1 did not require CASA inspectors to consider the format and useability of the operations manual when conducting an assessment of the manual. The CAAP provided guidance for the content in the form of topic headings and numbering. There was no discussion or guidance on the format of the manual; however the text intimated that the document should be produced in paper format. If an operator chose to produce the manual in electronic format, no guidance on how to go about producing this was contained in the CAAP or AOC Manual.

CASA produced a draft advisory circular AC 119-380(1) *Structure and content of operations manual*, dated November 2003, which was intended to provide guidance to operators on how to produce an operations manual under the new regulations. This draft advisory circular did not contain any guidance on how to produce a manual in electronic format.

In December 2004 CASA introduced a policy statement[144] indicating that, if an operator was required to provide manuals to CASA, and those manuals were produced in an electronic form, CASA must accept those manuals in that form. However, the policy document did not provide any guidance on assessing the useability of the manual if it was provided in an electronic format.

Comparison of CASA guidance with ICAO guidance

ICAO Annex 6 *Operation of Aircraft, Part I, International Commercial Air Transport – Aeroplanes*– Appendix 2 contained guidance pertaining to the contents of an operations manual. Section 2 *Flight Operations* contained the following sections which were not contained in CASA's CAAP 215-1:

- standard operating procedures (SOPs) for each phase of flight;
- instructions on the maintenance of altitude awareness and the use of automated or flight crew altitude callout;
- stabilised approach procedure;
- limitations on high rates of descent near the surface;
- conditions required to commence or continue an instrument approach;
- instructions for the conduct of precision and non-precision instrument approach procedures;

144 CASA Regulatory Policy – CEO-PN039-2004, issued December 2004.

- allocation of flight crew duties and procedures for the management of crew workload during night and IMC instrument approach and landing operations and instructions; and
- training requirements for the avoidance of controlled flight into terrain and policy for the use of the ground proximity warning system (GPWS).

CASA's draft Advisory Circular AC 119-380(1) *Structure and Content of Operations Manual*, dated November 2003, included the above items. However, specific guidance on limitations on high rates of descent near the surface was not included.

Evaluation of the Transair Operations Manual

Following the audit in December 1999 and the follow-up meeting with the Transair chief pilot, CASA noted that Transair's operational manuals were written by a contractor and that they were 'totally unacceptable in their current format and need to be completely re-written'. The chief pilot agreed to rewrite the *Transair Operations Manual* and he was advised at the time to write the manual in the format proposed by draft CASR Part 119.[123] Transair submitted a revised operations manual in August 2000.

There was no documentation on CASA files to indicate what actions were taken in regard to the *Transair Operations Manual* until August 2001. In August 2001, a CASA inspector advised the chief pilot that the *Transair Operations Manual*, dated October 2000, was acceptable to CASA. CASA did not note any problems with the manual during its subsequent approval of AOC variation applications.

Several audits identified problems with specific aspects of the *Transair Operations Manual*. For example, two CASA audits (September 2001 and February 2005) had identified problems with the procedures regarding the placement of the non-handling pilot's hand on the thrust levers during the take-off roll. Audit observations relating to this problem were issued in both audit reports. The September 2001 audit also issued an audit observation relating to the procedures for crew standard calls when reaching an assigned altitude during climb. None of CASA's audits identified any other problems associated with Transair's procedures relating to multi-crew operations.

No problems were noted on audit files regarding Transair's descent and approach procedures, including the absence of criteria for stabilised approaches. As noted in Section 1.17.7, the Transair chief pilot reported that he had discussed stabilised approach criteria with a CASA inspector, who had advised him that this information was not required in an operations manual for Metro aircraft. Other CASA inspectors reported that they believed it was important to include stabilised approach criteria in an operations manual. A review of several other Metro operators found that they all included stabilised approach information in their operations manuals.

The audit in August 2004 identified that the *Transair Operations Manual* had not been updated to include the Inverell base or the base manager, and that the base manager did not have a formal job description. An RCA was issued for these deficiencies. The same audit identified limitations with the document control process, relating to the process of issuing the manual in CD-ROM format. None of the AOC variation approvals or audits identified any problems associated with the useability of the manual after it was issued on CD-ROM.

1.18.9 Evaluation of Transair's training and checking organisation

Processes for evaluating a training and checking organisation

The AOC Manual provided substantial guidance for CASA staff on interpreting the regulatory aspects of flight crew training and checking, and the required and suggested qualifications and duties of check, training and supervisory pilots. The AOC Manual included the checklist *Assessment of the Training and Checking Manual*. This checklist included items on a range of topics, including: the structure of the training and checking organisation; course outlines; qualifications, experience and training programs for check, training and supervisory pilots; prescribed methods for conducting training sequences; and frequency of proficiency checks.

The *Flying Operations AOC Checklist* was used by CASA as part of the variation approval process. This checklist indicated that the training and checking organisation was a part of the organisation that required approval and that the training and checking manual also required approval.

In terms of surveillance, flight crew training was included in CASA's list of audit elements, both before and after the introduction of *Surveillance Procedures Manual*.

Evaluation of Transair's training and checking organisation

On 21 August 2001, Transair's CAR 217 training and checking organisation was re-approved as part of a variation to the AOC. There was no evidence on file that the checklist *Assessment of the Training and Checking Manual* was completed.

All of the CASA audits of Transair from September 2001 to February 2005, except August 2004, listed flight crew training as one of the elements examined. A file note for the February 2005 audit stated that a sample of pilot files were examined. The inspector who conducted the audit stated that he focussed primarily on induction training, although he also examined other training records. This inspector also reported that he considered that one base check and one line check per year was sufficient to meet the requirements of CAR 217(2). This view was not consistent with the AOC Manual and other inspectors (see Section 1.17.8). None of the audits identified any problems associated with the duration or quality of endorsement training, frequency of proficiency checks, or whether the pilots conducting flight proficiency line checks held the appropriate instrument of approval.

In addition to the audits, a CASA inspector completed a Metro endorsement with Transair, and then completed 50 hours in command under supervision (ICUS) in November 2001 (see Section 1.17.8). He also conducted a base check on the Transair contractor check pilot in December 2001. The November 2001 audit report stated that the inspector who completed the 50 hours ICUS flying would provide input into that audit. There was no evidence on the file of any input into the audit, and no report on the ICUS flying was located by the investigation. The inspector reported that he considered this to be line training rather than a surveillance activity.

The Transair deputy chief pilot had duties regarding the management of training and checking activities listed in the *Transair Operations Manual* (see Section 1.17.8). The deputy chief pilot and the contractor check pilot both reported that they had never been questioned by CASA during any audit. There was no evidence on CASA files that CASA inspectors had held discussions with the deputy chief pilot, contractor check pilot, or any of the Metro supervisory pilots, during CASA audits.

1.18.10 Evaluation of Transair's organisational change

Processes for evaluating organisational change

The AOC Manual provided no requirement or guidance for CASA inspectors, when assessing an application to vary an AOC, to consider other recent changes associated with the operator that had previously been assessed and approved. No mention was made on the relevant checklists regarding recent organisational changes or the organisation's processes for change management.

In terms of surveillance, the *Surveillance Procedures Manual* advised that recent changes in an organisation should be considered when developing the scope of an audit. Change management was listed as one of the elements of the CASA management system model. The *Surveillance Procedures Manual* contained general guidance for assessing the ability of an organisation to manage change. This included the following questions listed in the appendix:

> Are procedures in place to ensure that the integrity of the system is maintained when handling changes such as:
>
> - Changes or expansion to operations…
> - Growth in number of aircraft, staff, equipment etc…
> - Change of key personnel…
> - Introduction of new routes
>
> Are procedures in place to identify hazards and manage risks?
>
> Are change management procedures based on recognised practice?
>
> Does the change management process include robust record keeping?

Evaluation of Transair's organisational changes

None of the AOC assessments in the period 1999 to 2004 identified any problems associated with changes in Transair's activities.

The audits in 2004 intentionally focussed on Transair's new activities in New South Wales. In the August 2004 audit, CASA noted that the operator admitted to 'still being on a learning curve when it comes to intensive 28 sector per day RPT operations within New South Wales as opposed to its previously mainly charter background'. No RCAs or AOs were raised relating to change management issues in any of the audits.

1.18.11 Evaluation of Transair's risk management processes

Processes for evaluating risk management processes

When assessing an application to vary an AOC, the AOC Manual provided no requirement or guidance for CASA inspectors to consider an organisation's hazard identification and risk management processes or safety management program. CASA's educational materials on safety management systems provided general guidance on hazard identification and risk management processes.

The *Surveillance Procedures Manual* stated that an operator should conduct hazard identification and risk management, at a minimum:

> During implementation of the management system and at regular intervals;
>
> When major operational changes are planned (also see 'Change Management');
>
> If the organisation is undergoing rapid change, such as growth and expansion, offering new services, decreasing existing services, or introducing new equipment or procedures (see 'Change Management');
>
> When key personnel change (see 'Change Management').

No guidance was provided in the *Surveillance Procedures Manual* regarding how to evaluate the quality of an organisation's processes to identify hazards and analyse risks. The manual referred to some definitions from the Australian Standard AS/NZS 4360 *Risk Management*, but contained no further mention of the standard. There was no guidance on how an organisation should be expected to incorporate the type of processes discussed in this standard into its policies and procedures. In addition, no mention was made of how to assess whether personnel in an organisation had the appropriate skills to conduct hazard identification and risk analysis processes.

CASA advised that basic risk principles were taught in training on the *Surveillance Procedures Manual*, and that some specialist risk training was made available to some employees.

Evaluation of Transair's risk management processes

No mentions were made regarding hazard identification, risk management or safety management issues in CASA's assessment of applications to vary Transair's AOCs.

Following the December 1999 audit (see Section 1.18.6), the Transair chief pilot advised CASA that he intended to introduce a quality assurance system that incorporated a safety system modelled on the examples discussed in the CASA guide, *Aviation Safety Management: An Operator's Guide*. At a meeting with CASA management from the Brisbane airline office in January 2000, the chief pilot agreed to employ a quality manager to be responsible for implementing and managing a 'comprehensive safety system' within Transair, the training of Transair management about safety systems, and the rewriting of the company's manuals. It was also agreed that Transair would provide weekly reports to CASA regarding the progress of these items, and monthly progress/assessment meetings would be held for 3 months to enable CASA to determine that satisfactory progress was being made by Transair in implementing the agreed actions. In addition, CASA decided it would conduct a special audit at the end of March 2000 to confirm that Transair was meeting the AOC issue standards, followed by a normal scheduled audit in May 2000. There were no subsequent notes on CASA files regarding these monitoring actions.

In the September 2001 audit report, CASA issued an audit observation regarding Transair's safety program. The observation stated that the safety program manual was still in its draft stage. The observation suggested that 'this project be afforded the highest priority'. It also suggested that Transair consider outsourcing the development of the manual as well as the development of a quality management system. A note on the September 2002 audit file stated that Transair's safety manual was still in draft form.

In the August 2003 audit, CASA examined the management system model element titled 'Review of Safety Management'. The audit examined Transair's 'introduction of safety management systems to meet the future requirements of Part 119, 141 and 142 and as such does not have a direct bearing on the current compliance status of the company'. The examination focused on Transair's new hazard/incident database, and noted that the operator had encountered some difficulty getting used to the software and associated concepts. The actual processes used by Transair to identify hazards and assess risks were not discussed in the audit report or on the audit file. There was no discussion in the audit report or on file as to whether the operator was complying with its procedures for handling incident reports.

The scope of the 2004 audit was intended to include the element titled 'safety programme'. The audit report stated that, due to time constraints, this element was not examined. CASA advised that it was not uncommon that audit elements were postponed and rescheduled for a later audit.

1.18.12 Evaluation of Transair's flight operations

Processes for evaluating flight operations

In addition to assessing the operations manual, and training and checking organisation, the primary means of assessing an operator's flight operations during the AOC assessment process was through proving flights and port inspections.

The AOC Manual stated that proving flights, observed by CASA inspectors, were 'a practical demonstration by the AOC applicant that the documented procedures and systems previously inspected can work together in real time to produce a safe operation'. The manual stated that proving flights were required in certain situations, including the initial issue of an AOC authorising charter or RPT operations, and 'a major change in company structure – for example, an additional main base'. The AOC Manual stated that, in 'deciding whether a proving flight was warranted, CASA will consider the previous history of the operator…'.[145] The manual noted that, where there may be some doubt as to the justification for a proving flight, an inspector could observe the first revenue flight.

In terms of processing applications to add a new port to an AOC, the AOC Manual material primarily consisted of the requirements for a port inspection. The manual

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145 The *Civil Aviation Act 1988* Section 27AD stated that CASA 'may' require proving flights in order to assess whether the applicant can safely conduct operations covered by the application.

stated that ‘An operating port inspection is required at all aircraft bases and all RPT destinations’. The *Checklist – FOI Inspection of Operating Port* included items relating to the suitability of the aerodrome in relation to runway and movement area, documentation and facilities available at the port, passenger and freight handling, and refuelling facilities. The AOC Manual also required inspectors to conduct an evaluation of performance data required under CAO 20.7.1B for aircraft above 5,700 kg maximum take-off weight, such as the Metro 23 aircraft. CASA inspectors reported that the items they considered when assessing an application to add a port to an RPT AOC included aircraft performance charts, and the types of items included on the operating port checklist.

The operating port checklist and the AOC Manual did not include an assessment of the operator’s approach and landing procedures[146], or the qualifications and experience of the flight crew in using the instrument approaches associated with the aerodrome. There was no requirement for operators to provide this information when applying to add a new port to an AOC. There was also no requirement for an operator to conduct a risk assessment or a safety case[147] when adding a new port to its AOC.

As noted in Section 1.18.3, CASA’s surveillance policy since 1999 focussed on systems-based audits rather than product-based audits. However, there were still mechanisms for conducting observational flights or ‘en route inspections’ and ramp inspections. No required frequency of these activities was stated.

The *Surveillance Procedures Manual* (and previously the ASSP Manual) contained checklists to use for various spot checks, such as ramp inspections, port inspections, en route inspections, and operational records inspection. The operational records inspection form and the ramp check form contained items on proficiency checks, such as CAR 217 proficiency checks and CAR 218 route qualifications.

Due to the Metro only having two seats in the cockpit, CASA flying operations inspectors were required to sit in the passenger cabin for en route inspections. Consequently there was a limited potential for a sample of observation flights viewed from a passenger seat to detect flight operational issues, such as speeds in excess of procedural requirements. Flying operations inspectors also reported that it was difficult to detect problems with some operational issues when they were not rated or experienced on the aircraft type.

Process for collecting information during audits

The *Surveillance Procedures Manual* contained general guidance on collecting evidence during audits. The guidelines stated that evidence should be objective, obtained with the knowledge of the operator, verified for correctness and completeness, and recorded accurately and concisely. The manual also stated that the audit team should ‘verify what they say they do versus what they actually do’.

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146 The AOC Manual stated that inspectors should be satisfied that the operator understands its obligations in the determination of ‘aircraft landing minima’ and has published appropriate material in the operations manual.

147 A safety case is a document presenting a line of argument and evidence that an operation will be conducted at an acceptable level of risk.

There was no guidance in the manual regarding the importance of collecting information from line employees and personnel other than the key personnel. CASA advised that its inspectors were required to complete a 5-day audit course which included content on the importance of collecting information from other sources.

There were also no mechanisms or guidance in the manual on how to encourage employees to volunteer information. More specifically, there were no mechanisms or guidance on how to obtain information confidentially, which could then be used to focus the search for further information rather than be used as evidence to justify findings.

Evaluation of Transair flight operations

For the initial approval for Transair to conduct RPT (cargo) operations in October 1999, proving flights and port inspections were not completed. The flying operations inspector who signed the *Flying Operations AOC Checklist* recommended that the AOC be issued as there was no change to the operation other than the reclassification to RPT and that the operation 'had been running for two years on a charter basis, with no significant deficiencies reported'.

In December 1999 CASA conducted unscheduled surveillance of Transair at Cairns to ascertain if the correct aircraft was being used on the international RPT freight operation to Papua New Guinea. The surveillance identified that VH-TFQ was being used on the route but was not an aircraft that held a Certificate of Airworthiness that permitted it to be used for RPT operations.

En route inspections were conducted as part of the audits in June 2001 (Christmas Island – Jakarta – Christmas Island) and September 2001 (Cairns – Port Moresby – Cairns). These inspections occurred prior to the approval for Transair to conduct RPT operations on these routes in September 2001.

There was no record of a proving flight or en route inspection conducted for the Cairns – Bamaga – Cairns route or the Cairns – Lockhart River – Bamaga – Lockhart River – Cairns, nor a port inspection at Bamaga, prior to RPT passenger operations in September 2001. As stated earlier, a CASA inspector conducted 50 hours ICUS flying based in Cairns in November 2001. A port inspection of Bamaga was carried out by a dangerous goods inspector as part of the February 2005 audit. This audit also included an en route inspection on the Cairns – Lockhart River – Bamaga – Cairns sectors.

No en route inspections for Transair operations were recorded on CASA files in the period between September 2001 and January 2004. Proving flights were recorded on file for the Gunnedah – Inverell – Sydney route in January 2004 and the Inverell – Sydney – Cooma route in July 2004. Following the January 2004 proving flight, en route inspections and port inspections were conducted on Transair's New South Wales operations during the February 2004 audit, after RPT operations had commenced. Further en route inspections and port inspections for the New South Wales operations were conducted during the August 2004 and February 2005 audits.

En route inspections during the August 2004 audit and the February 2005 audit were conducted on aircraft being used on Transair's Big Sky Express operation, including VH-TFQ. This aircraft was not authorised for RPT operations at the time of these inspections, and had previously been identified in 1999 as an aircraft not to be used for RPT operations (see above). The aircraft had been incorrectly included on Transair’s AOC on 9 January 2004 as an aircraft approved for RPT use. The aircraft was removed from the list of aircraft on the AOC authorised for RPT operations on 23 July 2004, following a letter from CASA to Transair’s chief pilot two days earlier directing that the aircraft not be used for RPT operations.[148]

All en route and port inspections were considered satisfactory, although most identified a small number of problems regarding specific procedures or practices. The February 2004 audit issued an RCA on load sheets not being left at Gunnedah. The same problem was not detected during the inspections at Bamaga in February 2005 (see also Section 1.6.18). It was reported that the inspector who conducted the en route inspection could not recall whether he examined the issue of load sheets.

The audit reports indicated that the en route inspections in New South Wales in 2004 and 2005 had involved some discussions with some line pilots, including base managers. However, the brief notes on file indicated that these discussions focussed on specific procedural aspects. Other than these en route inspections, there was no indication on CASA files that surveillance activities had involved discussions with line pilots. There was no indication in the audit files of discussions with training personnel (other than the chief pilot) regarding operating standards or organisational issues.

There was no record on CASA files after December 1999 of an operational records inspection form or a ramp check form being used during surveillance activities relating to Transair. CASA inspectors reported that, if such activities had been conducted, the relevant checklists would have been completed and placed on file.

Transair's application to include Lockhart River as an operating port was submitted on 23 August 2004. Attached to the application were contact details and qualifications of ground handling personnel, performance charts for landing and takeoff, departure procedures and 'route and aerodrome requirements' for Lockhart River to be included in the *Transair Operations Manual*. The documentation for the manual did not specify any particular hazards for operating at the aerodrome, and no reference was made to approach procedures. CASA's assessment of the application noted some problems with the departure procedures and performance calculations, which were rectified. There was no indication that aspects of Transair's instrument approach procedures were considered.

1.18.13 Evaluation of Transair’s maintenance control

Processes for evaluating maintenance control

The AOC Manual provided guidance on how inspectors should assess the maintenance processes of an operator. This included the evaluation of the maintenance control manual, the system of maintenance for each aircraft type, the systems for managing airworthiness directives and maintenance records, maintenance training programs and contractual arrangements with outside maintenance providers. Guidance was also provided for the assessment of the

148 VH-TFQ was issued with a Certificate of Airworthiness in the ‘normal’ category in 1994. CAO 82.3 paragraph 6.1 required that this type of aircraft had to be in the ‘transport’ category for use in low-capacity RPT operations.

person nominated as the maintenance controller and the inspections of maintenance facilities and aircraft.

Evaluation of Transair maintenance control

Transair's application to add the Inverell – Brisbane route to its AOC was assessed by the flight operations team leader and recommended for approval by the acting manager of the Brisbane airline office on 7 April 2004. On 8 April, the acting airworthiness team leader recommended that the approval not be processed until Transair demonstrated that it had adequate maintenance control in place. More specifically, the maintenance controller was on leave and the person acting in the position had not been approved by CASA to act in that role. The acting maintenance controller also was unaware of the details of the application to vary the AOC. The application was approved by a CASA delegate in Canberra and the AOC issued on 8 April 2004. It was unclear whether he was advised of the acting airworthiness team leader's recommendation. No information addressing the airworthiness team leader's concerns was recorded on file. This inspector reported that he never received any feedback regarding his concerns.

CASA inspectors from the Brisbane airline office reported that there was ongoing concern regarding the maintenance controller's workload. In the August 2004 audit, CASA inspectors noted that the maintenance controller had a high workload and was barely keeping up with his record keeping duties. The audit report stated that if another Class A aircraft was added, as was intended, the maintenance controller would need a full-time assistant rather than the current part-time assistant. Another Metro aircraft (VH-UUN) was added to the operator's RPT fleet in April 2005, and the AOC was varied to include that aircraft, but the maintenance staffing level remained the same.

In the February 2005 audit, eight aircraft survey reports were issued for Transair aircraft used on the Big Sky Express routes. The airworthiness inspectors report stated that these items 'need to be addressed and continually monitored by the maintenance controller as the condition of the aircraft indicate that the standards of maintenance need to be improved'.

In a scheduled audit in January 2006, further problems were identified with Transair's maintenance control processes. The audit report stated:

> It is evident that due to a number of roles and tasks that the MC [maintenance controller] is responsible for, he has been unable to complete each function to the depth and quality required. The MC is supported by a Technical Records Clerk. A position of Alternative Maintenance Controller exists to conduct maintenance control functions when the MC is absent however this position is currently unfilled. The Technical Records Clerk's role as described in the MCM [*Maintenance Control Manual*], permits him to maintain time in service information in the Aircraft Status Report for the MC. No other functions of this position are described.
>
> The audit findings show that regulatory compliance has not been achieved due to an inability to comply with the processes described in the operational and airworthiness control documents. It is evident that inadequate resources have been provided by [Transair] to ensure such compliance. [Transair's] internal quality and safety systems have been ineffective in identifying and correcting its inability to comply with its own documented processes.

It is noted that previous CASA audits conducted in 2004 and 2005 identified similar examples of deficiencies with maintenance control, document control and quality control.

1.18.14 Evaluation of complaints about Transair

A former Transair pilot contacted the CASA Sydney airline office in September 2004 with concerns regarding the flight operations of Transair's Big Sky Express operation in New South Wales. Two CASA inspectors interviewed the pilot and at the end of the meeting compiled a list of items that were forwarded to the CASA Brisbane Airline Office for further investigation. The two Sydney-based inspectors indicated in the document that 'The pilot expressed his concerns clearly and sincerely. There is no reason to doubt the veracity of his information'.

The Brisbane airline office advised the Transair chief pilot of the allegations. The CASA inspectors reported that the chief pilot was able to refute the claims made by the pilot. CASA then informed the chief pilot that they would be conducting a follow-up investigation to collect documentary evidence to support the chief pilot's responses to the allegations. This follow-up investigation occurred approximately 5 weeks later due to '…the preliminary answers given by [the chief pilot], and the higher priority of other matters in this office…'.

In conducting the follow-up investigation to collect documentary evidence, the CASA inspector visited Transair's office and discussed each of the specific allegations with the chief pilot. In relation to the claim of 'poor training of first officers illustrated by not knowing how to complete an aircraft walk around', the CASA investigation note indicated that the company maintenance procedures were consulted and indicated that the pilot in command was responsible for the walk-around inspection.[149] The CASA inspector further indicated that 'company pilot training files were inspected and found to have pre-flight certifications signed'. The inspector summarised this part of the investigation as 'Pilot training records and documentation tend to support a conscientious approach by the company to pilot training'.

In relation to the claim of 'no instrument rating check undertaken/or check of instrument proficiency before revenue operations', the CASA investigation note indicated that 'the pilot was route checked including an ILS approach into Sydney. The pilot signed the check report'. In addition, regarding the claim of 'no examination of aircraft knowledge prior to being released to line operations', the CASA investigation found 'he had just come from an operation on the same aircraft flying the same routes. He had been given a four-sector check, which is considered the industry norm'.

The CASA inspector summarised the investigation by concluding that the allegations were satisfactorily answered by the chief pilot. He also indicated that the person who made the allegations appeared to have problems and had a 'chip on his shoulder'. He also indicated that CASA would increase its surveillance of the Big Sky Express operation. A one-page summary of some aspects of the allegations was included in a bound copy of the CASA February 2005 audit report.

149 The *Transair Operations Manual* stated that, although the pilot in command was responsible for ensuring that a walk-around inspection was completed, either the pilot in command or the copilot could conduct the inspection.

There were no other complaints about Transair listed on any CASA files provided to the investigation.

Two pilots of Trans Air PNG made written and verbal complaints about the safety of operations of that operator to the Civil Aviation Authority of Papua New Guinea. The same pilots reported that they made verbal complaints to the ATSB in July 2002 and October 2004. No record of the 2002 complaint could be found by the ATSB. The issues raised in the 2004 report related to regulatory matters. The ATSB suggested to the pilots that these matters be referred to CASA, and offered to pass on any complaints submitted in writing to the ATSB to help ensure they were addressed. The pilots declined to submit their concerns in writing. CASA reported that it had never received any written or verbal complaints from these pilots prior to the accident. The two pilots were subsequently interviewed by the ATSB during the VH-TFU investigation.

1.18.15 Evaluation of Transair's risk profile

Processes for evaluating an organisation's risk profile

CASA had tools for evaluating organisation risk profiles so that surveillance resources, other than those used for scheduled audits, could be directed to those operators that presented a higher risk to aviation safety. These included the financial viability assessment and the safety trend indicator (STI). Developmental work had also occurred on a tool to assess the risk level of airline operators.

Financial viability assessments

Section 28(2) of the *Civil Aviation Act 1988* allowed CASA to take into account the financial position of an organisation when considering an application for the issue or variation of an AOC. The AOC Manual provided some guidance to CASA inspectors regarding what information was required so that an assessment could be made of the financial position of an organisation when processing an application to issue or vary an AOC. The manual described those situations where a financial viability assessment was required, including when an AOC was varied to include authorisation to conduct RPT operations.

When the applicant was a corporate entity, such as a proprietary limited company, the AOC Manual specified that the applicant 'must provide' financial information including copies of the latest financial statements and business plan, forecast expenditure over the first three years of operation on essential safety-related activities and details of how the applicant intended 'to fund its essential safety related activities vis a vis other competing expenditures'. This financial information was to be evaluated by a CASA senior risk assessor and any recommendations made by the assessor were to be included in any report or AOC submitted to CASA senior management for consideration.

Safety trend indicators

In October 2000, CASA introduced the STI as an assessment tool for monitoring safety and targeting surveillance resources by determining the relative risk of operators. CASA described the STI in the *Surveillance Procedures Manual* as a questionnaire:

> … that provides a profile of an organisation, to assist with decisions regarding the scheduling of Special Audits. An STI also functions as limited audit, providing an opportunity to review an organisation's performance.

The STI form was divided into two sections, the first seeking general information about the operator, including details of the operator's aircraft fleet and overall judgement of the performance of the operator compared with 12 months prior and relative to other organisations carrying out similar work. The second section of the AOC STI contained 30 safety indicator questions, which rated aspects of the organisation's operation during the preceding 12 months.

The 30 safety indicator questions covered a number of aspects including organisational change, personnel issues such as morale and staff training, compliance and accident/incident history, the documenting, application, review and standardisation of processes and procedures, and the maturity and effectiveness of the organisation's safety system.

Based on the responses to the 30 items, an overall AOC Safety Indicator score was calculated. Non-favourable responses were summed. The *Surveillance Procedures Manual* stated that organisations with a weighted STI score[150] greater than seven would be included in an 'STI Area Office Report (high-risk report)'. If the STI score of a particular operator, together with other information gathered, indicated that the operator was of a high risk, CASA would plan a special audit on that operator.

The STI was initially intended to be used for all types of operators. The *Surveillance Procedures Manual* stated that, for general aviation passenger-carrying operators, a scheduled audit was to be conducted every 12 months, with an STI also conducted every 6 months.

Methods used in airline offices for assessing operator risk

CASA inspectors reported that it was widely perceived that the STI was not appropriate for assessing the risk level of airline operators. As airlines were being audited twice a year, the tool also did not provide any additional information than was already been obtained through audits.

An external audit report of CASA surveillance processes in June 2002 recommended that:

> In recognition of the concerns that Airline Offices have over the STI process, and the data quality issues that have been identified, the STI process needs to be formally postponed until a more appropriate risk based analysis process has been developed…

In 2003, CASA inspectors ceased conducting STI assessments for airline operators. The organisation which conducted the June 2002 audit report completed another audit of CASA's surveillance processes in May 2003. That report stated that 'CASA does not have a comprehensive risk assessment framework in place that would enable the assessment of the relative risk of each operator or the planning of an audit program based on this assessment'. The report recommended that:

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150 The weighted score took account of varying operational factors, such as the size of the operation and whether it involved the carriage of passengers, the raw score, and the number of items marked as 'don't know'.

> CASA should develop a comprehensive risk assessment framework that will inform the surveillance planning process, help to define and target resource allocations and assist with individual operator audit planning.
>
> Ideally, the framework should be supported by a predictive safety information system.
>
> The risk assessment should be based on specific operator information, including ESIRs, ASIRs, MDRs[151], previous findings and scope of surveillance conducted previously, level of overall knowledge of the operator, operator experience, industry information and professional judgement.
>
> The assessment should be documented…

CASA management stated that developmental work had been conducted on an 'airline risk tool' for evaluating the risk levels of airline operators. It was reported that, although some trial work had been conducted using this tool, the tool had not been implemented prior to the accident due to concerns within CASA regarding its reliability.

The *Surveillance Procedures Manual* stated that, when determining whether to conduct special audits or spot checks, inspectors should consider risk indicators, such as information from STIs, industry intelligence, previous audits and other intelligence such as incident reports. CASA inspectors from the Brisbane airline office also reported that assessments of which operators were associated with higher levels of risk was based on these sources of information and other interactions with the operators. They reported that there was no systematic tool or process used.

Evaluation of Transair risk profile

CASA advised there was no evidence of a financial viability assessment having been completed on Transair when the company upgraded its operation from charter to RPT operations. CASA also advised that:

> as a matter of law CASA could not properly have refused to issue an Air Operator's Certificate purely on the grounds of a financial viability assessment, if the applicant otherwise satisfied all of the requirements of Section 28 of the *Civil Aviation Act 1988*. [see Section 1.18.2]

CASA inspectors completed five STIs on Transair between March 2000 and May 2003. Four of the STIs were completed after Transair commenced RPT operations. The summary results for the STIs, and a comparison with the 'high risk score' level, are presented in Figure 29. Further details on each of the STIs are presented in Appendix H.

After CASA stopped conducting STIs on Transair, there was no evidence provided to the investigation that any other organisational risk score was generated and reported to CASA senior management.

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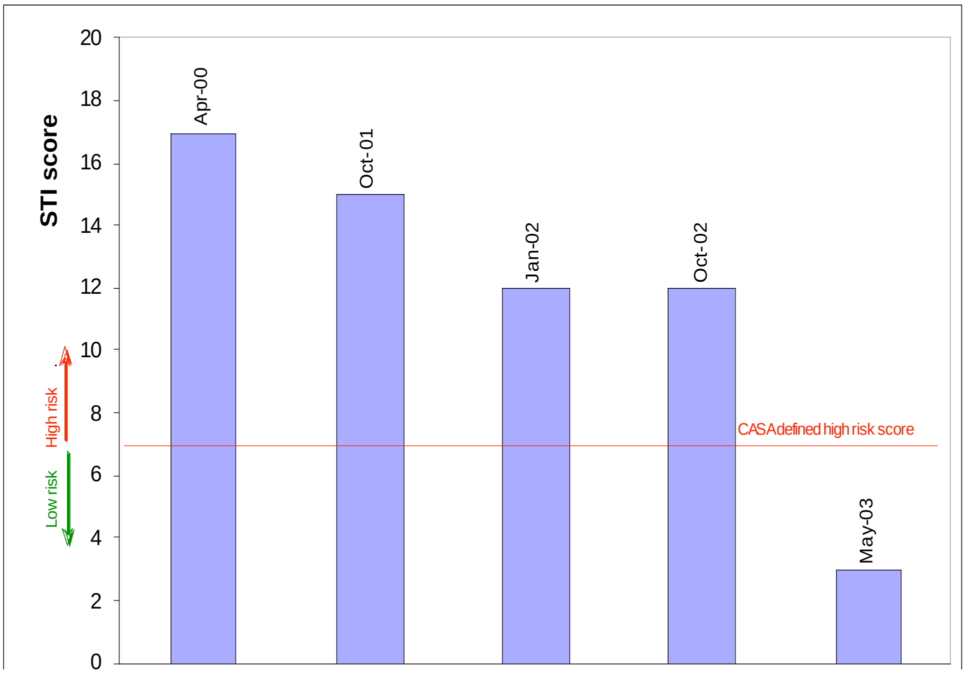
151 Electronic Safety Incident Reports (ESIRs) formed part of Airservices safety occurrence reporting system. Air Safety Incident Reports (ASIRs) were a type of occurrence report provided to the ATSB. They were subsequently referred to as Air Safety Accident or Incident Reports. Major Defect Reports (MDRs) were reports provided to CASA on aircraft airworthiness issues. They were subsequently referred to as Service Difficulty Reports.

Figure 29: Transair's safety trend indicator (STI) scores



There was no record on CASA files of special audits or spot checks being carried out on Transair operations after December 1999. CASA inspectors from the Brisbane airline office reported that they did not consider Transair to be a high risk operator.

CASA management reported that they had not been advised of any concerns relating to Transair's operations. CASA advised that no formal report of relative risk ratings was ever provided to the CASA chief executive officer. Transair was mentioned twice in other reports to the chief executive officer prior to the accident.

- Transair was included in the airline operations branch 'Top 10 operators' list in February 2004. This draft report provided 'the ten highest profile operators, selected on the basis of indicative risks, complexity and rate of change'. The report also noted that an inspector review 'indicated that this operator is still a lower risk operator'. Transair was not included in the same report that contained the 'Top 20 operators' based on ESIR relative risk.
- Transair was listed in the CASA airline operations branch 'Top 20 operators' list in March 2004. The basis for inclusion in this draft report included ESIRs, current RCAs, operation changes, fleet variation and size, route coverage, financial indicators and delayed audits. The document stated that the list was not an indicator of risk or safety performance. Transair was included on the list due to a delayed audit, financial issues, and expanded routes. The listing noted that the recent task of approving routes had identified minimal issues, so the audit delay was considered low risk.

CASA advised that reporting formats were subsequently changed and Transair did not feature on any further reports to the chief executive officer.

1.18.16 Regulatory oversight of Aero-Tropics

Throughout the period 2001 to 2005, Aero-Tropics had been audited annually by CASA as well as unscheduled surveillance in the form of additional audits and ramp inspections. The audits were exclusively directed at surveillance of Aero-Tropics' own RPT operations and they did include any evaluation of the operational relationship between Aero-Tropics and Transair. However, there were safety implications for Transair operations as the service provider for the Cairns - Lockhart River-Bamaga RPT service as there were some deficiencies identified in Aero-Tropics' operations.

In the May 2002 audit, CASA auditors identified deficiencies with Aero-Tropics training and checking system documentation for tracking dangerous goods training of both aircrews and operational support personnel. The March 2004 audit found that the dangerous goods manual in the company's library was an out-of-date edition.

A CASA inspector conducting scheduled surveillance of Aero-Tropics' operations in February 2003, issued an RCA to Aero-Tropics and the Bamaga aerodrome operator due to runway pavement markings not being visible. The inspector noted that responsibility for ensuring the maintenance of aerodrome standards was shared between the aerodrome operator and all RPT operators using that aerodrome. There was no evidence that indicated Aero-Tropics or CASA passed this information on to Transair.

1.19 RNAV (GNSS) instrument approaches

1.19.1 Overview of instrument approaches

A landing approach to a runway can be conducted visually in visual meteorological conditions (VMC) and/or by using navigation instruments. However, in weather conditions below that determined for VMC (termed instrument meteorological conditions or IMC), pilots must conduct an instrument approach using navigation instruments provided they are appropriately qualified. During an instrument approach, pilots refer to navigation instruments to position the aircraft (longitudinally, laterally and vertically) near the runway at the minimum descent altitude, a position known as the missed approach point (MAPt). By the missed approach point, the pilot must be able to make visual reference with the runway to continue the approach and to land the aircraft. If the pilot is unable to make visual reference a missed approached must be conducted using navigation instruments.

A number of different instrument approaches can be used, which can be broadly classified into two categories: precision approaches and non-precision approaches. Precision approaches provide the pilot with both lateral and vertical guidance down to the minima. The only precision approach currently operating in Australia is the instrument landing system (ILS). In contrast, non-precision approaches only provide the pilot with lateral and/or longitudinal guidance. This is a major disadvantage compared with precision approaches as altitudes and the descent path need to be calculated by the pilot based on charts and lateral positions obtained or calculated based on instrument approach aids. This disadvantage is reflected in the analysis by the Flight Safety Foundation of 287 fatal approach-and-landing accidents involving jet or turboprop aircraft above 5,700 kg between 1980 and 1996 worldwide.[152] The Flight Safety Foundation report found that three quarters of these accidents occurred in instances where a precision approach aid was not available or not used.

1.19.2 Overview of RNAV (GNSS) approaches

Instrument approach design criteria

The international design criteria for RNAV (GNSS) instrument approaches were specified in the ICAO document *Procedures for Air Navigation Services – Aircraft Operations* (PANS-OPS DOC 8168) *Volume II Construction of Visual and Instrument Flight Procedures* (PANS-OPS). PANS-OPS specified the criteria for the various approach segments as:

- initial approach segment - the ‘optimum length is 9.3 km (5.0 NM)’ (with a minimum distance determined by being able to accommodate the aircraft speeds of 210 kts);
- intermediate segment - ‘not to be less than 3.7 km (2.0 NM) allowing the aircraft to be stabilised prior to the final approach fix’; and
- final approach segment – ‘optimum length … is 9.3 km (5.0 NM)’.

In accordance with a decision made by CASA in 1996 and agreed to by the Australian aviation industry, Airservices[153] attempted to design all waypoint distances to be 5 NM when possible. PANS-OPS also required the descent gradient/angle to have an angle of no greater than 3.5 degrees (6.1 per cent) for Category C aircraft, and 3.77 degrees (6.5 per cent) for Category A and B aircraft[154], with an optimum slope of 3 degrees. A further PANS-OPS requirement for RNAV (GNSS) approaches was that the final approach path must be runway aligned allowing for a maximum 15-degree offset angle[155] on either side for Category C and D aircraft, or 20-degree offset angle for Category A and B aircraft. These criteria eliminated the need to conduct a circling approach. A 3-degree slope with 5 NM distances between the waypoints will give an approach similar to the one presented in Figure 30 for the Lockhart River runway 30 RNAV (GNSS) approach.

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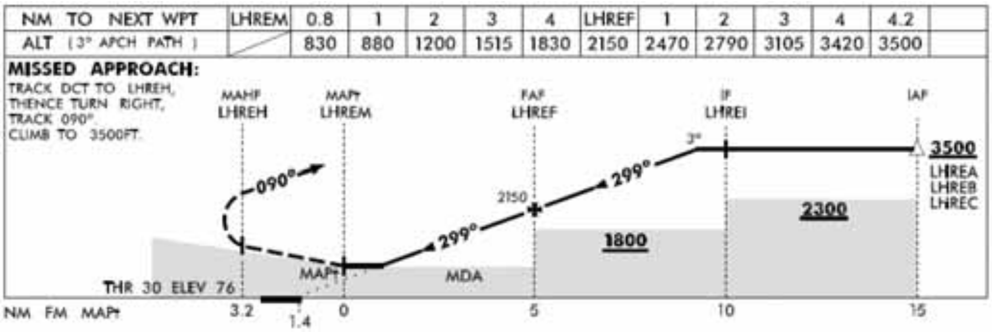
152 Ashford, R. (1998). A study of fatal approach-and-landing accidents worldwide, 1980-1996. *Flight Safety Digest, February-March 1998,* pp 1-41.

153 Airservices Australia was approved to design RNAV (GNSS) approaches and had designed most current Australian RNAV (GNSS) approaches.

154 Metro 23 aircraft were Category B (see also Section 1.17.7).

155 An offset angle was the angle between the runway centreline and the final approach track.

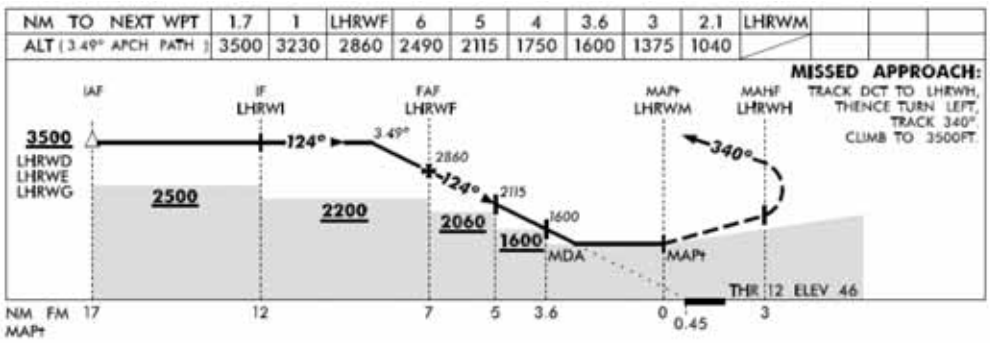
Figure 30: RNAV (GNSS) approach to Lockhart River runway 30. The approach uses the PANS-OPS optimum design.



Segment minimum safe altitudes were displayed between each pair of waypoints (shown as the grey shaded area and underlined[156] number in Figure 30 above). These altitudes indicated that it was not safe to fly lower than these levels, and some pilots set the aircraft's altitude alerter as a defence against descending below these altitudes. However, setting and re-setting the altitude alerter as the aircraft passed each altitude segment can significantly increase pilot workload.

Complications can arise when designing to PANS-OPS optimum criteria due to obstacle clearance requirements relating to such obstacles as mountains, or due to standard instrument departure (SID)[157] or standard arrival (STAR)[158] procedure requirements. High terrain may require a variation to the optimal approach as referred to in the PANS-OPS criteria. As such, distances between the waypoints can vary from 5 NM, the slope can be steeper than 3 degrees, and multiple segment minimum safe altitudes between each pair of waypoints can be used to maintain appropriate obstacle clearance. RNAV (GNSS) approaches that require such variations are a resultant compromise between approach angle, segment length, step altitudes and offset angle. The approach design also may take into account track length, flight time and environmental considerations (Figure 31).

Figure 31: The published Airservices Lockhart River Runway 12 RNAV (GNSS) approach.



156 Only on Airservices charts were these numbers bolded and underlined.

157 A standard instrument departure (SID) is a published departure procedure used by aircraft operating under the instrument flight rules. It specifies vertical and longitudinal tracking requirements to the minimum safe altitude and a specified point on the cleared air traffic control route.

158 A standard arrival route (STAR) is a published arrival route used by aircraft operating under the instrument flight rules. It specifies tracking data which links the en-route airways clearance to a point which is located at or near the destination aerodrome.

CASA instrument approach acceptance procedures

Before a newly designed instrument approach procedure could be published for general use, it had to be accepted by CASA. The acceptance process first involved a desk-top assessment of the design to determine whether the approach met the PANS-OPS criteria. CASA reported that, if an approach did not meet the criteria, it highlighted the deficiencies and rejected the design.

A CASA officer reported that RNAV (GNSS) approach designs that had not met the PANS-OPS optimal design criteria had been returned to Airservices to redesign with a higher minima. He also reported that an RNAV (GNSS) approach was not designed for Lord Howe Island aerodrome due to the complexity that would be needed.

If the design passed the desk-top assessment, the approach was then assessed by a validation flight by a specialist CASA officer. Training for these specialist flight validation pilots was reported as involving low level flying training and an awareness of the PANS-OPS criteria. The flight validation process included both an obstacle assessment and a 'fly-ability' check.

The validation flight was always manually flown, in VMC, in a single pilot operation, and generally in a Category B aircraft. Maximum Category B aircraft approach speeds were tested. There was no procedure to replicate approach speeds for the various aircraft approach categories that would be using the approach. There was also no process to fly the approach while accomplishing normal operating approach procedures as would be used by a commercial flight crew. The type of aircraft normally used for validation flights were not required to be fitted with GPWS, which meant that the validation flights may not have been able to determine whether GPWS alerts or warnings would be activated during the proposed procedure.

An approach that was within the PANS-OPS criteria could be 'not-accepted' by CASA if they considered it too difficult to fly safely. There were no reported instances of an RNAV (GNSS) approach design that had been rejected by CASA as a result of the flight validation process due to 'fly-ability' considerations.

Implementation of RNAV (GNSS) approaches in Australia

The first Australian RNAV (GNSS) non-precision approaches were developed and published for visual flight rules use during 1996-97. In 1998 CASA gave approval for RNAV (GNSS) approaches to be used for IFR operations and these were first used by an airline in 1999. By 2005, over 350 RNAV (GNSS) approaches had been published for Australian aerodromes and their use had become common among instrument-rated pilots operating aircraft ranging from single engine piston aircraft up to high capacity turbojet aircraft.

When RNAV (GNSS) approaches were initially introduced in Australia, CASA asked the aviation industry to comment on their useability. However, when subsequent RNAV (GNSS) approaches were published, no approach-specific feedback from industry was sought by CASA.

1.19.3 Lockhart River Runway 12 RNAV (GNSS) approach

Approach design and acceptance

Airservices designed the Lockhart River Runway 12 RNAV (GNSS) approach in 1999 based on the PANS-OPS design criteria. According to Airservices, the Lockhart River runway 12 RNAV (GNSS) approach was designed under a CASA delegation authorised under CAR 178. Airservices reported that they ensured newly developed instrument approaches were safe by designing them within the PANS-OPS limits. No other safety or risk assessment was done by Airservices specific to the Lockhart River runway 12 approach or any other RNAV (GNSS) approach including whether GPWS alerts or warnings would be expected to be activated if an aircraft was flown at the segment minimum safe altitude limits.

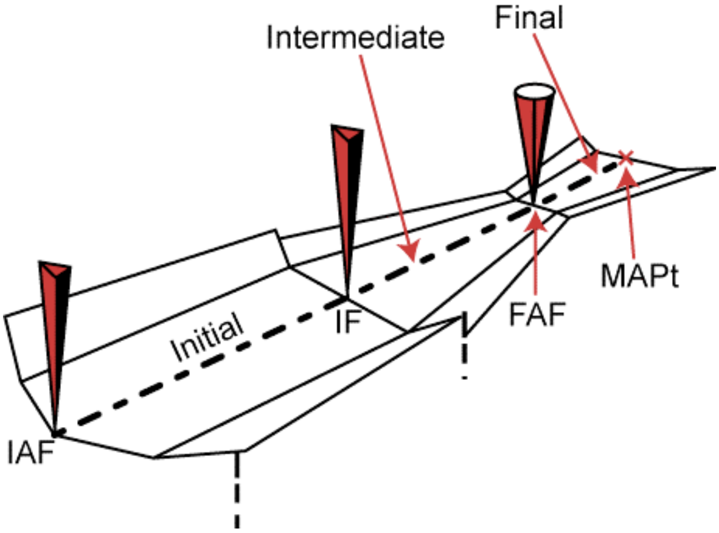
The final design was then submitted to CASA for approval and as part of that approval process, CASA conducted a flight validation of the draft final approach submission in September 1999. A representative from Airservices, as the designer, accompanied the CASA flying operations inspector on the validation flight.

Airservices designed the approach with a 5-degree offset angle because the elevation and location of Mt Tozer (see Figure 6 on page 8) increased the minimum descent altitude of an approach with an offset angle of less than 5 degrees north of the extended runway 12 centreline. The approach also could not be offset to the south of the extended centreline due to Mt Tozer. The preferred Lockhart River runway 12 RNAV (GNSS) approach option was a compromise between approach angle, offset angle and segment length and complied with PANS-OPS criteria (Figure 31).

According to the PANS-OPS criteria, the splay width[159] either side of centreline was 2 NM at and before the final approach fix, and 1 NM between the final approach fix and the missed approach point. These were fixed values, so as the final approach segment became longer, the narrower 1 NM splay was extended. With the final segment 7 NM in length and a 5-degree offset angle, Airservices designers were able to exclude Mt Tozer as the controlling obstacle. The resultant 7 NM segment length, the 5-degree offset angle and the 3.49-degree descent angle complied with PANS-OPS and CASA requirements.

159 The splay width refers to the airspace that is assured of obstacle clearance either side of the approach track.

Figure 32: Splay for each segment of an RNAV (GNSS) approach



The investigation engaged an independent approved instrument approach procedures designer to evaluate the Lockhart River Runway 12 RNAV (GNSS) published instrument approach. The scope of this evaluation was to:

- examine the design criteria of the Lockhart River runway 12 RNAV (GNSS) instrument approach to determine whether it complied with relevant design standards; and
- determine whether the approach was an appropriate design given the fixed limitation of the terrain in the vicinity of the Lockhart River aerodrome.

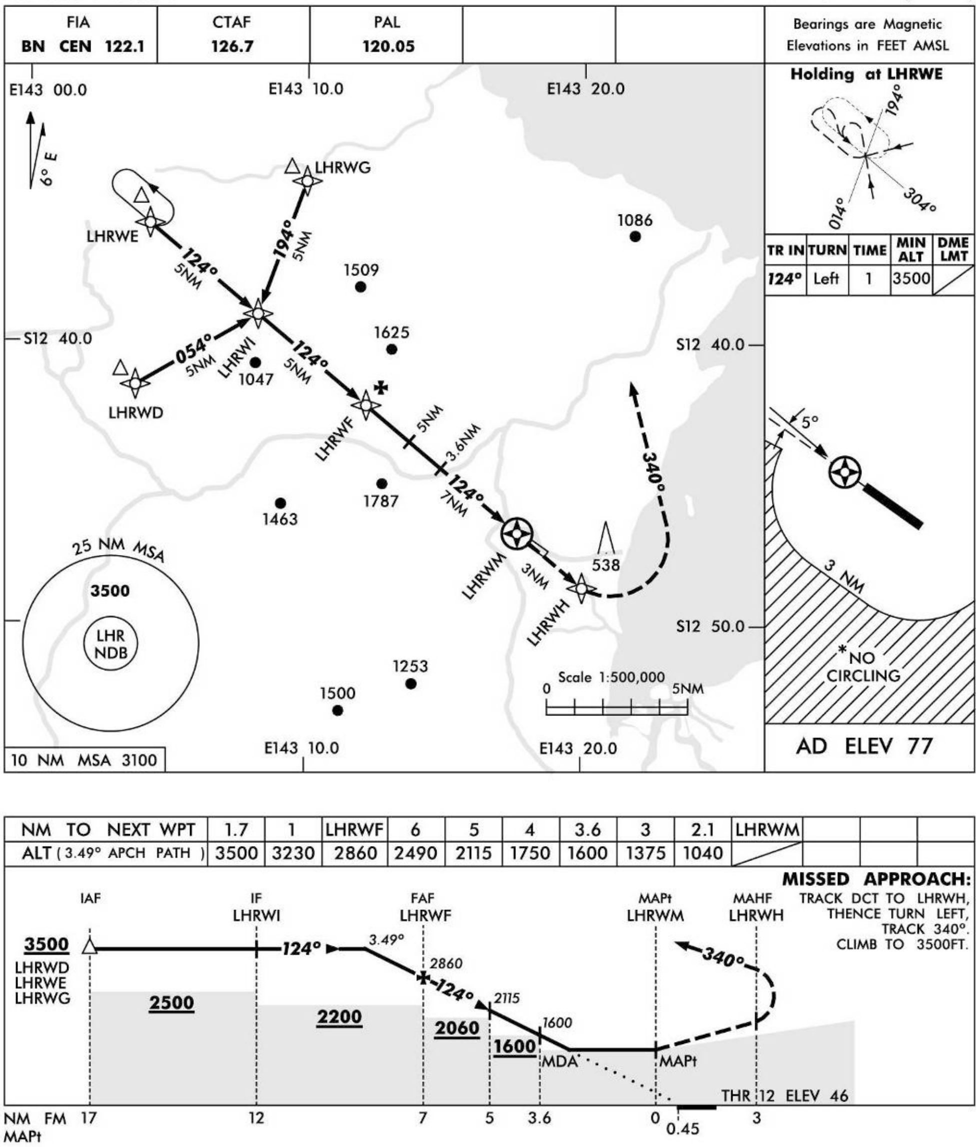
The findings in the independent designer's report and the design options provided by the designer showed that:

- Airservices complied with relevant PANS-OPS procedures and CASA requirements in the design of the Lockhart River Runway 12 RNAV (GNSS) approach;
- the 5-degree offset angle and 3.49-degree descent angle option was appropriate given the location of controlling obstacles to the north-west of Lockhart River aerodrome; and
- an RNAV (GNSS) approach aligned with the runway centreline, over the valley to the north-west of Lockhart River aerodrome (but closer to Mt Tozer), produced a minimum descent altitude which was too high to permit a straight in approach to land on runway 12.

Approach chart design

There were two aviation information providers that produced approach charts for Lockhart River: Airservices and Jeppesen (see Figure 33 and Figure 34 respectively). Jeppesen reported that the Jeppesen Lockhart River Runway 12 RNAV (GNSS) approach chart dated 19 November 2004 was examined following the accident. The chart was found to be fully compliant with Jeppesen production specifications and to accurately reflect the Airservices Australia source procedure. All Cairns-based Transair pilots reported that they used Jeppesen charts.

Figure 33: Lockhart River Runway 12 RNAV (GNSS) approach chart published by Airservices



USE QNH

RWY 12 RNAV (GNSS)

25 NOV 2004

LOCKHART RIVER, QLD (YLHR)

FIA	CTAF	PAL			
BN CEN 122.1	126.7	120.05			Bearings are Magnetic Elevations in FEET AMSL

TR IN	TURN	TIME	MIN ALT	DME LMT
124°	Left	1	3500	

NM TO NEXT WPT	1.7	1	LHRWF	6	5	4	3.6	3	2.1	LHRWM			
ALT (3.49° APCH PATH)	3500	3230	2860	2490	2115	1750	1600	1375	1040				

NOTES

1. MAX IAS: INITIAL : 210KT.

*2. NO CIRCLING BEYOND 3NM SOUTH OF RWY 12/30.

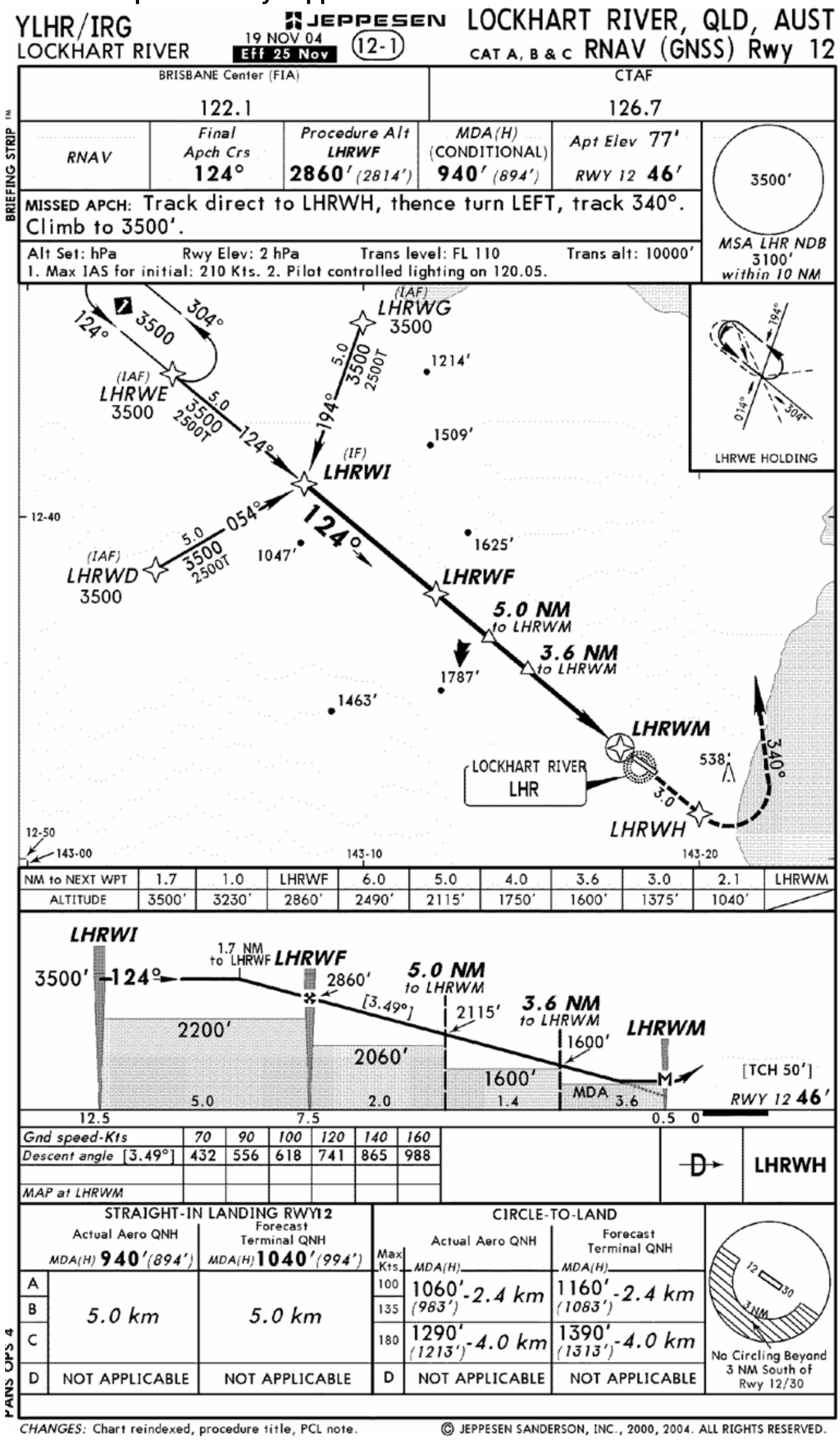
CATEGORY	A	B	C	D
S-I GNSS	1040 (994-5.0)			NOT APPLICABLE
CIRCLING*	1160 (1083-2.4)		1390 (1313-4.0)	
ALTERNATE	(1583-4.4)		(1813-6.0)	

Changes: PROC NAME, ALTN/MINIMA, PAL, Editorial.

LHRGN01-101

AIRSERVICES AUSTRALIA

Figure 34: Lockhart River Runway 12 RNAV (GNSS) approach chart published by Jeppesen

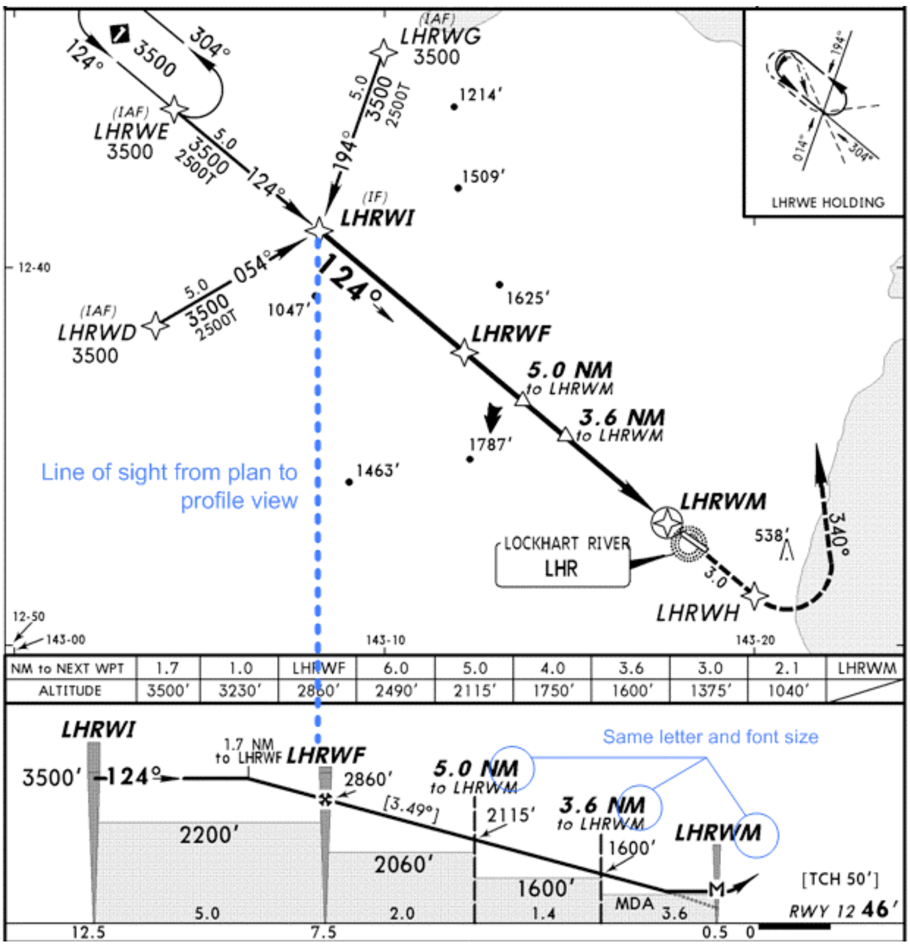


Unlike the Airservices charts, the Jeppesen charts did not display the first segment of the approach in the profile diagram from the initial approach fix (waypoints LHRWG/E/D) to the intermediate fix (waypoint LHRWI) (Figure 35). Instead, the profile diagram commenced from the intermediate fix. Jeppesen reported that this was to maximise the space available to display the details of the profile view. The plan-view provided details of all segments, starting from the initial approach fix.

For the Lockhart River runway 12 approach, the plan and profile-views superficially followed a similar spacing, but with one less segment on the profile diagram. As such, on the Lockhart River Runway 12 RNAV (GNSS) approach chart, the second waypoint (LHRWI) on the plan diagram was coincidently aligned with the second waypoint (LHRWF) in the profile diagram (Figure 35).

The investigation identified a number of other Jeppesen charts with Australian RNAV (GNSS) approaches where waypoints on the plan-view diagram coincidentally aligned with different waypoints on the profile diagram. Some of these approach designs also had multiple altitude limiting steps. For example, the Canberra Runway 30 RNAV (GNSS) approach had an initial approach fix (SCBEB) on the plan-view diagram aligned with the intermediate fix on the profile diagram (SCBEI), and the intermediate fix on the plan-view (SCBEI) aligned with the final approach fix on the profile (SCBEF).

Figure 35: Jeppesen chart line of sight between diagrams



On Jeppesen charts, the beginning of the intermediate altitude limiting steps (in between waypoints) was printed with the first line using the same font type and size, using capital letters for the nautical mile indications, and in the same positions, as the waypoint names (Figure 35).[160] The final letter on the first line was 'M', as was the final letter for the missed approach waypoint before the runway. Furthermore, as explained in Section 1.19.4, pilots needed to focus on the last letter of a waypoint (as the first four letters were the same for all waypoints) to identify their position.

Most distances displayed on RNAV (GNSS) approach charts referenced the next waypoint (rather than a single reference point like the missed approach point). This was to be consistent with GPS displays (see Section 1.19.4). The only continual reference to the missed approach point was displayed under the profile diagram on the Airservices chart. The Jeppesen chart displayed the distance to the runway threshold under the profile diagram. On the Jeppesen RNAV (GNSS) approach charts, there was only one reference to the distance to the runway threshold before the final approach fix due to the initial segment not being displayed on the profile diagram.

Segment minimum safe altitudes were in bold and underlined on Airservices charts, but on Jeppesen charts, were not bolded and not underlined and were presented as black letters on a grey background. Jeppesen charts did not show the runway offset between the final approach track and the runway heading as a numerical value, but the graphical representation of the runway in the plan-view was designed to indicate an offset.

Terrain depiction on approach charts

The Lockhart River Runway 12 RNAV (GNSS) approach chart was produced by Jeppesen only in black and white printing. On the plan-view diagram, the ocean was shaded grey and the terrain was white with high terrain depicted using spot heights (Figure 35), but no contour lines or terrain elevation shading. The ICAO Annex 4 *Aeronautical Charts*[161] stated 'Appropriate spot elevations are those provided by the procedures specialist.' The spot heights depicted that were closest to the approach were Mount Tozer to the South, (1,787 ft, highlighted by an arrow as the highest terrain on the chart) and Mount Dobson to the north (1,625 ft). North Pap and South Pap were not depicted. Therefore, there was no indication on the chart of the existence of terrain under the approach path.

The *Flight Safety Foundation Approach-and-Landing Accident Reduction Task Force*[162] recommended in 1999 that regulatory authorities should:

> Support the development and use of instrument approach and area charts that depict colored contours to present either terrain or minimum flight altitudes.
>
> Support the development of charts that depict terrain profile below the initial and final approaches, including the missed approach, within the vertical-profile box of the approach chart.

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160 Jeppesen reported that 'big bold type' was introduced for certain types of information on Jeppesen charts in March 1995 to enhance chart readability.

161 ICAO Annex 4, 10th edition, July 2001.

162 Flight Safety Foundation ALAR Task Force (1999). Analysis of critical factors during approach and landing accidents and normal flight. Data Acquisition and analysis final report. *Flight Safety Digest, Nov 1998-Feb 1999*. (pp 1- 77).

The ICAO Annex 4 *Aeronautical Charts* stated:

> 11.7.2 Relief shall be shown in a manner best suited to the particular elevation characteristics of the area. In areas where relief exceeds 1 200 m (4 000 ft) above the aerodrome elevation within the coverage of the chart or 600 m (2 000 ft) within 11 km (6 NM) of the aerodrome reference point or when final approach or missed approach procedure gradient is steeper than optimal due to terrain, all relief exceeding 150 m (500 ft) above the aerodrome elevation shall be shown by smoothed contour lines, contour values and layer tints printed in brown. Appropriate spot elevations, including the highest elevation within each top contour line, shall also be shown printed in black.

Australia had not notified a difference to ICAO Annex 4 paragraph 11.7.2.[163]

The Lockhart River Runway 12 RNAV (GNSS) approach had a final approach gradient greater than the optimum of 3 degrees, and the height of both North Pap (1,614 ft) and South Pap (1,453 ft) had relief higher than 500 ft above the Lockhart River aerodrome which had an elevation of 77 ft.

ICAO Annex 4 also stated that the profile-view on an instrument approach chart should display either a ground profile-view or minimum altitude in the intermediate and final segments. Jeppesen reported it 'has opposed the concept of depicting terrain in profile because of distortion due to profile views are not to scale. [sic]'

Jeppesen had issued instrument approach charts for Australian aerodromes, with plan-view diagrams using contour lines and different shades of brown to represent different elevation levels (an example is provided from Cairns aerodrome in Figure 36). However, Jeppesen limited this practice to approach charts with terrain exceeding 4,000 ft above the aerodrome anywhere on the chart, or 2,000 ft above the aerodrome within 6 NM from the airport reference point, and did not include contour lines for approach charts outside of these criteria (including when the final approach procedure gradient was steeper than optimal due to terrain). The highest elevation of terrain within 6 NM from Lockhart River aerodrome (Mt Tozer) was 1,787 ft, and the final approach slope was higher than the optimum 3 degrees due to terrain (Mt Tozer).

Airservices' instrument approach charts used spot heights only to depict terrain. A depiction of the elevation of terrain in the profile-view under the vertical approach path (see example in Figure 37) had not been included on any Australian instrument approach charts, although they all included segment minimum safe altitudes.

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163 Amendment number 1 to the supplement to Annex 4 – *Aeronautical Charts*, 10th edition, dated 17 November 2003.

Figure 36: Jeppesen RNAV (GNSS) approach chart plan-view diagram for Cairns runway 15

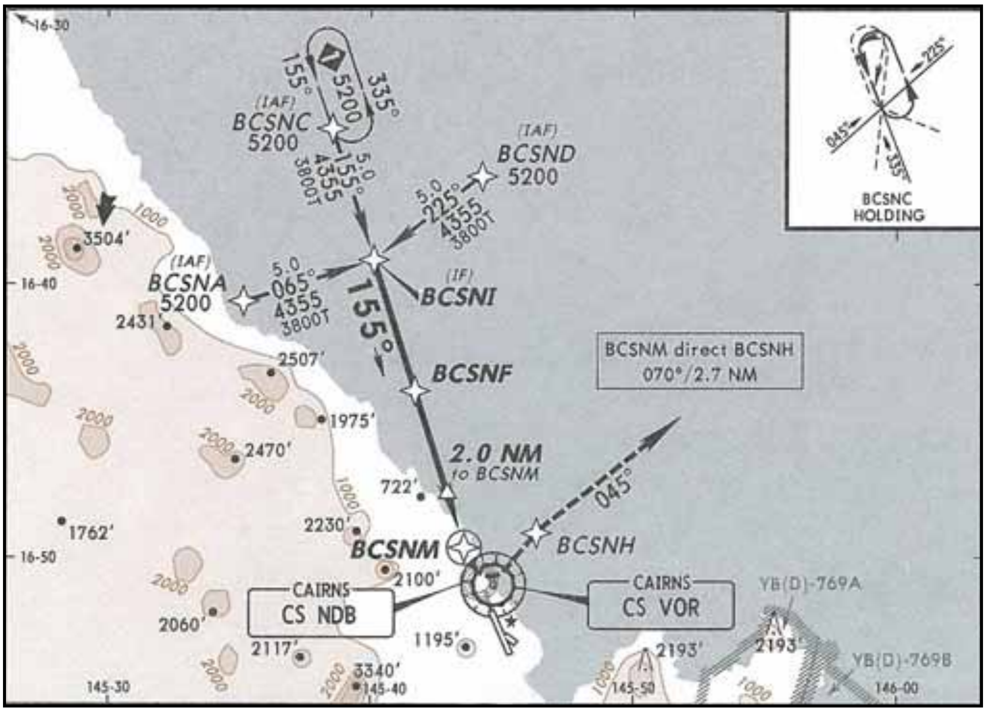
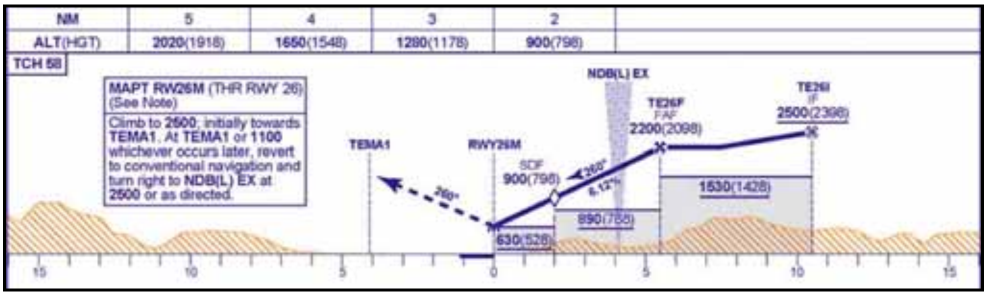


Figure 37: Exeter (UK) RNAV (GNSS) approach profile-view showing terrain depiction



Interviews of other pilots

The investigation interviewed a sample of 10 pilots who regularly operated into Lockhart River and regularly used RNAV (GNSS) approaches. All pilots operated Category B performance aircraft and none had any association with Transair or Aero-Tropics. Using open-ended questions, the pilots were asked about their general opinions and experiences. They were not asked to comment on any of the specific aspects of the approach as outlined below.

Of the 10 pilots, nine stated that they used an autopilot when conducting RNAV (GNSS) approaches. When asked about their opinion of RNAV (GNSS) approaches in general, five indicated that the approaches were high workload, and three indicated that maintaining situational awareness could be difficult. Five of the pilots indicated that the lack of a single distance display referenced to the missed approach point made the approaches more difficult and/or reduced situational awareness.

Eight of the pilots had personal experience flying the Lockhart River Runway 12 RNAV (GNSS) approach. When asked specifically about that approach, six of the eight pilots indicated that after conducting the approach on several occasions, they now actively avoided this approach, either in IMC (three pilots) or at any time (three pilots). Of the two pilots without personal experience of the runway 12 approach, one indicated that he actively avoided the runway 12 RNAV (GNSS) approach, and the other stated that he would use it if required, but only in VMC.

The eight pilots experienced on the approach stated that the proximity of terrain under the approach resulted in it being one of the most ‘unforgiving’ approaches. Six pilots indicated that there was typically significant turbulence on the final approach until the ‘final hill’ (South Pap) was cleared, and this could result in the pilot having difficulty reading the instruments and the autopilot being unable to maintain effective control of the aircraft. Four of the eight pilots reported the approach was steeper than the usual 3 degrees and three indicated that it had close and multiple altitude limit steps, each of which increased the difficulty of the runway 12 approach.

Only one of the 10 pilots always set the altitude alerter for each altitude limiting step, while the remainder indicated that this would involve too much work and/or it would interfere with the autopilot (as the autopilot would capture the selected altitude). Those nine pilots stated that the altitude alerter would be set to the minimum descent altitude.

The pilots interviewed did not have experience operating on the Lockhart River Runway 12 RNAV (GNSS) approach in aircraft fitted with GPWS.

Approach incident history

A search of the occurrence database held by the ATSB revealed that there had been 18 occurrences reported in the Lockhart River area between 1991 and 2005. The majority of these reports were not aerodrome specific and included occurrences within 20 NM of the aerodrome. Only one of the reports related to the Lockhart River Runway 12 RNAV (GNSS) instrument approach and it was received 2 days after the accident involving VH-TFU. As explained in Section 1.16.2, this aircraft operator’s pilots reported that they always experienced GPWS alerts and warnings while conducting the Lockhart River Runway 12 RNAV (GNSS) approach.

1.19.4 Human factors issues associated with RNAV (GNSS) approaches

RNAV (GNSS) approaches were relatively new at the time of the accident, both in Australia and internationally. Along with the US and Canada, Australia was at the forefront in the implementation of these approaches. As noted in Section 1.19.2, the first RNAV (GNSS) instrument ratings in Australia were issued to pilots in 1998, and the approaches were first used by an airline operator in 1999. By 2005, over 350 RNAV (GNSS) approaches had been published for aerodromes across the country.

GPS airborne receivers

The GPS receiver used for RNAV (GNSS) approaches at the time of the accident were required to meet the minimum requirements of the FAA technical standing order TSO-C129a. The TSO allowed the distance information displayed during an

RNAV (GNSS) approach to be referenced to the next waypoint. This was the same as for en route navigation (the original use for GPS in aviation), but differed from other non-GPS based instrument approaches (such as those involving a DME) that displayed distance to the runway threshold or missed approach point (MAPt). Some of the pilots from Transair reported that not having a distance to the threshold, unlike other instrument approaches, reduced situational awareness.

Research by the FAA[164] reported instances where GPS receivers affected pilot performance during the intermediate approach segments, because they did not allow easy access to distance-to-the-runway information. To obtain a distance-from-the-aerodrome, the report noted that pilots were required to either mentally calculate the distance information or access this information on the GPS receiver by exiting the current function page, entering a new page, and then returning to the original page, requiring at least four key strokes, or up to nine if done incorrectly.

Before RNAV (GNSS) approach procedures were adopted in Australia, an Airservices, CASA and industry GNSS Implementation Team (GIT) considered the issue of not having a distance to the missed approach point reference on the GPS display. A submission to the group from a CASA field office in November 1996 argued that a distance to the missed approach point needed to be displayed to the pilots, possibly on a separate display (such as the DME display) if space was not available on the GPS receivers themselves. However, CASA ultimately accepted the design standards from the TSO-C129 without any additional technical requirements of displaying distance to the runway information.

The FAA[165] identified that other human factors issues identified for TSO-C129 GPS receivers were mostly the result of the large number of possible functions with a small number of buttons and knobs, and a small display screen, in order to perform these functions. Research findings suggested that pilots perceived GPS readability was reduced due to the small unit size, which made alphanumeric symbols difficult to read, especially under ambient light conditions[166], and that the cluttered displays, and in some cases the use of capital letters on displays, reduced readability.[167]

Although TSO-C129 specified the minimum performance standards for GPS receivers, it did not specify a standard set of controls, features, function names, displays or operating modes. The potential for confusion and additional workload for pilots using more than one GPS receiver resulting from this lack of design consistency between manufacturers had also received commentary from researchers.[165] Due to such concerns, CASA's CAO 40.2.1 Section 13.4A specified that a pilot must not complete an RNAV (GNSS) approach in IMC as pilot in command unless he or she had conducted at least three RNAV (GNSS) approaches

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164 Findings from Winter & Jackson (1996) *GPS Issues.* (DOT/FAA/AFS-450). Oklahoma City: FAA. reported in: Joseph, K. M., & Jahns, D. W. (1999). *Enhancing GPS Receiver Certification by Examining Relevant Pilot-Performance Databases.* (DOT/FAA/AM-00/4). Washington: FAA.

165 Williams, K. W. (1999). *GPS User-Interface Design Problems: I* (DOT/FAA/AM-99/13). Washington, DC: FAA.

166 Nendick, M. & St. George, R. (1996). GPS: Developing a human factors training course for pilots. In B. J. Hayward & A. R. Lowe (Ed.s) *Applied Aviation Psychology* (pp 177-184). Aldershot: Ashgate.

167 Heron, R. M., & Nendick, M. D. (1999). Lost in space: Warning, warning. In D. O'Hare (Ed.), *Human Performance in General Aviation* (pp. 193-224). Aldershot: Ashgate.

using the same GNSS receiver as that fitted to the aircraft. Furthermore, CAO 40.2.1 Section 11.3B required this process to be repeated if the pilot in command had not completed an RNAV (GNSS) approach using the same GPS receiver within 6 months.

Garmin 155XL GPS receiver in VH-TFU

The Garmin 155XL GPS receiver fitted to VH-TFU had two display modes that the crew could have used: 'MAP' and 'NAV' summary. The MAP page, which included a moving map, showed a pictorial representation of the aircraft in relation to the waypoints, as well as limited numerical information. The NAV summary page only showed numerical information and the previous and next waypoints, along with a lateral deviation from track display as a course deviation indicator (CDI). Lateral tracking accuracy was also shown on the pilot in command's horizontal situation indicator (HSI). Numerical information displayed included track, and seconds and distance to the next way point (see Figure 38).

Figure 38: Garmin 155XL NAV summary page (top) and MAP page (bottom)

A review by the FAA[168] cited several research papers, which showed that moving map displays can greatly increase pilots' situational awareness. A number of respondents to the ATSB pilot survey (summarised in Section 1.19.5) also gave this opinion, and stated that the main problem with older GPS units was that the moving map was not available or not practical.

The moving map was available in the receiver, but the extent of the approach that could be shown on the screen was extremely limited due to the small vertical screen size in conjunction with the automatic scaling of the display which changed the scale from 20 NM to 1 NM as the aircraft approached each waypoint. The *Transair Operations Manual* did not specify which page should be used during an

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168 Williams, K. W. (1999). *GPS User-Interface Design Problems: II* (DOT/FAA/AM-99/26). Washington, DC: FAA.

RNAV (GNSS) approach. However, one of Transair's pilots stated that the Garmin 155XL defaulted to the NAV summary page once armed and that Transair pilots never used the moving map display during an RNAV (GNSS) approach. Furthermore, the MAP page did not include a CDI display and the copilot's HSI in VH-TFU did not display GPS tracking information.

In line with the TSO-C129a, the Garmin 155XL receiver displayed no information about altitude limiting steps that occurred between waypoints – neither in terms of seconds to go, distance to go, nor via a scaling change in the map mode.

Transair's pilots from the Cairns base regularly flew two aircraft: VH-TFU that was normally operated on the Bamaga route, and VH-TGD (a Metro III aircraft) that was normally operated on a Port Moresby freight route. VH-TGD was fitted with a Garmin 155 GPS receiver, which was a predecessor GPS receiver to the Garmin 155XL fitted on VH-TFU. The Garmin 155 was a simpler model than the 155XL, displaying the same data (at similar locations) on the NAV summary page but on three lines of information rather than four. Unlike the Garmin 155XL, the Garmin 155 did not have a MAP page (moving map and navigation information display). Pilots were required to manually arm an approach on the earlier 155 model, but on VH-TFU, the 155XL automatically armed the approach.

RNAV (GNSS) approach pilot workload

To date, apart from the ATSB study report in Section 1.19.5, only one published research study[169] could be located that reported on measures of pilot workload during RNAV (GNSS) approaches. This study investigated navigation accuracy and pilot workload for RNAV (GNSS) and ILS approaches using airline pilots operating Boeing 737 NG aircraft using LNAV[170] and barometric VNAV[171] with the autopilot engaged.

The study found good tracking accuracy and low pilot workload based on subjective workload ratings (using the NASA-TLX[172]) completed at the end of the flight. The low workload ratings and higher pilot acceptance were reported as being due to (compared with other non-precision approaches) the change from a cognitive task (of calculating vertical position) into a perceptual task (of matching the approach path with the aircraft's position) due to the autopilot and VNAV capabilities of the aircraft. However, most aircraft operated by low capacity RPT operators did not have VNAV capabilities except very recent and top-end models. VH-TFU was not equipped with an autopilot and did not have VNAV functionality.

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169 Goteman, O., & Dekker, S. (2003). Flight crew and aircraft performance during RNAV approaches: Studying the effects of throwing new technology at an old problem. *Human Factors & Aerospace Safety, 3(2)*, 147.

170 Lateral NAVigation (LNAV) is an autoflight system mode that directs the aircraft to fly to a selected sequence of waypoints.

171 Vertical NAVigation (VNAV) is an autoflight system mode that directs the aircraft to fly a vertical profile based on a selected sequence of altitude constraints.

172 The US National Aeronautics and Space Administration Task Load Index (NASA-TLX) was a subjective workload measure, as described by Hart & Staveland (1988) in P. A. Hancock & N Meshkati (Eds.), *Human Mental Workload* (pp. 139-184). The TLX had six scales (mental demand, physical demand, temporal demand, performance, effort, and frustration) and used 7 point Likert[191] scale judgements.

Situational awareness

The most commonly cited definition of situational awareness is from Endsley[173], who defined situation awareness[174] as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Situational awareness involves three stages:

- perception (observing the environment);
- comprehension (how does the state of the perceived world affect the individual now); and
- projection (how will it affect the individual in the future).

A loss of situational awareness could occur when there was a failure at any one of these stages resulting in the pilot not having an accurate mental representation of the physical and temporal situation.

In its review of 279 worldwide fatal approach-and-landing accidents of aircraft with a MTOW[175] greater than 5,700 kg, the *Flight Safety Foundation Approach-and-Landing Accident Reduction Task Force*[176] found the most common causal factor (47.3 per cent[177]) and the second most common primary causal factor (18.6 per cent) involved pilots having a lack of position awareness in the air.

RNAV (GNSS) approaches, like all non-precision approaches, do not provide the pilot with vertical navigation. Compared with precision approaches (such as ILS approaches), the complexity of non-precision approach procedures can increase pilot workload and diminish terrain awareness.[178] In addition, the above task force indicated that more than 75 per cent of approach-and-landing accidents world-wide have occurred where a precision-approach aid was not available or not used.[176] Similarly, other accident research has showed that there was a five-fold increase in the accident rate for commercial aircraft flying non-precision approaches compared with those flying precision approaches.[179]

No published studies (apart from the ATSB pilot survey summarised in Section 1.19.5) could be located that have investigated potential or actual losses of situational awareness during RNAV (GNSS) approaches.

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173 Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors, 37*(1), 32-64.

174 ‘Situational awareness’ is also referred to as ‘situation awareness’.

175 MTOW refers to maximum takeoff weight. Metro 23 aircraft have a MTOW of 7,484 kg.

176 Flight Safety Foundation (1998). Analysis of critical factors during approach and landing accidents and normal flight. Data Acquisition and analysis final report. *Flight Safety Digest, Nov 1998-Feb 1999*. (pp 1- 77).

177 More than one causal factor could be attributed to each accident, with an average of 3.8 factors attributed to each accident.

178 Flight Safety Foundation ALAR Task Force (1998). Aircraft Working Group final report. *Flight Safety Digest, Nov 1998-Feb 1999*.

179 Enders, J. H. *et al* (1996). Airport Safety: A study of accidents and available approach-and-landing aids. *Flight Safety Digest, March 1996*

Waypoint naming convention in Australia

Waypoint names for Australian RNAV (GNSS) approaches followed a standard format. The first four letters of each waypoint remained the same within an approach, and represented the three-letter aerodrome identifier (LHR for Lockhart River), and the general direction from which the aircraft has travelled on the final approach (W for west). The fifth letter was the only variation between the waypoints. The fifth letter of the initial approach fixes were, for example, E, D, or G. The final four waypoints had the standard fifth letter of I (for intermediate fix), F (for final approach fix), M (for missed approach point) and H (for the holding point beyond the runway for when a missed approach is conducted).

CASA reported that the system used in Australia was designed to increase situational awareness by using standard letters across all approaches, and to use letters that had intrinsic meaning of which position on the approach they were referring to. A similar philosophy had been adopted in a number of countries for the same reason (see next section).

Research has shown that when reading, people can more easily identify words printed in lower-case than those printed in capitals.[180] This is attributed to the different word shapes of lower case words producing additional recognition cues.[181] The different word shapes are mainly a result of the different heights of lower-case letters (for example, g, i, f, m compared with G, I, F, M).

Research has shown that searching for labels (place names) on maps is about 10 per cent faster when they are written in lower case (with an initial capital) rather than all capitals.[182,183] Labels printed in all capital letters must be examined more closely to distinguish them.[184] Searching for unpronounceable labels (non-words) on maps has been shown to be nine per cent slower than searching for words when the person is well practiced at the task.[183] However, there is no general case advantage when searching for non-word labels, but they are generally faster to identify when they are written in the same case as the source of the search label.[183]

People can more easily discriminate numerals from letters compared with looking for a particular letter among other letters. Research has shown that people can automatically (that is, instantly) identify a number among letters, but when identifying a letter among other letters, identification is slower in general and

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180 Examples of research showing the superiority of reading words printed in lower-case letters rather than capital letters include Tinker, M. A. & Patterson, D. G. (1928). Influence of type form on speed of reading. *Journal of Applied Psychology, 12*, 359-368. See also Poulton, E. (1967). Searching for newspaper headlines printed in capital or lower-case letters. *Journal of Applied Psychology, 51*, 417-425.

181 Neisser, U. (1966). *Cognitive Psychology.* Appleton-Century-Crofts: New York.

182 Phillips, R. J. & Noyes, L. (1977). Searching for names in two city street maps. *Applied Ergonomics, 8,* 73-77.

183 Phillips, R. J., Noyes, L., & Audley, R. J. (1977). The legibility of type on maps. *Ergonomics, 20*, 671-682.

184 Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design* (7th ed.). New York: McGraw-Hill Book Company.

identification time depends on the number of other letters surrounding the target letter.[185]

When people read, they naturally look at the whole word starting with the beginning of the word.[184] Furthermore, research has shown that when searching for labels on maps, the most important aspect of the label to assist identification is the initial letter.[186] Research has also shown that when searching for a letter in three-letter or five-letter sequences, the time taken to detect the letter increased the further its position moved from the first letter.[187] However, for RNAV (GNSS) approach waypoints, the pilot had to ignore the first four letters and focus on the final letter only.

In summary, as RNAV (GNSS) waypoint names were unpronounceable labels, identification should have been facilitated to some extent as they were written in the same case as they were displayed on the GPS receiver (that is, upper case). However, use of all upper case letters and no numerals reduced the discrimination characteristics between the repeating letters (LHRW) and the changing letter (G, I, F, M) in the waypoint names. Furthermore, as all waypoint identifiers in an approach had the same first four letters, pilots could not use the first letter of the waypoint identifier as a recognition cue as would be the case in most reading tasks. Due to the nature of the time pressure during an approach, there would be times when pilots needed to make quick glances at the approach chart and/or GPS display.

Waypoint naming conventions – other countries

In other countries, different waypoint naming conventions have been used for RNAV (GNSS) approaches.

In the United States, the runway waypoint name was based on the runway name such as RW01, but each other waypoint name (for the three initial approach fixes (IAF), the intermediate fix (IF) and final approach fix (FAF)), was akin to an en route pronounceable waypoint name with different letters for at least the first three letters. This had the advantage of the runway waypoint name being very easily distinguished from the others, and that each other waypoint was sufficiently different to make it unlikely they would be confused with one another.

In the United Kingdom[188], the IF and final approach fix were given names based on the first two letters of the aerodrome, followed by the two numbers of the runway name, and then I or F respectively (e.g. NH28F for Blackpool runway 28 final approach fix). As numerals are automatically distinguished from letters,[185] the final letter of the waypoint was more salient. The runway threshold waypoint name was

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185 Schneider, W. & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84,* 1-66. Shiffrin, R. M. & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127-190.

186 Phillips, R. (1979). Why lower case is better? *Applied Ergonomics, 10,* 211-214.

187 Neisser, U. (1963). Decision time without reaction time. *American Journal of Psychology, 76,* 376-385.

188 The United Kingdom system was based on a trial of five RNAV (GNSS) approaches in 2006 conducted by the UK Civil Aviation Authority in partnership with the University of Leeds and Imperial College London.

given the name of the runway (e.g. RWY28 or RW23M). The three initial approach fixes given waypoint names akin to en route pronounceable waypoint names (e.g. TOVEL, ROBLU, and BARSU), reducing the chance that the initial approach fix waypoints could become confused with the IF waypoint.

In New Zealand, a similar approach was taken except with the initials of the approach fixes at the start of the waypoint name, followed by the runway number. For example, Ohakea Runway 27 RNAV (GNSS) approach used the waypoint names IF27 for the intermediate fix, FF27 for the final approach fix, and RW27 for the runway threshold waypoint. Other approaches in New Zealand had a missed approach waypoint (prior to the runway threshold) instead of the runway threshold waypoint such as MA12 for the Kaitaia runway 12 approach. Locating the changing characters at the beginning of the waypoint name places them where the reader's eye naturally falls so search times would be reduced. The first waypoints in New Zealand RNAV (GNSS) approaches (either initial approach fix or intermediate fix) were always given waypoint names akin to en route waypoints, such as POLOK and HARTS for the two initial approach fixes for the Okahea Runway 27 RNAV (GNSS) approach, again reducing the chance that the initial approach fix waypoints could become confused with the intermediate fix waypoint.

1.19.5 Perceived pilot workload and perceived safety of RNAV (GNSS) approaches safety study

Below is a summary of a ATSB Aviation Safety Research and Analysis study *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches* conducted by the ATSB which was linked to this investigation.[189]

Objectives

The objective of this research study was to gain an understanding of the experiences and perceptions of RNAV (GNSS) approaches in Australia from pilots who were currently using these approaches. Specific objectives were to understand pilot perceptions of:

- pilot workload during an RNAV (GNSS) approach;
- ability to maintain situational awareness during an RNAV (GNSS) approach;
- ease of approach chart use during an RNAV (GNSS) approach;
- how safe RNAV (GNSS) approaches were; and
- which aspects of RNAV (GNSS) approach and chart designs contributed to these perceptions.

Methodology

A survey was mailed to all Australian pilots[190] holding a civilian licence and a command instrument rating endorsed for RNAV (GNSS) approaches. The first part

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189 Godley, S. T. (2006). *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches.* (Aviation Safety Research and Analysis Report 20050342). Australian Transport Safety Bureau: Canberra. <http://www.atsb.gov.au/publications/2006/20050342_RNAV.aspx>

of the survey asked for assessments on a range of approach types, including visual (day), visual (night), instrument landing system (ILS), distance measuring equipment (DME) arrival, very-high-frequency omni-directional radio range (VOR) /DME, NDB, and RNAV (GNSS) approaches. This was done so perceptions about the RNAV (GNSS) approach could be contrasted with other approaches. Assessments were given for the following Likert scales[191]: preparation time and effort; mental workload; physical workload; time pressure; approach chart interpretability; situational awareness; and safety.

Part 2 of the survey involved open-ended answers to questions specifically dealing with the RNAV (GNSS) approach. Respondents were asked to write which aspects of the RNAV (GNSS) approach contributed to mental workload, physical workload, time pressure, approach chart interpretability, and safety. Separately, they were asked to indicate if any aspects of the RNAV (GNSS) approach could be improved, what were the circumstances in which they were the most difficult, and were there any particular locations where they were difficult. Part 2 also queried respondents about training and equipment, and asked them to indicate the details of any incident they had been involved in during an RNAV (GNSS) approach.

Part 3 of the survey sought details of pilot experience, both in general and for each approach type specifically. It also asked respondents to indicate their main method of flying each approach, either using autopilot or by hand-flying, and whether they conducted each approach mainly inside or outside of controlled airspace.

Demographic data

There were 748 surveys completed and returned to the ATSB, a response rate of 22 per cent.[192] Survey responses were received from individuals representing a broad range of pilot licence holders (private, commercial, and air transport pilot licences) covering a variety of aircraft types (single engine piston aircraft through to narrow-body high capacity jet aircraft). These respondents were representative of the range of pilots and aircraft using RNAV (GNSS) approaches.

Throughout the survey, questions that asked respondents to provide an assessment of their experience on a range of approach types always included the RNAV (GNSS) approach as the last approach on the list. Questions specifically targeting the RNAV (GNSS) approach were not used until the second part of the survey. Furthermore, the survey title, 'Pilot Experiences on Instrument Approaches', did

190 Pilot details were not provided to the ATSB. An independent mailing house distributed the surveys to pilots from details provided directly to them by CASA. Licence holders with a Private IFR rating were not targeted in this survey.

191 Likert scales are continuous rating scales. All scales in the survey had seven points (1 representing low/easy/safe and 7 representing high/difficult/dangerous) except situational awareness which had a four point scale (1 representing no experienced losses of situational awareness, 2 few losses, 3 losses sometimes, and 4 losses often).

192 Several pilots holding an RNAV (GNSS) endorsement reported that they did not receive the survey. Therefore, it is possible that the true response rate was higher than 22 per cent. A response rate of 25 to 31 per cent was obtained in past unsolicited surveys by the ATSB within the Australian aviation industry.

not mention RNAV (GNSS) approaches. These two strategies were used to obscure the fact that the main topic of interest of the survey was RNAV (GNSS) approaches. This was done to maximise the likelihood that the sample of pilots who chose to complete and return the survey was a representative sample of the pilot group using these approaches. That is, to minimise the likelihood that respondents were biased either in favour or against RNAV (GNSS) approaches.

As with all surveys using a sample of a total population, the results below represent an estimate of the population of RNAV (GNSS) endorsed pilots, rather than exact measure of that population. Inferential statistical tests were used to determine whether differences existed between the various visual and instrument approaches. These tests take into account the number of respondents within each group as well as the variation between respondents within each group. All statistical tests used an error rate of less than 0.01.

Respondents were placed in groups based on the main aircraft they operated using aircraft performance categories. The three main groups were Category A aircraft (typically small single and twin-engine aircraft), Category B aircraft (typically larger twin-engine propeller aircraft), and Category C aircraft (typically high capacity RPT aircraft). A Metro 23 aircraft was in the Category B aircraft approach performance category.

Findings

Pilot workload was perceived as being higher for the RNAV (GNSS) approach than for all other approaches except the non-directional beacon (NDB) approach, which, for the respondents, involved similar workload levels.

Respondents indicated they had trouble maintaining situational awareness more often on the RNAV (GNSS) approach than each of the other approaches except for the NDB approach.

Respondents also indicated that they perceived the RNAV (GNSS) approach as safer than the NDB approach, equivalent to a visual approach at night, but perceived it as less safe than all other approaches included in the survey.

The runway alignment of RNAV (GNSS) approaches was reported as increasing safety by 30 per cent of respondents.

There were some differences between the responses from pilots from Category C aircraft (mostly high capacity aircraft) and those from Category A and B aircraft. The slower Category A and B aircraft results were as above with regards to workload, situational awareness and perceived safety. However, pilots from Category C aircraft typically rated workload, situational awareness and safety as no worse than other non-precision approaches. These differences were likely to have been due to two main reasons. Firstly, the Category C aircraft pilots conducted RNAV (GNSS) approaches mostly using autopilots and had more sophisticated autopilot systems and vertical navigation (VNAV) capabilities not available to the slower and less complex aircraft. Secondly, high capacity airline pilots mostly conducted RNAV (GNSS) approaches inside controlled airspace while the Category A and B aircraft mostly conducted RNAV (GNSS) approaches outside controlled airspace, which increased workload levels during an approach. It is possible that more detailed approach briefings and company approach procedures in high capacity airlines may have also contributed to the differences found.

The concern that most respondents had concerning the design of RNAV (GNSS) approaches was that they did not use references for distance to the missed approach point throughout the approach on the global positioning system (GPS) or flight management system (FMS) display and the consequential limited references on the approach charts were inadequate. This response was common from respondents in all types of aircraft categories, and was listed as affecting all areas of this survey. It was one of the most common issues influencing mental workload, approach chart interpretability, and perceived safety, influenced physical workload and time pressure assessments, and the most common aspect of the approach that trainees took the longest to learn. The inclusion of distance to the missed approach point on the cockpit display and approach chart was also the most common improvement suggestion by respondents.

Short and irregular segment distances and multiple minimum segment altitude steps (necessary for approaches in the vicinity of high terrain) were also identified as a major concern for many pilots. They were listed as the most common reason why pilots experienced time pressures and were one of the most commonly mentioned contributions to mental workload, physical workload, lack of approach chart interpretability, and perceived lack of safety. These sub-optimal characteristics were common in the list of aerodromes considered to have the most difficult RNAV (GNSS) approaches, including Lockhart River.

Approach chart interpretability was rated as more difficult for the RNAV (GNSS) approach than all other approaches, and by all aircraft performance categories. Unlike NDB and ILS approach charts, ease of interpretation did not increase with the number of approaches conducted per year.

The naming convention of using five capital letters for waypoint names with only the final letter differing to identify each segment of the approach was reported to cause clutter on the charts and GPS and FMS displays, and also to increase the chance of a pilot misinterpreting a waypoint.

The amount of time and effort required to prepare for an RNAV (GNSS) approach was reported as higher than for all other approaches.

Most (86 per cent) respondents considered their RNAV (GNSS) endorsement training to have been adequate. Of the 14 per cent who considered it not to have been adequate, the most common reason given was that not enough approach practice had been given.

Flight instructors who answered the survey indicated that the most common problem trainees had with learning the RNAV (GNSS) approach was maintaining situational awareness, often related to becoming confused about which segment they were currently in and how far away they were from the runway threshold.

There were 49 respondents who reported that they had been involved in an incident involving RNAV (GNSS) approaches. The most common incident (15 respondents) was commencing the descent too early due to a misinterpretation of their position, and a further three respondents indicated that they misinterpreted their position but that this was discovered before they started to descend too early. Another five incidents were reported from other losses of situational awareness. A further four respondents indicated that they had descended below the constant angle approach path and/or minimum segment steps.

1.20 Human factors and crew resource management training

1.20.1 Overview of human factors

The International Ergonomics Association defines[193] *human factors*, also known as ergonomics, as:

> …the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

In other words, human factors is the multi-disciplinary science that applies knowledge about the capabilities and limitations of human performance to all aspects of the design, operation, and maintenance of products and systems. It considers the effects of physical, psychological, and environmental factors on human performance in different task environments, including the role of human operators in complex systems. Essentially, the objective of human factors is to optimise the relationship between the human operator, technology, and the environment in order to enhance safety, efficiency and job satisfaction.[194]

Crew resource management

In a multi-crew cockpit environment, human factors is also concerned with ensuring the crew work in a co-ordinated way with each other, the aircraft systems, and the broader aviation system. Traditionally, this has been known as *crew resource management*.

Crew resource management (CRM) has generally been defined as a crew's 'effective use of all available resources - people, equipment, and information – to achieve safe, efficient operations'.[195] Effective CRM means that *all* crew members function as a team, rather than as a collection of technically competent individuals.

Trans-cockpit authority gradient

A trans-cockpit authority gradient refers to the differences in the expected operational contributions by each crew member. The gradient may be influenced by the crew member's experience, authority and willingness to act as an individual or as part of a team. An inappropriate balance of these socio-psychological influences can interfere with the proper exchange of information in the cockpit and thus with the safe operation of the aircraft. A steep gradient between a dominant pilot in command and submissive copilot may result in the pilot in command not listening to the concerns of the copilot and/or the copilot being less willing to communicate important information to the pilot in command.

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193 This definition was adopted in August 2000 by the International Ergonomics Association Council.

194 Further information on human factors is provided in many publications. For example, Adams, D. (2006). *A Layman's Introduction to Human Factors in Aircraft Accident and Incident Investigation.* ATSB Safety Information Paper B2006/0094.

195 Lauber, J. K. (1984). Resource management in the cockpit. *Air Line Pilot, 53*, 20-23.

An optimum trans-cockpit authority gradient recognises the command authority of the pilot in command, while encouraging the copilot to contribute to the crew's decision making processes. This optimum gradient facilitates communication, enables participative leadership, establishes a team culture and enhances crew situational awareness. These concepts are part of the CRM training syllabus outlined in the ICAO *Human Factors Training Manual*[196] (see Section 1.20.2).

1.20.2 Crew resource management training

Training in human factors and crew resource management is designed to teach flight crew the non-technical skills essential for operating in a complex time-critical environment, especially in a multi-pilot team. Generally, such courses train the concepts and associated behaviours as suggested by the ICAO *Human Factors Training Manual*. These topics include communications, situational awareness, problem solving and decision making, leadership and 'followership', stress management, interpersonal skills, and critiques.

The aim of any training is to ensure that pilots learn and transfer what they have learned into the cockpit environment. CRM training research[197] has shown that this is best achieved when trainees have been presented with information about the task, given examples of both effective and ineffective performances, are given practice, and are provided with meaningful and timely feedback both during and after the task.

According to the suggested practice from the ICAO manual, CRM training should include at least three stages:

a) an awareness phase where CRM issues are defined and discussed;

b) a practice and feedback phase where trainees gain experience with CRM techniques; and

c) a continual reinforcement phase where CRM principles are addressed on a long term basis.

Some aviation companies in Australia train CRM principles using classroom-based teaching and do not progress beyond the first stage above. The ICAO manual argued that relying on classroom instruction alone will probably not significantly alter pilot attitudes and behaviours in the long term.

Larger airlines in Australia and across the world have not only been training CRM principles in classroom, but have also been teaching CRM behaviours in the aircraft environment, particularly in flight simulators. This is done for crews, rather than individual pilots, and is referred to as line orientated flight training (LOFT). LOFT allows practice and feedback to be given about CRM behaviours, and provides a valuable insight for crew into their own behaviours, especially when these sessions are video-taped. When simulators are not available, role-playing can be used. Some airlines also evaluate CRM behaviours in similar sessions known as line orientated evaluation.

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196 ICAO (1998). *Human Factors Training Manual* (Doc 9683-AN/950). Montreal, Canada: International Civil Aviation Organization.

197 Salas, E., Wilson, K. A., Burke, C. S., Wightman, D. C., & Howse, W. R. (2006). A checklist for crew resource management training. *Ergonomics in Design, 14(2),* 6-15.

Research from questionnaires has indicated that the combination of CRM and LOFT training leads to positive attitude changes towards cockpit management in flight crew.[198] Furthermore, evidence obtained from line audits where crews were observed under non-jeopardy conditions have demonstrated that CRM training that includes LOFT also produces desired changes in *behaviour* in the cockpit on normal flights. Similarly, a meta-analysis of 58 published accounts of measures of CRM effectiveness found that CRM training generally produced positive reactions, enhanced learning, and promoted positive behavioural changes in flight crew.[199] However, due to the very low frequency of aviation accidents, it cannot be determined if CRM training had actually reduced the accident rate.[198,199]

By integrating CRM skills with technical skill training (in both initial and recurrent training), operators promote such behaviours as normal aspects of flying. Reinforcement during supervised and normal flights, and support from management, are also necessary for CRM to become a normal part of an operator's culture. Furthermore, without recurrent training and check pilots that continually reinforce CRM behaviours, the impact of CRM training has been shown to decay.[198]

The term 'Human Factors Management' has been introduced by some airlines in recent years instead of crew resource management. HFM includes CRM, but also encompasses training about human factors limitations. Such limitations include fatigue, stress, perception, mental workload, and memory.

1.20.3 Small operators and crew resource management

The ICAO *Human Factors Training Manual* acknowledged that, while a full-scale CRM program is the ideal objective for small operators, compared with high capacity airliners, several obstacles can make this difficult including higher pilot turnover, smaller training budgets, and less access to simulators. However, ICAO described a list of steps that can be progressively adopted by any aviation company according to their financial constraints as follows:

a) development of pilot awareness of CRM policies through distribution of booklets, pamphlets, republished articles and studies, and video tapes stressing "this could happen to you" types of incidents or accidents;

b) conduct of in-house seminars for crew members using role-playing for demonstrations of CRM techniques;

c) phase-in of CRM principles in to initial first officer training programmes. Open cockpit atmosphere and assertiveness training would be key elements in such training;

d) integration of CRM policies into recurrent ground school curricula, into captain upgrade training, and into flight operations manuals;

e) recruitment of a core-nucleus of training-staff personnel for development of in-house CRM training programmes;

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198 Helmreich, R. L., & Foushee, H. C. (1993). Why Crew Resource Management? Empirical and theoretical bases of human factors training in aviation. In E. Wiener, B. Kanki, & R. Helmreich (Eds.), *Cockpit Resource Management* (pp. 3-45). San Diego, CA: Academic Press.

199 Salas, E., Burke, S. C., Bowers, C. A., & Wilson, K. A. (2001). Team training in the skies: Does crew resource management (CRM) training work? *Human Factors, 43*(4), 641-674.

f) employment of an outside consultant for preparation of in-house CRM programmes; and

g) outright purchase of a complete CRM programme from a third-party vendor.

1.20.4 Joint Aviation Authorities non-technical skills

In order to train and give feedback on CRM behaviours, as well as to evaluate them, a recognised list of observable behaviours was needed. In 1997, a European project by the Joint Aviation Authorities (JAA) was established to define a set of scientifically evaluated non-technical skills. These non-technical skills were defined as pilots' attitudes and behaviours in the cockpit not directly related to aircraft control, system management, and standard operating procedures.

These skills, presented in Appendix I, can be used in any multi-crew training environment. There were four primary categories (cooperation; leadership and management; situation awareness; decision making), each with three-to five elements (16 in total). These 16 elements represent the core non-technical competencies that European airline pilots must demonstrate, along with technical competencies, in order to pass recurrent checks.

1.20.5 Threat and error management

The latest advances in CRM training have included error management, and most recently, threat and error management. Error management focused on Reason's error normalisation principle[200] that accepts that pilots will sometimes make errors and rather than focusing all training efforts on minimising crew error, pilots must be taught strategies to recognise and then manage errors before they have a negative consequence.

Threat and error management is an extension of error management. Threat and error management trains crew in strategies which can be used to explicitly identify hazards and potential hazards to the safety of the operation, referred to as threats, well in advance of these threats occurring. Identification of threats then leads to threat management strategies being developed by the crew, and then a continual reassessment of these threat management strategies.

The November 2006 revision of ICAO Annex 1, *Personnel Licensing*, recommended that threat and error management be taught to pilots at all levels of flight crew licensing.

1.20.6 Crew resource management training requirements - overseas

In September 1993, the UK Civil Aviation Authority (CAA) released Aeronautical Information Circular 143/1993 *Crew Resource Management*. This circular required all pilots engaged in public transport operations to attend a crew resource management course accredited by the CAA lasting a minimum of 2 days, although the CAA stated that a 3-day course would be preferable. The circular also set out a model syllabus for a CRM course.

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200 Reason, J. (1990). *Human error*. Cambridge: Cambridge University Press.

In February 1993, the US FAA released Aeronautical Circular AC120-51A *Crew Resource Management Training*, which replaced an earlier circular on the subject of Cockpit Resource Management released in 1989. AC120-51A provided guidelines for air carriers in the implementation of CRM principles.

The US Federal Aviation Regulation (FAR) for Part 121 operations[201] (which included Metro 23 aircraft), paragraph 121.404 stated:

> After March 19, 1998, no certificate holder may use a person as a flight crewmember….unless that person has completed approved crew resource management (CRM)…..initial training.

Furthermore, FAR 121.427 stated that recurrent ground training for flight crew must include:

> … (4) Approved recurrent CRM training. For flight crewmembers, this training or portions thereof may be accomplished during an approved simulator line operational flight training (LOFT) session.

Similarly, the European Joint Aviation Authority regulations for commercial aircraft operations (JAR-OPS 1) required general human factors awareness training at the ATPL level, and in addition, required operators to provide flight crew with the following:

- JAR-OPS Subpart N 1.943 required an initial CRM training course during a pilot’s first year;
- JAR-OPS Subpart N 1.965(e) required recurrent CRM training that ensured that:

> (1) Elements of CRM are integrated into all appropriate phases of the recurrent training; and
>
> (2) Each flight crew member undergoes specific modular CRM training. All major topics of CRM shall be covered over a period not exceeding 3 years.

In addition to the training requirements above, JAR-OPS also states that CRM skills assessment should be included in an overall assessment of flight crew members’ performance.

1.20.7 Crew resource management training requirements - Australia

In agreement with the ICAO Annex 1, CASA required ‘human performance and limitations’ awareness training to be undertaken by pilots at each level of pilot licences. The required syllabus for these licences covered awareness of human factors issues in line with ICAO first step of CRM training outlined above.

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201 Part 121 operators included ‘domestic operations’ which included aircraft with a passenger-seat configuration of more than 9 passengers, excluding each crew member.

On 31 January 1995, the then Bureau of Air Safety Investigation[141] issued the following recommendation[202]:

> The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (CASA) require operators involved in multi-crew air transport operations to ensure that pilots have received effective training in crew resource management (CRM) principles. To this end, the CASA should publish a time table for the phased introduction of CRM training to ensure that:
>
> (i) CRM principles are made an integral part of the operator's recurrent check and training program and where practicable, such training should be integrated with simulator LOFT exercises;
>
> (ii) the CASA provides operators and/or CRM course providers with an approved course syllabus based on international best practice;
>
> (iii) such training integrates cabin crew into appropriate aspects of the program; and
>
> (iv) the effectiveness of each course is assessed to the satisfaction of the CASA.

CASA provided a series of responses to this recommendation in subsequent years. In August 2002, the status of this recommendation was classified as closed-acceptable action, due to the development of proposed regulations covering CRM training. In April 2000, CASA issued a discussion paper (DP 0001OS) regarding the proposed CASR Part 121A (currently known as CASR 121). CASR Part 121A was intended to prescribe the operating rules that would apply to the operation of large aircraft (greater than 5,700 kg maximum take-off weight) engaged in commercial air transport operations, including aircraft of the same size as VH-TFU engaged in RPT operations. The proposed safety regulation included the mandating of CRM training for flight crew for initial training, conversion training, command/upgrade training, and recurrent training, with some assessment requirements.

Since April 2000, CASA had advanced the initial discussion paper with the issuing and reissuing of draft advisory circulars and notice of proposed rule making, and has organised workshops with industry representatives to devise the final details of CASR 121. However, as at the date of this investigation report, CASR 121 had not been implemented.

Although there were no regulatory requirements in Australia to enforce CRM training, CASA encouraged existing high capacity RPT operators to adopt initial and recurrent CRM training processes. Before issuing an AOC to a new high capacity RPT operator, CASA personnel were required to verify that the operator had processes for initial and recurrent CRM training, complete with a training syllabus.[203] There were no similar requirements for low capacity RPT operators[94],

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202 BASI recommendation IR19950101.

203 CASA *Compliance Management Instruction 01/35*, February 2005.

such as Transair.[204] In comparison, similar operations in the US and Europe did have CRM training requirements.

1.21 Controlled flight into terrain

1.21.1 Overview

The Flight Safety Foundation defined 'controlled flight into terrain' (CFIT) as an occurrence where 'an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew'. The factors leading to CFIT events are varied, and can include loss of flight crew situational awareness, loss of terrain awareness, non-adherence to standard operating procedures, and operations in areas of low cloud base and/or poor visibility.

Controlled flight into terrain continues to be the main reason, worldwide, for aircraft accidents involving fatalities and aeroplane hull losses. In global terms, since the advent of commercial jet operations, 9,000 fatalities have been attributed to CFIT events. The majority of the CFIT accidents occur during the approach and landing phase of flight.

In Australia, the number of RPT CFIT accidents is few. However, a review of the accident data revealed that the outcome of a CFIT is likely to be catastrophic.[205] Appendix J contains a summary of Australian CFIT accidents that occurred during the approach and landing phase of flight involving aircraft that were engaged in charter and RPT operations.[206]

1.21.2 Flight Safety Foundation CFIT Task Force

Background

In 1992, the Flight Safety Foundation organised an international CFIT Task Force that was dedicated to reducing CFIT events. The international CFIT Task Force comprised representatives of aircraft manufacturers, aviation training organisations, aircraft equipment manufacturers, airlines, pilot groups and government and regulatory agencies. Five teams were formed to study the causes and factors of CFIT events, and to make recommendations to prevent these types of accidents.

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204 Recent ATSB investigations have identified other low capacity RPT operators of multi-crew aircraft who have not conducted CRM training. For example, see ATSB Aviation Occurrence Report 200404589, Aircraft Loss of Control, Lake George, NSW, 21 November 2004, VH-TAG, Fairchild Industries SA227-AC Metro III. Published July 2006.

205 More information on general aviation CFIT accidents can be found in ATSB Aviation Research Paper B2004/0010 *General Aviation Fatal Accident: How do they happen?* (This research paper is available on the ATSB internet site at <http://www.atsb.gov.au/publications/2004/pdf/Fatal_accidents_how_happen.pdf >)

206 RPT flights are identified as scheduled flights in Appendix J.

The CFIT Task Force made recommendations to ICAO in 1994, such as:

- broadening the requirements for GPWS to include aircraft of 5,700 kg or greater, or more than nine passenger seats;
- requiring predictive GPWS for all turbine aircraft and aircraft with 30 seats or more;
- including colour-shaded depiction of terrain on approach charts (also see Section 1.19.3);
- replacing all 3-pointer altimeters in IFR aircraft (see Section 1.6.7);
- designing and presenting approaches with 3-degree approach slope;
- including automated or flight crew altitude call-outs; and
- recognising the important CFIT-avoidance benefits to be gained from the use of GPS/GNSS.

In December 1996, the Task Force released a CFIT education and training aid. ICAO recommended that those in positions of responsibility in civil aviation should apply the recommendations of the CFIT Task Force, and '…make the best use of the education and training aid'.

Netherlands National Aerospace Laboratory report

In 1996, the Flight Safety Foundation published a report produced by the Netherlands National Aerospace Laboratory on factors associated with CFIT events involving commercial aircraft operators.[207] The report focused on 156 CFIT events that occurred between 1988 and 1994, and found that the descent and approach phases of landing accounted for about 70 per cent of the accident sample. The report concluded that on a world-wide basis, there appeared to be a five-fold increase in accident risk for commercial aircraft flying non-precision approaches compared with those flying precision approaches.

Assessing CFIT risk

In 1994, the Flight Safety Foundation designed and published *CFIT Checklist: Evaluate the Risk and Take Action* to evaluate CFIT risk, as part of its international program to reduce CFIT events that present risk to aircraft, flight crews, and passengers (see Appendix K).

The Flight Safety Foundation intended that the checklist be used to 'assess CFIT risks for specific flights, identify factors that identify those risks, and enhance pilot awareness of CFIT risk'. The checklist was designed to allow a pilot/operator to assign numerical values to a variety of factors that allow a CFIT risk score to be determined. A significant CFIT risk score can be analysed to determine strategies for reducing that risk.

The Flight Safety Foundation recommended specific interventions to manage CFIT risk including:

- the use of standard operating procedures, standard call-outs and checklists;

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207 National Aerospace Laboratory NLR TP 977270 *Controlled flight into terrain (CFIT) accidents of air taxi, regional and major operators*. R. Khatwa and A.L.C. Roelen 1997

- the content and conduct of descent approach briefings;
- crew resource management;
- strategies and procedures for handling interruptions/distractions;
- procedures for barometric and radio altimeters;
- descent and approach profile management;
- terrain awareness;
- the use of stabilised approaches; and
- the use of constant angle non-precision approaches.

Lockhart River CFIT risk assessment

The investigation evaluated the specific risk factors associated with the accident flight and Transair, using the Flight Safety Foundation CFIT checklist. The CFIT risk reduction factors were calculated using information about the adequacy of Transair's corporate culture, flight standards, hazard awareness and training, and aircraft equipment. To some extent the evaluation was subjective, but confirmed by an external expert involved in preparing the CFIT checklist.

The evaluation indicated that the CFIT risk for Transair operating into Lockhart River was a 'significant threat'. The calculated risk was at a level such that, to reduce the risk to an acceptable value, improvements were required in Transair's practices, flight standards, training and hazard awareness, as well as the installation of a terrain awareness and warning system (TAWS).

1.21.3 Flight Safety Foundation ALAR Task Force

Background

In 1996, the Flight Safety Foundation formed the Approach-and-Landing Accident Reduction (ALAR) Task Force to independently analyse data that could lead to the identification and/or resolution of approach-and-landing issues. In January 1999, the ALAR Task Force concluded[208], amongst other things, that:

- establishing and adhering to adequate standard operating procedures and flight crew decision-making processes improve approach-and-landing safety;
- unstabilised approaches cause approach-and-landing accidents;
- the risk of approach-and-landing accidents increases in operations conducted in low light and poor visibility; and
- effective use of radio altimeters will help to prevent approach-and-landing accidents.

From those conclusions the Task Force developed recommendations to aviation regulators, operators, air traffic services and flight crews. These included CFIT

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208 Flight Safety Foundation (1999). Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents. *Flight Safety Digest, Nov 1998-Feb 1999*.

training and modified approach procedures; development and fitting enhanced GPWS equipment; development of precision approaches and improved charting; and the extension of radar services with minimum safe altitude warning system capability.[209] The recommendations provided the framework for a series of 34 briefing notes to help prevent approach and landing accidents, including those which involve CFIT. The briefing notes provided guidance for the development of operational practices and procedures that were aimed at increasing the safety of flight. The briefing notes included, but were not limited to:

- standard operating procedures
- standard calls
- normal checklists
- approach (arrival) briefings
- crew resource management
- interruptions/distractions
- barometric and radio altimeters
- descent and approach profile management
- stabilised approaches
- constant angle non-precision approach.

Standard operating procedures

Standard operating procedures (SOPs) are specified in an operations manual to ensure that flight operations are conducted in a consistent and safe manner and are resistant to crew error. Effective crew coordination and crew performance depend upon the crew having a shared mental model of each task. That mental model, in turn, is founded on SOPs.

The ALAR briefing note *Operating Philosophy* described the importance of SOPs as a risk control for minimising CFIT accidents. The briefing note stated that:

> Adherence to standard operating procedures (SOPs) is an effective method of preventing approach and landing accidents (ALAs), including those involving controlled flight into terrain (CFIT).
>
> Crew resource management (CRM) is not effective without adherence to SOPs.
>
> The Flight Safety Foundation Approach-and landing Accident Reduction (ALAR) Task Force found that 'omission of action/inappropriate action' (i.e., *inadvertent* deviation from SOPs) was a causal factor in 72 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.
>
> The task force also found that "deliberate non-adherence to procedures" was a causal factor in 40 percent of the accidents and serious incidents.

209 Minimum safe altitude warning system (MSAW) used computer software incorporated into the US FAA ATC radar software to provide general terrain monitoring for all aircraft within a predetermined geographic area and approach path monitoring for certain aircraft operating within an approach capture box (a rectangular area surrounding a runway and final approach track).

The ALAR briefing note included a *Standard Operating Procedures Template* that was adapted from the FAA Advisory Circular 120-71, *Standard Operating Procedures for Flight Deck Crewmembers*. The template topics included approach philosophy (including stabilised approaches being standard, limits for stabilised approaches and go-arounds), information needed for each type of approach (including flap/gear extension, standard calls and procedures) and the initiation of go-arounds (see Appendix L).

Stabilised approaches

The Flight Safety Foundation ALAR briefing note *Constant-angle Non-precision Approach* described the approach as having a constant-angle descent using the vertical speed, with altitude-distance checks. In the detailed briefing note for the conduct of the approach was a definition of a stabilised approach.

The briefing note recommended that all flights must be stabilised by 1,000 ft above aerodrome elevation (AAL) in instrument meteorological conditions (IMC) and by 500 ft AAL in visual meteorological conditions (VMC). It defined a stabilised approach as one where all 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 ft/min; if an approach requires a sink rate greater than 1,000 ft/min, a special briefing should be conducted;
- power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
- all briefings and checklists have been conducted;
- specific types of approaches are stabilised if they also fulfil the following: instrument landing system (ILS) approaches must be flown within one dot of the glided slope and localiser, etc: during a circling approach, wings should be level on final when the aircraft reaches 300 ft AAL; and
- unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilised approach require a special briefing.

An approach that becomes unstabilised below 1,000 ft AAL in IMC or below 500 ft AAL in VMC, requires an immediate go-around.

Non-precision approach factors

The Flight Safety Foundation ALAR briefing note *Constant-angle Non-precision Approach* identified from training feedback and line-operations experience factors that reduced the performance of crew conducting non-precision approaches. Some of those factors identified were:

- late descent preparation;
- incomplete briefing;

- inadequate cross-check and backup by the handling pilot/non-handling pilot;
- late configuration of the aircraft;
- final approach speed not stabilised at the final approach fix;
- incorrect identification of the final approach fix; and
- premature descent to the next step-down altitude (if multiple step-downs) or below the minimum descent altitude.

The briefing note also identified the elements of a successful non-precision approach. Some of the relevant elements were:

- completing an approach briefing;
- planning aircraft configuration setup;
- monitoring descent;
- managing aircraft energy condition during intermediate approach and final approach;
- not descending below an altitude before reaching the associated fix;
- determining the correct angle (vertical speed) during the final descent; and
- beginning the descent at the correct point.

1.21.4 CFIT awareness training material

In addition to the CFIT education and training material provided by the Flight Safety Foundation (described above), material was available from the US FAA and ICAO. The FAA website provided a valuable set of reference materials. Similar material was available from ICAO and other national regulatory agencies.

The training material consisted of two volumes and a video presentation 'CFIT- an encounter avoided'. The material covered all issues relating to CFIT and included case studies of CFIT accidents.

1.21.5 Developments in approaches with vertical guidance

Following the outcome of studies of CFIT accidents, ICAO made a recommendation in 2003[210] that:

> air navigation service providers move rapidly, in coordination with airspace users, with a view to achieving, as soon as possible, worldwide navigation capability to at least APV I[211] performance

This recommendation meant that the minimum level of approach guidance available should be that provided by the approach procedure with vertical guidance

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210 Recommendation 6/1(b): ICAO Eleventh Air Navigation Conference, Montreal, 22 Sept – 3 Oct 2003.

211 APV refers to 'approach procedure with vertical guidance'. ICAO Annex 10 – *Aeronautical Telecommunications*, Volume I (*Radio Navigation Aids*), Chapter 3, Section 3.7.2.4 (Table 3.7.2.4-1: *Signal-in space-performance requirements*) defined 'APV I' as having a GNSS user receiver position accuracy of 16 metres horizontally and 20 metres vertically.

(APV) rather than a non-precision approach. The recommendation was endorsed by the Asia Pacific regional implementation group as recommended policy for the region. Subsequently, a paper was presented to the Aviation Policy Group[212] in 2006 to seek an Australian policy on this initiative, which endorsed a proposal for CASA to undertake a cost-benefit analysis to help determine the most suitable methods for providing an APV capability in Australia.

True vertical guidance is currently available with barometric-VNAV on the latest model high capacity jet aircraft (such as Boeing 737 NG aircraft). Barometric-VNAV can upgrade an RNAV (GNSS) approach from a non-precision approach to an APV.

Although aircraft based augmentation (ABAS), such as barometric-VNAV, is capable of providing APV approaches to FMS-equipped airliners, other augmentation solutions may be needed if vertical navigation is going to accessible by regional airlines and general aviation aircraft. Various augmentation systems could provide the necessary technical solution, and include satellite-based augmentation systems (SBAS) or ground-based augmentation systems (GBAS). The Australian Strategic Air Traffic Management Group (ASTRA) is also examining options for an augmentation solution to meet Australia's needs.

212 The Aviation Policy Group comprises senior representatives of the Department of Transport and Regional Services, the Department of Defence, CASA and Airservices Australia.

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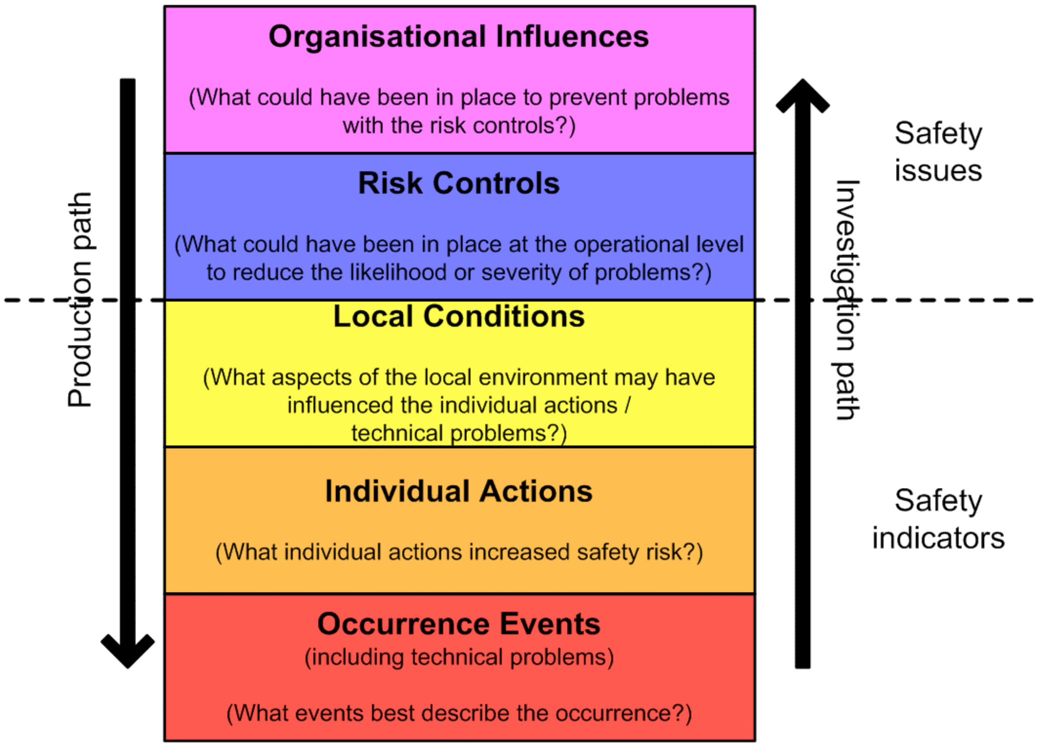
2 ANALYSIS

2.1 Introduction

In common with most serious transport accidents, the Transair VH-TFU accident involved a number of factors. This section of the report discusses the safety factors that were found to have contributed to the accident, as well as other safety factors identified during the course of the investigation that were also considered to be important. The factors are discussed in terms of the analysis model shown in Figure 39.

Figure 39: ATSB investigation analysis model



The five levels of factors in the model are:

- **Occurrence events**, or the key events that describe the occurrence or 'what happened'. Examples include technical failures, loss of aircraft control, breakdown of separation and controlled flight into terrain (CFIT).
- **Individual actions**, or observable behaviours performed by operational personnel. Such actions can describe how the occurrence events happened. It is more productive to consider actions that increase risk as actions that should not be produced in similar situations in the future, rather than failures of the individuals involved. Furthermore, it is widely acknowledged that people make errors everyday and that professional pilots are no exception. Improvements in aviation safety will occur not by focusing solely on eliminating human error and violations, but by also ensuring there are adequate controls in place to ensure that when errors and violations do occur, they do not lead to an accident.

- **Local conditions**, or those conditions which exist in the immediate context or environment in which individual actions or occurrence events occur, and which can have an influence on these actions and events. Examples include skills, experience, task demands, and environmental factors.
- **Risk controls**, or the measures put in place by an organisation to facilitate and assure the safe performance of operational personnel and equipment. Examples include procedures, training, supervision, equipment design and equipment availability.
- **Organisational influences**, or those conditions which establish, maintain or otherwise influence the effectiveness of an organisation's risk controls. Examples include organisational structure, risk assessment processes, and regulatory surveillance.

Although some of these factors are associated with actions of individuals or organisations, it is essential to note that the key objective of a safety investigation is to identify safety issues - that is, the safety factors that can be corrected to enhance the safety of future operations. In accordance with ICAO Annex 13 and the *Transport Safety Investigation Act 2003*, the objective of investigating accidents and incidents is to prevent the occurrence of future accidents and not for the purposes of apportioning blame or liability.

Prior to discussing the safety factors identified during the investigation, a review of the flight profile and circumstances under which the flight was being conducted is presented.

2.2 Overview of the flight

Type of approach

The crew of VH-TFU were conducting an area navigation global navigation satellite system (RNAV (GNSS)) approach to runway 12 at Lockhart River in instrument meteorological conditions (IMC).

During the approach, the aircraft deviated below the published approach path and impacted with terrain. Both crew members and all 13 passengers were fatally injured and the aircraft was destroyed.

Handling pilot

It is very likely that the pilot in command was manipulating the aircraft controls[9] during the descent and approach because of the following.

- Transair procedures and pilot practice involved the non-handling pilot making radio calls and for one of the pilots to be the handling pilot for all northbound sectors from Cairns to Bamaga and with the other pilot performing the handling pilot duties for all southbound sectors from Bamaga to Cairns.
- The pilot in command was making the common traffic advisory frequency (CTAF) and other radio calls on the northbound flights. The copilot was making the CTAF broadcasts and other communications during the southbound flight.

- In particular, the copilot was making the CTAF broadcasts during the approach to Lockhart River.

However, even when a copilot is the handling pilot, the pilot in command is responsible for monitoring the copilot's performance and the progress of the approach. Regardless of who is the handling pilot, the pilot in command is responsible for the overall conduct of the flight.

Flight profile

The FDR data showed that, during the entire descent and approach, the aircraft engine and flight control system parameters were normal and that the crew were accurately navigating the aircraft along the instrument approach track. The FDR data and wreckage examination showed that the aircraft was configured for the approach with the landing gear down and flaps extended to the half position. There were no radio transmissions made by the crew on the air traffic services frequencies or the Lockhart River CTAF indicating that there was a problem with the aircraft or crew.

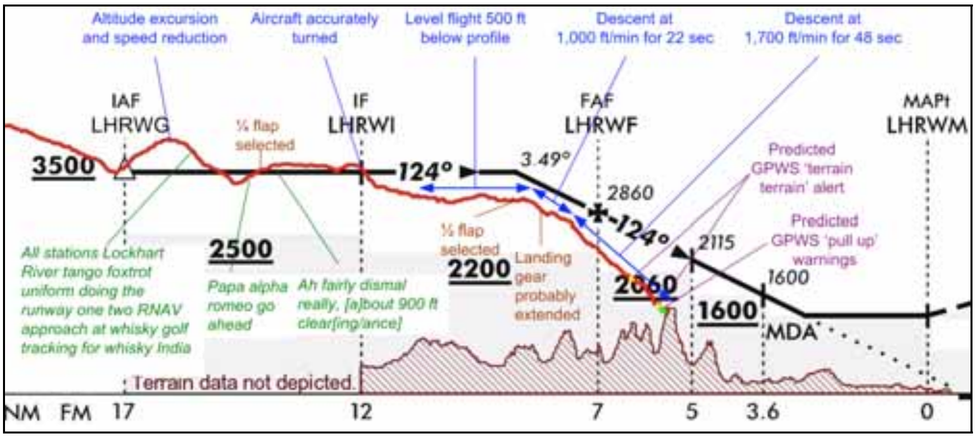
The FDR data also showed that as the aircraft passed abeam waypoint LHRWG (the initial approach fix, or IAF), the crew descended the aircraft to 3,500 ft above mean sea level (AMSL), which was the initial recommended approach altitude (see Figure 40). An altitude excursion to about 4,000 ft occurred after the aircraft passed the initial approach fix. The investigation was unable to determine the reason for this excursion, but it may have been an intentional manoeuvre to decelerate the aircraft.

The crew accurately turned the aircraft at waypoint LHRWI (the intermediate fix, or IF). However, rather than maintaining the recommended altitude of 3,500 ft, they immediately began to descend the aircraft. This descent occurred about 3 NM before the recommended descent initiation point.

After descending to 3,000 ft, the crew maintained a steady altitude of about 500 ft below the recommended approach altitude of 3,500 ft. During this level flight, the aircraft's speed reduced to the maximum half flap extension speed (180 kts) and the flaps were extended. The aircraft did not descend below the segment minimum safe altitude (2,200 ft) during this initial descent and levelling.

At 1.4 NM before waypoint LHRWF (the final approach fix, or FAF), the crew recommenced the descent at 1,000 ft/min for about 22 seconds. The crew then reduced engine power from about 36 per cent to about 30 per cent, which further increased the rate of descent to an average of 1,700 ft/min over the final 48 seconds before the aircraft collided with trees at 1,210 ft AMSL. During this final descent, at about 28 seconds before the impact with terrain, the crew descended below the segment minimum safe altitude of 2,060 ft.

Figure 40: Vertical approach profile.



The FDR data showed that the aircraft's airspeed passing the initial approach fix was about 226 kts, reducing to about 176 kts at the intermediate fix and 177 kts at the final approach fix. The airspeed remained at about 175 kts, which also equated to the maximum landing gear extension speed, until the final 5 seconds of the flight.

These speeds exceeded the handling speeds for instrument approaches specified in the *Transair Operations Manual*, which were the speeds specified in the *Aeronautical Information Publication* (AIP) for a Category B aircraft such as the Metro 23 aircraft type involved in the accident. After the final approach fix, the speed exceedance averaged 44 kts above the Category B speeds.

Weather conditions

The Bureau of Meteorology assessment of weather conditions at Lockhart River at the time of the accident was that the cloud was overcast with broken low cloud with a base between 500 and 1,000 ft AMSL. This meant that the aircraft probably entered the low cloud at about 3,000 ft and was probably in IMC for most of the final 90 seconds of flight. The aircraft impacted terrain at about 1,210 ft. It is likely that this terrain was in cloud.

If the cloud base was as low as 500 ft at the time of the accident, then it is likely that the terrain below the aircraft after it passed the intermediate fix (LHRWI) would have been mostly obscured by clouds.

The FDR data indicated that the aircraft encountered increasing turbulence during the final 25 seconds of the flight, due to the combined effect of the wind speed being about 25 kts, the direction of the wind, and the relatively high terrain in the South Pap area.

2.3 Occurrence events

2.3.1 Controlled flight into terrain

The accident was almost certainly the result of controlled flight into terrain; that is, an airworthy aircraft under the control of the flight crew was flown unintentionally into terrain, probably with no prior awareness by the crew of the aircraft's proximity to terrain. This finding is based on a consideration of information related to flight controls, engines and propellers, potential for pilot incapacitation and potential for windshear conditions.

Flight controls

Information available from the FDR and the wreckage provided strong evidence that the aircraft's flight control systems were complete, functional and being operated by the crew up until the aircraft collided with the terrain. The positions of the flight controls recorded on the FDR were consistent with the profile that the aircraft had flown on the accident flight and preceding flights. There were no sudden or dramatic changes in the recorded parameters that would indicate a failure of any of the flight control systems. Changes in the flight control positions up until the collision also indicated that they were free to operate as designed.

Although the horizontal stabiliser trimming screw jack was found severed, it is very likely that this damage was the result of the impact. Both the FDR data and the measured extension indicated that it was within the normal range of operation and not at an extreme position. In addition, the FDR showed that the trim had been operated as expected during the approach, and there were no large changes in the trim position around the time of the increased rate of descent.

Engines and propellers

The available evidence shows that there were no problems related to the engines or propellers prior to the impact. Damage to the propellers examined on-site was consistent with them operating at high speed, which was consistent with the 99-100 per cent propeller RPM parameter recorded on the FDR. Also the propeller RPM and engine torque values recorded on the FDR were consistent with the flight profile of the aircraft on the accident and the preceding flights.

As the torque produced by the engine is balanced by the drag produced by the propellers as they rotate through the air, a sudden loss of a propeller blade would result in a sudden change in the propeller RPM and the engine torque. Because there were no major changes in the propeller RPM and torque of either engine, it is considered that the engines and propellers were complete and operating normally up until the FDR stopped recording information.

Although the light globes in the cockpit annunciator panel relating to the operation of the left engine had illuminated, it is very likely that these light globe indications occurred moments before the cockpit impacted the terrain, and therefore did not indicate the status of the annunciator panel prior to the aircraft impacting the trees.

Potential for pilot incapacitation

There was no evidence of pilot incapacitation. A review of medical records, post mortem results, interviews with friends and associates of the two pilots and examination of speech data found no evidence of medical or physiological problems that were likely to have influenced either pilot's performance. The FDR data indicated that the handling pilot was actively making control inputs to correct the effect of turbulence on the aircraft's flight path during the final 10 seconds of the flight. There was also no evidence in the FDR data of abnormal flight control inputs, including the elevators, during the accident flight. In addition, there were no radio broadcasts that indicated any problems associated with the crew or the flight.

Potential for windshear conditions

Until the last 5 seconds of flight, there was no evidence that the aircraft encountered windshear conditions. The FDR data showed that the flight path during the last 48 seconds of recorded data was consistent with flight control inputs and power settings with no evidence of windshear.

During the last 5 seconds of recorded data, when the aircraft was well below the segment minimum safe altitude, there was increasing mechanical turbulence from the South Pap ridge line. There was a loss of airspeed at this time, consistent with windshear, however this was shortly before impact and unrelated to the earlier sustained high rate of descent during the last 48 seconds of recorded data.

2.3.2 Other potential technical problems considered by the investigation

In addition to flight controls and engines, the investigation examined whether technical failures associated with any of the other equipment on board the aircraft may have been related to the circumstances of the accident. Potential scenarios involving failures of the global positioning system (GPS) unit, altimeters and vertical speed indicators were considered.

Potential problems associated with the ground proximity warning system (GPWS) or radio altimeter are discussed in Section 2.4.4.

Potential for GPS receiver interference

The likelihood of unintended signal interference to the GPS receiver from radio frequency transmissions emitted by mobile phones or other electronic sources was considered very unlikely. No phone calls were transmitted through the Lockhart River mobile telephone base station during the approach phase of flight.

The likelihood of a receiver autonomous integrity monitoring (RAIM) failure was also considered very unlikely. There were no RAIM outages predicted for the Lockhart River area. There was a reported RAIM failure for 10 to 50 seconds sometime during the half hour that included the approach of VH-TFU. However, as this was also 200 NM to the east of Lockhart River, it is unlikely that this RAIM event would have affected the GPS receiver in VH-TFU.

The FDR information provided further evidence that the GPS receiver was operating as normal, as the data showed that the aircraft accurately tracked along the RNAV (GNSS) approach from the turn at waypoint LHRWI until the point of impact, which was located on the published final approach track. It is very unlikely that this tracking would have been as accurate as recorded on the FDR, especially given the turbulence present, if the GPS was providing erroneous location information or if the crew were maintaining a heading by reference to the directional gyro and magnetic compass alone. The Lockhart River RNAV (GNSS) approaches could not continue with reference to the NDB alone as there was no distance information available to the crew.

Potential for altimeter or vertical speed indicator failures

There was no indication that the altimeters were not functioning correctly prior to the accident. The barometric scale on the pilot in command's altimeter was not set to the appropriate QNH. However, as the setting would have resulted in the altimeter reading about 70 ft lower than the actual altitude of the aircraft, it is very unlikely that this error would have had any involvement in the accident. If the correction for the incorrect QNH setting is added to the altitude indicated on the pilot in command's altimeter as found at the accident site, the resultant figure equates to the elevation of the accident site.

Although only one vertical speed indicator (VSI) was recovered, there was no indication that it was not functioning correctly prior to the accident.

2.4 Individual actions

The aircraft was equipped with a cockpit voice recorder (CVR), but due to a malfunction within the unit, conversations between the crew and other sounds during the accident flight were unavailable to the investigation. The lack of CVR data significantly hindered the investigation's ability to conclusively determine the precise sequence of events leading up to the collision with terrain.

Nevertheless, an examination of the available evidence identified four significant individual actions leading up to the collision. The individual actions were:

- The crew commenced the Lockhart River Runway 12 RNAV (GNSS) approach, even though the crew were aware that the copilot did not have the appropriate endorsement and had limited experience to conduct this type of instrument approach.
- The descent speeds, approach speeds and rate of descent were greater than those specified for the aircraft in the *Transair Operations Manual*. The speeds and rate of descent also exceeded those appropriate for establishing a stabilised approach.
- During the approach, the aircraft descended below the segment minimum safe altitude for the aircraft's position on the approach.
- The aircraft's high rate of descent, and the descent below the segment minimum safe altitude, were not detected and/or corrected by the crew before the aircraft collided with terrain.

2.4.1 Decision to conduct the runway 12 RNAV (GNSS) approach

The crew were aware of the likely weather conditions in the Lockhart River area due to air traffic control (ATC) advising them of the amended terminal aerodrome forecast (TAF), as well as their own observations during the northbound flight. The crew would have been aware that they probably needed to conduct an instrument approach in order to land at Lockhart River. Although the forecast cloud base (1,000 ft) was at about the minima for the published approaches, it was reasonable for the crew to continue with the flight, given that the amended TAF indicated there would be only temporary deterioration of the weather conditions below those required for landing, and that sufficient holding fuel was available if required.

The weather information available to the crew suggested that the appropriate option for landing at Lockhart River was runway 12. The wind information provided in the amended TAF, as well as their own observations during their northbound flight, indicated that the wind direction resulted in a headwind component[213] for runway 12. The wind speed provided by ATC to the crew was 15 kts gusting to 25 kts, which meant that the tailwind component for a runway 30 landing equated to or exceeded the aircraft's landing tailwind limit of the aircraft.

There were three options available to the crew attempting to conduct an instrument approach and landing on runway 12 at Lockhart River:

- the runway 12 RNAV (GNSS) approach;
- the runway 30 RNAV (GNSS) approach with a circling approach to runway 12; or
- the non-directional beacon (NDB) approach with a circling approach to runway 12.

If the crew were appropriately qualified, then the runway 12 RNAV (GNSS) approach would have been the most suitable option because of the following.

- The minimum descent altitude for the runway 12 RNAV (GNSS) approach was 120 ft lower than for the other two approaches.[214] Given that the copilot reported the cloud base to be '[a]bout 900 ft', the runway 12 approach provided the pilots with a higher likelihood of becoming visual and conducting a landing at Lockhart River.
- As the aircraft was approaching Lockhart River aerodrome from the north-north-west, the initial approach fixes of LHRWG and LHRWE provided the most direct transition to the runway 12 RNAV (GNSS) approach. To conduct the runway 30 RNAV (GNSS) approach or the runway 30 NDB approach with a circling approach to land onto runway 12 would have resulted in additional flight time of about 10 minutes for the 35-minute sector from Bamaga.
- Runway-aligned approaches are, in general, safer than circling approaches (see also Section 2.5.5).

Both pilots were required to be endorsed in order to conduct the approach. Although the pilot in command was appropriately endorsed to conduct an RNAV (GNSS) approach, the copilot was not endorsed and had no formal training in conducting such approaches. A company supervisory pilot had demonstrated RNAV (GNSS) approaches to the copilot in visual conditions at Bamaga, and the copilot had very likely flown the runway 30 RNAV (GNSS) approach at Lockhart River on the northbound flight on the day of the accident. However, there was no evidence that the copilot had participated in an RNAV (GNSS) approach where the final approach segment contained multiple altitude limiting steps such as the Lockhart River Runway 12 RNAV (GNSS) approach.

In summary, the copilot's lack of familiarity and training with the RNAV (GNSS) approach, coupled with his low experience level in general, would have resulted in more attention being needed to complete his role in the approach compared with a more experienced and qualified copilot. The copilot's limited experience with

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213 A headwind is desirable for landing as it provides increased margins of safety due to lower touch down ground speed and shorter landing roll.

214 When landing on runway 12, the Runway 30 RNAV (GNSS) and NDB approaches had higher minimum descent altitudes than the Runway 12 RNAV (GNSS) approach because they were circling approaches rather than being runway aligned.

RNAV (GNSS) approaches may have also made it difficult for him to detect any deviations during the approach and could have increased the pilot in command's workload during a critical phase of flight (see Section 2.5.1).

Both pilots were endorsed for the NDB approach, and therefore that approach was the only one available to the crew when there was instrument meteorological conditions (IMC).

2.4.2 Descent and approach speeds and rate of descent

The descent speeds during the accident flight significantly exceeded the operator's procedures. The *Transair Operations Manual* stated that the descent speed should be V_{MO}-10 kts (that is, 236 kts), and the required speed below 5,000 ft was 210 kts. The FDR indicated that the descent speed on the accident flight between 10,000 ft and 5,000 ft averaged 249 kts, and the speed between passing 5,000 ft and passing abeam LHRWG at 3,500 ft was 239 kts.

For approach speeds, the *Transair Operations Manual* stated that its pilots were to use speeds for instrument approaches as prescribed in the AIP for the appropriate category of aircraft, determined according to the V_{REF} of the aircraft. The Metro was a Category B aircraft as its V_{REF} was 99 to 120 kts, and therefore the prescribed speeds were a maximum of 180 kts at the initial approach fix and 130 kts at the final approach fix. This was confirmed by the chief pilot who stated that all Transair aircraft were operated as Category B. Furthermore, the flight plan submitted to Airservices nominated that VH-TFU was being operated as a Category B aircraft.

The FDR data showed that the aircraft's speed during the approach significantly exceeded the Category B approach speeds, and was significantly higher than the normal speeds reported by Transair pilots (that is, about 180 kts at the initial approach fix and about 125 to 140 kts at the final approach fix). They were also significantly higher than the speeds specified by other Metro operators in Australia.

The FDR data was only able to specify speeds within a range of accuracy of ± 15 kts for speeds greater than 150 kts. However, the FDR data for the accident flight indicated that the two flap extensions occurred within 2 kts of the normal speeds reported by Transair pilots, suggesting that the FDR speed data was more accurate than ± 15 kts. Even if speeds on the accident flight were slightly less than the speeds stated above, they still significantly exceeded relevant procedures and recommendations.

The *Transair Operations Manual* did not specify a maximum rate of descent for an approach, although the non-flying pilot was required to call if the rate of descent was greater than 1,000 ft per minute. The AIP advised that the rate of descent should not normally exceed 1,000 ft/min after passing the final approach fix. The vertical rate of descent of 1,700 ft/min after the aircraft passed the final approach fix significantly exceeded this recommendation.

The Flight Safety Foundation's criteria for a stabilised approach included a maximum speed of V_{REF} +20 kts, or 134 kts for the accident flight, and a maximum rate of descent of 1,000 ft/min at 1,000 ft above aerodrome level (AAL). Given that the aircraft speed exceeded 170 kts with an average rate of descent of 1,700 ft/min for the final 48 seconds until the impact at 1,210 ft AMSL (or about 1,130 ft AAL), it was almost certain that the criteria for a stabilised approach would not have been met at 1,000 ft AAL.

As the pilot in command was flying a relatively difficult instrument approach in IMC with a relatively inexperienced copilot, it would have been prudent to operate at a significantly slower speed and reduced rate of descent. The higher than specified speeds and rate of descent reduced the amount of time available to the crew to configure the aircraft for the approach, accomplish the approach procedures, and maintain their awareness of their position on the approach. For example, had the aircraft speed at the final approach fix been 130 kts, the crew would have had about 10 more seconds available to conduct their tasks and monitor the approach. Significant additional time would also have been available prior to reaching the final approach fix. In summary, slowing the aircraft to the specified speeds would have assisted the crew in managing the workload during the approach phase.

2.4.3 Descent below segment minimum safe altitude

The aircraft descended through the segment minimum safe altitude of 2,060 ft about 11 seconds after passing the final approach fix, and about 28 seconds prior to the impact with terrain. The segment minimum safe altitude is designed to ensure that aircraft maintain a safe height above terrain. Descending below the specified altitude increases the risk of collision with terrain.

The investigation considered a range of different scenarios to explain why the descent through the minimum sector altitude was conducted.

a. Misinterpretation of position along the approach.

b. 'Shooting for the hole' to acquire visual contact with the ground.

c. Expediting the descent to the minimum descent altitude.

d. Misinterpretation of vertical position.

e. Incorrect selection of approach chart.

a. Misinterpretation of position along the approach

A potential scenario is that the crew were attempting to conduct a constant angle descent procedure, but lost awareness about their position along the approach. More specifically, the crew may have thought they were closer to the missed approach point than they actually were, meaning that they would have also thought they were too high on the profile and therefore needed to descend at a higher than normal rate. Information consistent with this scenario includes:

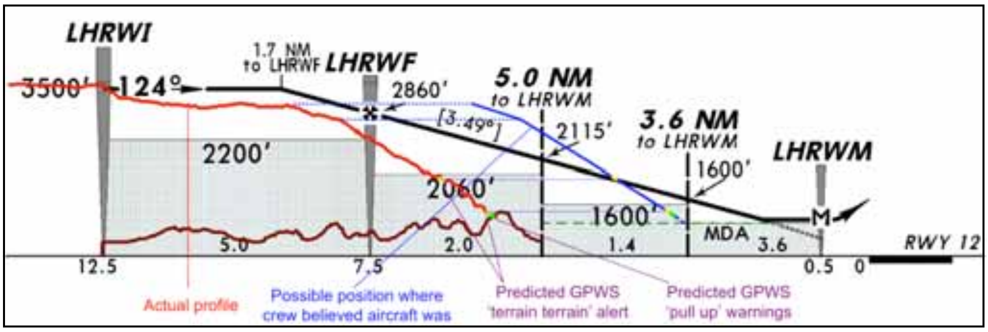
- The rate of descent in the final 48 seconds was relatively constant, which would be consistent with the crew attempting to achieve a specific height by a specific distance from the missed approach point.
- The ATSB pilot survey *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches* showed that there is a potential for pilots to lose awareness of their position along an RNAV (GNSS) approach. This is particularly the case for more complex types of approaches, such as that for Lockhart River Runway 12 RNAV (GNSS) approach (see Section 2.6.6). Aspects of the approach chart design also added to the potential for pilots to lose situational awareness (see Section 2.6.8).

- The copilot had limited knowledge and experience of conducting RNAV (GNSS) approaches, particularly relatively complex approaches such as the Lockhart River Runway 12 RNAV (GNSS) approach.
- There were several factors which increased the workload of the crew (see Section 2.5.1) making it more likely that one or both of the pilots may have made errors when determining or communicating their position along the approach.

The ATSB pilot survey showed that a relatively common error was for pilots to believe they were one altitude limiting step further along the approach than they actually were. However, it is unlikely that confusion of one waypoint with another was a factor on the accident flight. The descent from 3,500 ft soon after the intermediate fix (LHRWI) may have occurred because the crew believed they were one segment (or waypoint) further along the approach. However, if this occurred, the crew detected the error as the descent was discontinued shortly after (see Figure 40).[215] In addition, it is unlikely that the crew believed they were one segment (or waypoint) further along the approach at the final approach fix (LHRWF), given the vertical profile of the aircraft.

Rather than confusing one waypoint with another, the crew may have confused the altitude limiting steps. The FDR data indicated that, at the descent rate recorded, the aircraft would have reached between 900 and 1,000 ft at about the altitude limiting step '5.0 NM to LHRWM' (5 NM to the missed approach waypoint) on the Jeppesen chart (see Figure 2 on page 2). This would have placed the aircraft at about the minimum descent altitude (MDA, or 1,040 ft) at the '5.0 NM to LHRWM' position. Therefore, the crew may have confused the '5.0 NM to LHRWM' position with either the '3.6 NM to LHRWM' position or the LHRWM waypoint. The blue profile shown on Figure 41 corresponds to what the crew would have believed the flight path to be according to such a scenario. The red profile corresponds to the actual flight path of the aircraft.

Figure 41: Profile that the crew may have believed they were following overlaid on a Jeppesen profile diagram. (Note: diagram not to scale.)



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215 There are other reasons why the crew may have descended the aircraft at LHRWI and leveled at 3,000 ft, including maintaining the 'minimum sector altitude' of 3,100 ft when within 10 NM from the Lockhart River NDB. The 'minimum sector altitude' provides a 1,000 ft obstacle clearance when within a specified sector and within 10 NM or 25 NM radius of the nominated navigation aid or aerodrome reference point. There was no requirement to maintain the recommended profile entry altitude of 3,500 ft, only to not descend below the segment minimum safe altitude of 2,500 ft.

Alternatively, the distance from the LHRWF to the LHRWM was 7 NM, whereas on most approaches the distance between the final approach fix and the missed approach point was 5 NM. If the crew thought they were 2 NM closer to the missed approach point prior to reaching LHRWF, then the initiated rate of descent would have also placed the aircraft at the minimum descent altitude at about the '5.0 NM to LHRWM' position (or where the crew thought was about 3 NM to the missed approach point). This scenario would also correspond to the blue profile on Figure 41.

It could be argued that it was unlikely that the crew thought they were further along the approach than they were because the speed of the aircraft would have been too high for landing. However, FDR evidence from previous flights indicated that it was possible to decelerate the aircraft to the landing speeds used on some previous flights within the distance that the crew may have thought was available.

It could also be argued that, given the critical nature of the vertical speed indicator in assessing pitch performance during a non-precision instrument approach, the crew would detect a high rate of descent, even if they had lost position awareness on the approach. However, there have been many CFIT accidents in the past where pilots operating in a multi-crew environment have been known to lose situational awareness on the approach and the rate of descent has continued to be excessive until impact.[216] There are also other reasons to explain why the crew of VH-TFU may not have detected or corrected the high rate of descent, such as workload (see Section 2.5.1) or a breakdown in crew coordination (see Section 2.5.3).

b. 'Shooting for the hole' to acquire visual contact with the ground

A second potential scenario is that the crew were attempting to manoeuvre the aircraft through a hole in the cloud. This practice, sometimes referred to as 'shooting for the hole', is performed to acquire and maintain visual contact with the ground. As the forecasted weather indicated that the cloud base would be below the MDA for temporary periods, the crew may have descended through a hole in the cloud to ensure they obtained visual contact with the ground by the time they reached the missed approach point. Such a hole is sometimes referred to as a 'sucker hole'.

The rate of descent increased before the final approach fix. An increase in the rate of descent could be expected if the crew were attempting to remain within a hole in the cloud. If the crew were 'shooting for the hole', they may also have been less concerned about monitoring the aircraft's rate of descent.

However, it is unlikely that the crew were shooting for a hole in the cloud because of the following.

- If the crew were in visual contact with the ground and were navigating the aircraft along the final approach track, they should have realised their proximity to high terrain and initiated a climbing avoidance manoeuvre as the aircraft approached the South Pap ridge. The FDR data did not indicate the commencement of any avoidance manoeuvre. Therefore, it is

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216 An example of this phenomenon was the Bureau of Air Safety Investigation Report 199501246, Israel Aircraft Industries, Westwind 1124, VH-AJS, Alice Springs NT, 27 April 1995 (published August 1996). Another example was the US National Transportation Safety Board Aircraft Accident Report AAR-78-13, National Airlines, Inc., Boeing 727-235, N474NA, Escambia Bay, Pensacola, Florida, May 8 1978.

extremely unlikely that the crew were in visual contact with the ground during the latter stage of the flight.

- The FDR data showed that the aircraft remained on the published approach path until the impact with the ground. If the crew did descend through a hole in the broken to overcast cloud, the hole would have also had to have been coincidentally located on the published approach track.

It is possible that the crew were shooting for a hole, but then lost visual contact with the ground and continued descending in IMC. If this was the case, and the crew were aware of their position in relation to the missed approach point, they would very likely have initiated a climbing avoidance manoeuvre given that the aircraft was below the segment minimum safe altitude. The pilot in command, who was very likely to have been the handling pilot, was aware of and reportedly concerned about the proximity of terrain under the descent path (see page 14). Accordingly, it was considered unlikely that he would have intentionally descended below the segment minimum safe altitudes if he was in IMC.

However, the crew may have become confused about their position in relation to the missed approach point due to a reduced monitoring of the aircraft's position on the GPS receiver display during a 'shooting for the hole' manoeuvre. If the crew mistakenly believed their position was closer to the missed approach point, it is possible that they would have continued the descent, even though the aircraft was in IMC (see scenario *a*).

c. Expediting the descent to the minimum descent altitude

A third potential scenario was considered whereby the crew attempted to descend to the MDA as early as possible in order to increase their chance of getting below the cloud base and obtaining visual contact with the ground. It was reported that the pilot in command had used this practice on approaches into Bamaga.

However, Transair pilots reported that the pilot in command would be unlikely to use this technique at Lockhart River, and intentionally descend through a segment minimum safe altitude in IMC, because he was aware of the proximity of terrain underneath the approach path. Nevertheless, it is possible that the crew may have thought they were further along the approach than they actually were (see scenario *a*), or that the pilot in command thought he had passed the higher terrain. The approach charts did not depict the terrain profile under the approach path (see Section 2.6.8).

d. Misinterpretation of vertical position

A fourth potential scenario was that the crew misinterpreted their vertical position and thought that they were higher than their actual altitude. Such a misinterpretation could have been due to a misreading of the altimeter or an incorrect selection of the QNH on the altimeter subscale.

The copilot's side of the cockpit contained a three-point altimeter of the type that has been linked to a number of accidents due to crew mis-reading the altimeter display. Due to the nature of these altimeters, mis-readings will be either by 1,000 ft or 10,000 ft. For this scenario to have explained the aircraft's descent profile, the error would have had to have been a continuous mis-reading during a 48-second period, which would seem unlikely. In addition, the copilot's altimeter had been modified in accordance with Civil Aviation Order (CAO) 103.4 to include a coloured warning sector which was exposed when the altimeter was indicating a height below 10,000 ft. Furthermore, the pilot in command's altimeter was a counter-drum pointer presentation, which has not been associated with pilot misinterpretation.

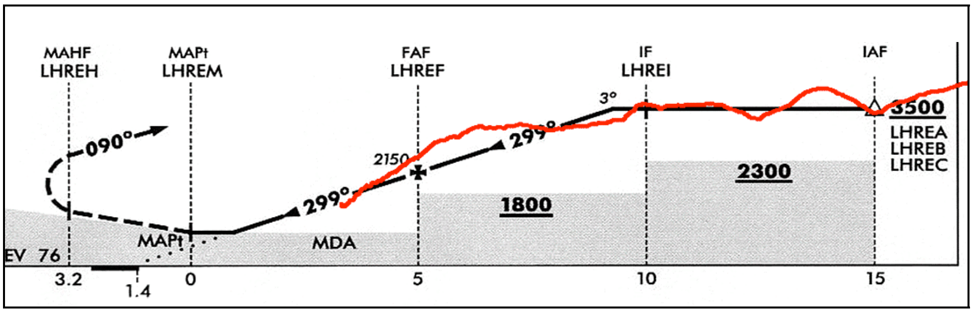
In terms of the QNH selection, Brisbane ATC advised the crew at 0932 that the QNH for Lockhart River aerodrome was 1013 hPa, and at 1134 the area QNH for their descent into Lockhart River was 1011 hPa. Examination of the altimeters from VH-TFU found the pilot in command's altimeter was set to 1010.5 hPa and the copilot's to 1012 hPa. The differences were unlikely to have been due to impact damage, and indicated that the crew had not cross-checked the settings prior to the approach. With the barometric pressure scales set as found in the wreckage, the altimeters would have been indicating an altitude that was about 70 ft (pilot in command) or 30 ft (copilot) below the aircraft's actual altitude. As the aircraft was over 800 ft below the recommended constant angle profile when it impacted terrain, it is extremely unlikely that such an omission would have resulted in the greater than required descent that was evident from the FDR data.

e. Incorrect selection of approach chart

Another possible scenario considered by the investigation was whether the crew may have inadvertently selected the Lockhart River Runway 30 RNAV (GNSS) approach chart instead of the chart for the runway 12 approach. When the accident flight path was superimposed on the runway 30 chart, the descent from 3,500 ft began at about the point where the runway 30 recommended descent profile commenced. The waypoint names for the intermediate fix, final approach fix, and missed approach point only differed by one letter between the two approaches.

However, this scenario would not be consistent with the aircraft levelling out at about 3,000 ft. In addition, the crew had broadcast that they were conducting a runway 12 approach via the 'whiskey golf' waypoint. The equivalent point on the runway 30 approach was 'echo charlie'. The GPS unit would also have been showing 7 NM instead of 5 NM after passing the intermediate fix (LHREI).

Figure 42: Vertical profile of VH-TFU overlaid on a Lockhart River Runway 30 RNAV (GNSS) approach profile diagram



Summary

It was considered very unlikely that the descent below the segment minimum safe altitudes was a result of misreading or mis-setting of the altimeters. However, given the absence of CVR information, the investigation was unable to conclusively determine which of the other scenarios was the most likely. Nevertheless, scenario *a* involved the crew losing situational awareness about the aircraft's position along the approach. Similarly, the most likely way that scenarios *b* and *c* could have led to the collision with terrain also involved the crew losing situational awareness about the aircraft's position along the approach. Therefore, a loss of situational awareness along the approach was considered to be a local condition that was a contributory safety factor to the descent below the segment minimum safe altitude.

2.4.4 Rate of descent not corrected

The rate of descent during the final 48 seconds of flight averaged 1,700 ft/min. There was no indication in the FDR data that the crew had attempted to correct the rate of descent, or the descent through the segment minimum safe altitude, prior to the collision.

There were four sources of aircraft information that could have potentially alerted the crew to the developing problem: altimeters, vertical speed indicators, radio altimeter and the GPWS.

Altimeters and vertical speed indicators

The altimeters and vertical speed indicators were both in a prominent position in each pilots' primary optimum field of view and each pilot's instruments were connected to separate static sources. There was no indication that there was a technical problem with any of these instruments (see Section 2.3.2). As discussed in Section 2.4.3(d), it is unlikely that the crew misinterpreted their position due to misreading the altimeter, or having incorrectly set the QNH subscale on the altimeter.

In accordance with Transair's procedures, the non-handling pilot should have announced to the handling pilot that they were descending at a rate higher than 1,000 ft/min during the second descent. The investigation could not determine if the non-handling pilot did not notice the rate of descent, noticed the rate of descent but did not make the call, or made the call and it was not responded to by the handling pilot.

Radio altimeter

If either pilot noticed that the radio altimeter's digital display was rapidly decreasing and decreasing towards zero, he would have been alerted to the fact the aircraft was approaching terrain. However, it is unlikely that the copilot would have noticed the radio altimeter's display changing unless he intentionally looked at the instrument, given that it was located in front of the pilot in command.

The pilot in command may have noticed the changing display as it was directly below his normal line of sight, although pilots would not normally be expected to monitor this instrument and his workload would have required him to focus on other sources of information. The radio altimeter would also have been rapidly changing throughout the final 48 seconds of the flight, even if the aircraft was on the published approach profile. In addition, it is difficult to determine if a rapidly changing digital display is increasing or decreasing.

In summary, even if one of the crew had looked at the radio altimeter, it is unlikely that it would have alerted him to the fact that the aircraft was rapidly approaching terrain.

Ground proximity warning system

The ground proximity warning system (GPWS) was effectively the last line of defence to prevent a collision with terrain, particularly if the aircraft was in IMC up until, or close to, the time of collision. Information gathered about the GPWS during the investigation included the following.

- Transair commenced RPT operations into Lockhart River in August 2004 and always operated the same aircraft, VH-TFU.
- Only one flight recorded on the FDR prior to the accident flight recorded a Lockhart River Runway 12 RNAV (GNSS) approach. This was on 27 April 2005, and the pilot in command of the accident flight was also the pilot in command for that flight. The Honeywell simulation of this approach predicted that the crew should have received GPWS mode 2 alerts and warnings.
- The copilot of the 27 April approach recalled that he had heard GPWS annunciations while conducting the runway 12 RNAV (GNSS) approach in visual conditions but could not recall whether he heard them on the 27 April flight.
- Apart from the copilot of the 27 April approach, all other Transair current and former pilots independently reported that they had never received any GPWS alerts or warnings when conducting the runway 12 RNAV (GNSS) approach. However, it was not common for Transair pilots to conduct that approach. Transair operated the Bamaga – Lockhart River route one to two times a week, and most of these approaches were conducted visually and normally tracked along the extended runway centreline which was over a valley.
- Most other aircraft operating into Lockhart River were not fitted with GPWS. However, a report to the ATSB after the accident from a crew operating two aircraft on the runway 12 RNAV (GNSS) approach indicated that they could not conduct the approach without receiving GPWS mode 2 alerts and warnings.
- The Honeywell simulations predicted that aircraft flying either the recommended constant angle approach or the step-down approach should always receive GPWS alerts and warnings in the vicinity of South Pap when the landing flap was not extended. Transair crews reported that landing flap was normally not extended until later in the approach.
- The CVR from VH-TFU had recorded sounds from multiple flights, including a number of GPWS alerts. None of these were mode 2 alerts or warnings. Based on the timing of the alerts on the CVR, none of the alerts on the CVR appeared to be linked to the accident flight.
- In addition to the CVR information, Transair pilots reported that they tested the GPWS before each flight. Reports of what was heard during these tests indicated that the GPWS computer was probably operational on VH-TFU.
- The Honeywell simulation for the accident flight predicted that the crew should have received a GPWS mode 2A alert ‘terrain terrain’ about 25 seconds before impact and at about 5 seconds before impact, an alert ‘terrain terrain’ and then a repetitive warning ‘pull up’ until the collision.

- There was no evidence from the FDR that the crew initiated any manoeuvre that may have been in response to a GPWS alert or warning.

There were three possible scenarios to explain why the GPWS was not effective in preventing the collision:

a. GPWS alerts and warnings not perceived and/or responded to;

b. GPWS technical failure; or

c. GPWS intentionally disabled.

a. GPWS alerts and warnings not perceived and/or responded to

One possibility is that the crew received GPWS alerts and warnings as predicted by the Honeywell simulation, but did not act on them. There may be a number of reasons for the crew not responding to any GPWS alerts and warnings.

- The crew did not notice or act upon the mode 2 ‘terrain terrain’ alert that occurred about 25 seconds before impact as it was very brief, not immediately followed by any other alerts and warnings, and the aircraft was about 2,000 AMSL.
- Based on the Honeywell simulation, the pilot in command probably received mode 2 GPWS annunciations during the approach on 27 April when in visual conditions and at a similar position on the approach. He may therefore not have been surprised if this occurred on the accident flight.
- If the crew thought that they were further along the approach than they actually were (see Section 2.4.3a), they may have associated the first alert with overflying South Pap. The final alert and subsequent repeating ‘pull up’ warnings were annunciated from about 5 seconds before impact. If the crew thought the initial GPWS alert was due to South Pap, then they may have initially thought the warnings during the final 5 seconds were spurious.
- The crew may not have perceived the annunciations. This phenomenon, referred to as ‘inattentional blindness’, can occur when pilots focus their attention on the most salient task, especially under moderate to high workload situations, and block out other information including aural alerts and warnings. There have been previous accidents where CVRs have shown that crews appeared to have not perceived GPWS annunciations during high workload situations.[217]
- Neither pilot had received training in responding to GPWS annunciations. Although the expected responses were outlined in the *Transair Operations Manual*, the description of the GPWS alerts and warnings in the manual did not include the ‘terrain terrain’ alert. Neither pilot had undergone CFIT awareness training that may have raised their awareness of the risks associated with the approach. This may have resulted in a delayed crew response if any GPWS alert or warning had occurred.

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217 Examples of an aircraft accidents involving this phenomenon include the Flying Tiger Line, Boeing 747-248F, N807FT, Kuala Lumpur Malaysia, 19 February 1989 (ICAO Adrep Summary), and the Korean Air, Boeing 747-300, HL7468, Nimitz Hill Guam, 6 August 1997 (NTSB Aircraft Accident Report 00/01).

Research outlined in Section 1.16.2 has shown that it takes on average about 5 seconds for a pilot to recognise a GPWS warning, and the combined crew and aircraft response time is generally about 12 to 15 seconds. Regardless of the reasons for the crew not responding to any GPWS alerts and warnings, it is very unlikely that the crew had any real prospect of avoiding a collision once the alert and warnings were annunciated from about 5 seconds before the impact.

b. GPWS technical failure

Operation of GPWS mode 2 relied on the GPWS computer, the radio altitude, and the GPWS landing flap switch. If the GPWS mode 2 had failed, the crew would not have received any GPWS alerts or warnings. This could occur if there was a failure in the systems supplying input to the GPWS computer, or a failure within the computer itself.

There were no recent entries in the VH-TFU *Flight/Maintenance Log* from previous flights of any problems with GPWS or radio altimeter system. There were also no other recorded maintenance issues that could suggest that any of the systems associated with the GPWS may have had a pre-existing problem that could have led to a failure of the GPWS.

Furthermore, there was evidence on the CVR that the GPWS had been providing alerts on previous flights, although none of these were mode 2 alerts. Most of the alerts were not those associated with testing of the system during pre-flight checks. The number of alerts evident on the CVR was not consistent with the reports from Transair pilots that they rarely received any GPWS alerts or warnings. It is possible that these pilots did not consider some types of annunciations as being relevant to the investigation (such as ‘glideslope’ or ‘too low gear’, see Appendix B). It is also possible that the alerts had occurred on previous flights involving the pilot in command and copilot of the accident flight.

The radio altimeter indicator was found in the aircraft wreckage with the flag across the display, indicating that electrical power to the indicator had been removed or the indicator had failed or the radio altimeter receiver/transmitter had failed. It is very likely that, had the radio altimeter indicator been functioning normally during the flight, the power interruption during the impact sequence would have caused the flag to appear. However, the investigation could not conclusively rule out the possibility that a radio altimeter system failure occurred during the accident flight, resulting in a GPWS failure.

Some overseas accident investigations have found that GPWS annunciations have been delayed; that is, an alert or warning has commenced after the time predicted by the manufacturer during subsequent laboratory simulations.[218] Reasons identified from past accidents for a delayed activation include the following.

- Loss of radio altimeter tracking. This can occur during heavy precipitation.
- Excessive rate-filtering of the radio altimeter data by the GPWS computer. This rate-filtering is performed to limit nuisance warnings.
- Reduction in the mode 2 warning envelope from mode 2A to mode 2B due to a faulty or mis-rigged flap position switch that would give a landing flap

218 An example of this phenomenon is given in Report 95-011, de Havilland DHC-8, ZK-NEY controlled flight into terrain near Palmerston North, 9 June 1995 published by Transport Accident Investigation Commission of New Zealand (http://www2.taic.org.nz/InvDetail/95-011.aspx).

indication to the GPWS computer when the flaps were actually at a less than landing flap setting. A simulation of the accident flight by Honeywell predicted that if the GPWS was using the mode 2B envelope, then the crew would not have received any alerts or warnings (see Appendix F).

There was no evidence that any of these conditions were present in VH-TFU during the accident flight.

c. GPWS intentionally disabled

It is possible that the crew intentionally disabled the GPWS, so that the system would not activate all alerts and warnings during the approach. This could be achieved either by selecting the flap override switch to the ON position (reducing the GPWS envelope to mode 2B) or by pulling the circuit breaker (stopping all alerts and warnings).

The crew may have selected the GPWS flap override switch if they had experienced a flap malfunction. Honeywell estimated that the reduced envelope would have resulted in no GPWS alerts or warnings being issued on the accident flight. However, as the FDR data indicates that the flaps were extended normally to the ¼ and ½ positions, and there was no evidence of a hydraulic system malfunction, it is very unlikely that there was a problem with the flaps that would have led the crew to select the flap override switch.

Disabling the GPWS could also occur if the crew were expecting to receive a nuisance alert or warning during the approach due to the proximity of the South Pap. Most Transair pilots reported that they never received a GPWS alert or warning while conducting the Lockhart River Runway 12 RNAV (GNSS) approach. However, it is possible that the pilot in command did receive mode 2 GPWS annunciations during the approach on 27 April 2005 when in visual conditions, and may therefore have been expecting this to occur on the accident flight. Nevertheless, there was no evidence from Transair copilots to indicate that the pilot in command had or would intentionally disable the system in IMC.

Summary

There was no evidence that the system failures discussed in scenario *b* had occurred, and there was no evidence to suggest that the GPWS was intentionally disabled as discussed in scenario *c*. Therefore, based on the available evidence, scenario *a* was considered to be a probable explanation of why the GPWS was not effective in preventing the crew continuing the descent towards terrain.

2.4.5 Other crew actions

On the day of the accident, the pilot in command arrived between 20 to 30 minutes prior to the scheduled departure time. His normal practice was to arrive about 20 minutes prior to the scheduled departure. This practice was undesirable as it could result in the pre-flight activities either being rushed or being completed by the copilot without appropriate supervision or checking by the pilot in command. However, there was no evidence that the pre-flight tasks were not appropriately completed prior to the departure from Cairns.

A review of the broadcasts made by the crew on the accident flight identified some errors by the copilot. These were:

- On departure from Bamaga, the copilot stated that the estimated time of arrival for Lockhart River was 1143. At 1135:48, while on descent the copilot revised the estimate for Lockhart River to 1138. At 1136:18, he broadcast on the CTAF that the estimated time of arrival was 1139. The accident occurred at 1143:39, about 11 km short of Lockhart River.
- On departure from Bamaga, the copilot advised that the aircraft was on climb to FL 180 (instead of FL 170). This error was detected by ATC.
- Prior to descent, the copilot was required to request traffic information from ATC. However, this did not occur until 40 seconds after the aircraft commenced descent. According to the AIP, the crew of an IFR flight outside controlled airspace were required to report position and intention approximately 1 minute prior to any change in level.

The reasons for these errors could not be determined. They may indicate a lack of monitoring by the pilot in command, ineffective crew coordination, or workload issues.

As noted in Section 1.12.7, the barometric pressure scale setting on both pilots' altimeters did not equate to the appropriate aerodrome QNH value. The settings also differed between the two altimeters. The reason for the discrepancies could not be positively determined. Regardless of the reason for the discrepancies, their existence probably indicated ineffective crew coordination (see also Section 2.5.3). As noted in Section 2.3.2, it was very unlikely that the errors in setting the altimeters had any influence on the accident.

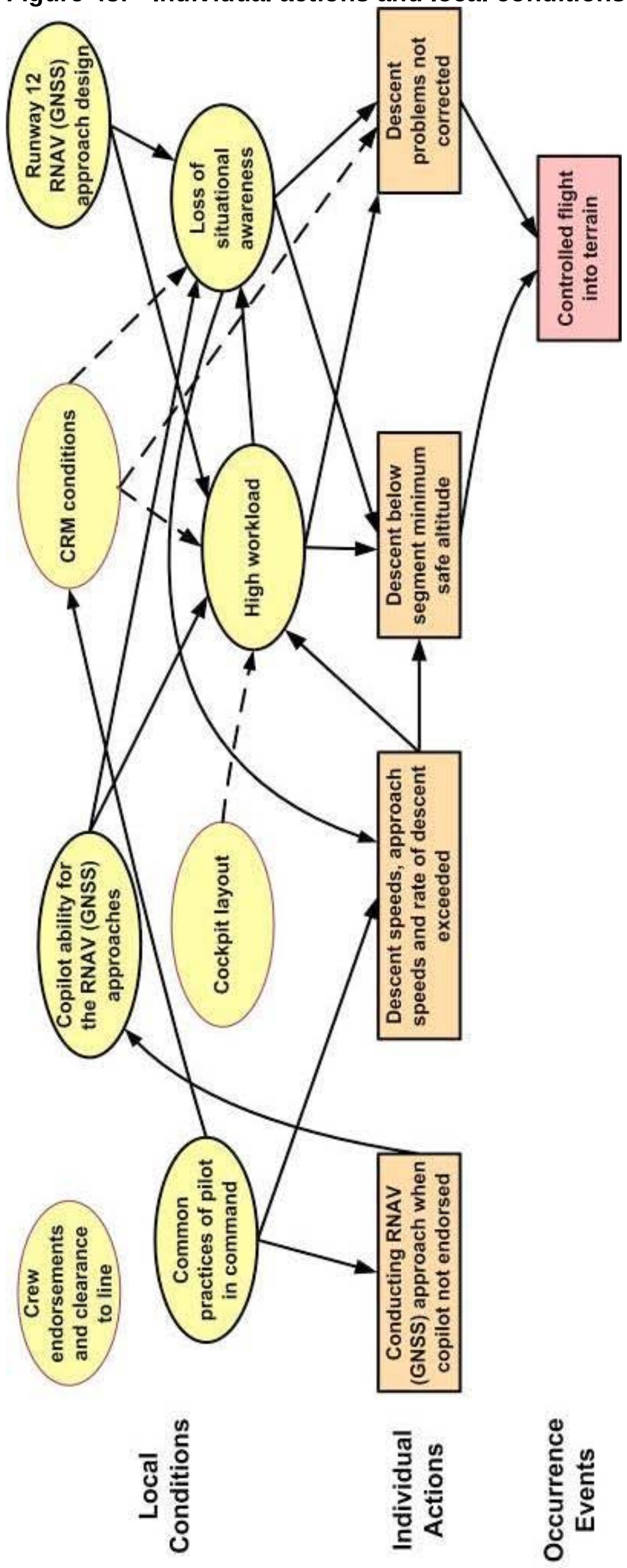
2.5 Local conditions

The absence of a CVR significantly restricted the ability of the investigation to determine the reasons the events identified in Section 2.4 occurred. Eight local conditions were identified as being safety factors:

- crew situational awareness;
- crew workload;
- common operating practices of the pilot in command;
- crew resource management (CRM) conditions;
- crew endorsements and clearance to line;
- Lockhart River Runway 12 RNAV (GNSS) approach design;
- copilot ability relating to RNAV (GNSS) approaches; and
- cockpit layout.

Figure 43 shows the relationship between these local conditions and the individual actions discussed in Section 2.4. Situational awareness was discussed in Section 2.4. The remainder are discussed in the rest of this section.

Figure 43: Individual actions and local conditions[219]



219 Dashed lines indicate a possible but not probable relationship. Black borders indicate contributing safety factors while purple boarders indicate other safety factors.

2.5.1 Crew workload

It is likely that the crew were experiencing a very high workload during the approach. In addition to the normal actions required to conduct the approach, such as configuring the aircraft, making radio broadcasts, and conducting checklists, the crew workload would have been influenced by several factors. It is unlikely that any one factor alone would have overburdened the crew. The factors probably contributing to the very high workload were:

- The compressed time available to fly each segment of the approach due to the higher than specified speeds during the approach (see Section 2.4.2).
- Flying with reference to instruments in IMC.
- The limited ability of the pilot in command to read the distance and waypoint information on the GPS, due to its location and the turbulence. This would have increased the amount of communication needed between the crew (see Section 2.5.7).
- The copilot's lack of formal training and limited experience with RNAV (GNSS) approaches, as well as his limited experience with Metro operations (see Section 2.5.5).
- The relatively high workload of RNAV (GNSS) approaches in general. This was due to the way distance information was presented on the GPS display and approach chart to reference the next waypoint rather than the missed approach point, requiring pilots to conduct mental arithmetic to determine their distance from the missed approach point (see Section 2.5.5).
- The additional relatively complex nature of the Lockhart River Runway 12 RNAV (GNSS) approach (see Section 2.5.5).
- The limited training in multi-crew operations and CRM, which could have increased workload especially if there was a breakdown in crew co-ordination as a result of the way the approach proceeded.
- The absence of an autopilot or any form of vertical altitude advisory guidance. This resulted in the crew needing to perform more cognitive tasks (calculating profiles and distances) as well as the perceptual tasks (monitoring aircraft position and altitude).
- The increased turbulence during the final 25 seconds of the flight, which would have increased the time taken to read cockpit instruments due to the perceived movement of the cockpit instrument panel.

The high workload levels would have increased the likelihood of the crew misinterpreting their position during the approach, and decreased the likelihood of the crew detecting the existence or magnitude of any misinterpretation of position prior to the collision. In addition, the pilot in command would have needed to dedicate much of his attention to controlling the aircraft and keeping it on track, and the copilot needed to dedicate much of his attention to monitoring the GPS display and approach chart due to the approach design and GPS location.

As a result, both pilots would have had less attentional capacity available to monitor other primary flight instruments. This would have made it more difficult to detect any altitude, rate of descent or speed deviations from what was expected and could have led to a breakdown in cross-checking procedures between the crew.

High workload levels and focused attention would also reduce the chance that any GPWS alerts and warnings were perceived or responded to by the crew.

2.5.2 Common operating practices

Two of the individual actions discussed in Section 2.4 appeared to be common practices rather than unique events, particularly for the pilot in command:

- decision to conduct the RNAV (GNSS) approach when one or both of the crew were not endorsed for the approach; and
- high descent and approaches speeds.

Conducting approaches when crew not endorsed

The decision to conduct the RNAV (GNSS) approach in IMC, even though the copilot was not endorsed for the approach, was not an isolated event. The crew had conducted another such approach on the northbound flight in IMC. There was also evidence from interviews with Transair pilots that the pilot in command had conducted RNAV (GNSS) approaches in the past when he and/or a copilot did not hold an appropriate endorsement for the approach. Transair pilots reported that they were aware of the company procedure that both pilots were required to be endorsed on RNAV (GNSS) approaches before conducting an approach. They also reported that the pilot in command was aware the copilot's instrument rating was not appropriately endorsed to conduct an RNAV (GNSS) approach.

The exact reasons for the pilot in command conducting the approach with a copilot who did not hold an appropriate RNAV (GNSS) approach endorsement could not be determined with certainty. Possible reasons include the following.

- Although the *Transair Operations Manual* required both flight crew to be RNAV (GNSS) endorsed to conduct an RNAV (GNSS) approach, the pilot in command may have perceived that it was an acceptable company practice to conduct RNAV (GNSS) approaches with unqualified crew. He had previously operated these approaches before he was endorsed.
- It is possible that the crew were not aware of the regulatory requirement of CAO 40.2.1. In addition, the intent of this requirement was arguably ambiguous as to whether it required both flight crew to be endorsed on a particular instrument approach in order to conduct that instrument approach. However, the *Transair Operations Manual* stated that both crew were required to be endorsed.
- The crew may have been experiencing time pressure. However, the flight was only slightly behind schedule for the arrival at Lockhart River, and there was no evidence to suggest that that Transair flight crews were under pressure from management to fly the shortest route in order to save fuel and/or time. Although there was no evidence of commercial time pressure, the investigation could not rule out any self-imposed time pressure.
- Other motivational factors such as convenience, overconfidence, and/or a desire to demonstrate skill levels.

Descent and approach speeds

The descent and approach speeds during the accident flight significantly exceeded company procedures, and the speeds that Transair pilots stated were their normal operating speeds. However, the speeds of the accident flight were consistent with the speeds used on two other RNAV (GNSS) approaches recorded on the FDR, both of which had the pilot in command on board. In addition, some pilots reported that the pilot in command generally operated flights at higher speeds than other pilots. This was confirmed by FDR data which showed that flights on which the pilot in command was on board were operated at faster speeds than other flights at 1,000 ft and 500 ft above aerodrome level.

It is unlikely that there was any commercial time pressure that influenced the choice of descent and approach speeds. However, the extent to which self-imposed time pressure and/or other motivational factors described above may have been involved could not be determined.

The extent to which the copilot may have been involved in the decision to conduct the approach and the choice of descent and approach speeds is discussed in Section 2.5.3, and the extent to which Transair management was or should have been aware of the practices is discussed in Section 2.6.3.

2.5.3 Crew resource management conditions

Operating a multi-crew aircraft, particularly in high workload situations, requires the two pilots to work in a coordinated manner and effectively communicate with each other. A breakdown in crew coordination or communication can lead to an unequal workload burden between the crew, a loss of cross-checking of information and detection of errors, and/or incorrect or untimely information being communicated.

There were several factors that influenced the potential for the crew of VH-TFU to have ineffective levels of coordination and communication, including the following.

- There was a steep trans-cockpit authority gradient, resulting from large differences between the crew in terms of age, experience, and position in Transair.
- Neither pilot had received any formal training in CRM skills.
- The endorsement training provided to either pilot did not include operating the aircraft in a multi-crew environment.
- Reports about the pilot in command’s operating practices indicated that he would often not involve a copilot in decisions and would not necessarily accept a copilot’s challenge of his actions, particularly for new copilots who had yet to earn his respect. Reports about the pilot in command’s operating practices also indicated his communication style in the cockpit could be curt and abrupt at times, particularly if the copilot was losing situational awareness. There were indications that these types of communication problems existed between the pilot in command and the copilot on previous flights.
- Reports that the copilot was not naturally assertive.

A steep trans-cockpit authority gradient without appropriate CRM skills reduced the likelihood that the copilot would voice any concerns that he may have had about the pilot in command's decisions and actions. It would have also increased the probability that the pilot in command made decisions without consulting the copilot and/or considering any concerns he may have expressed. Decisions and actions that may have had limited involvement from the copilot include the selection of the approach, the approach speeds, the rate of descent, and any go around or decision not to land. Possible concerns the copilot may have had but did not effectively address with the pilot in command included any detected problem with the assumed aircraft position, any discomfort with the fast approach speeds, any discomfort with the high rate of descent, and detection of a GPWS alert or warning.

Although the circumstances had a significant potential for creating CRM problems, the absence of CVR information meant that the investigation was unable to determine the extent to which any such problems influenced the crew's decision making and actions on the accident flight. Possible indicators that ineffective crew coordination occurred during the accident flight included the discrepancies between the altimeter-subscale settings, and errors in the copilot's radio broadcasts which were not subsequently corrected by the crew.

2.5.4 Crew endorsements and clearance to line

Transair's processes did not ensure that the crew met all the relevant regulatory and *Transair Operations Manual* requirements to conduct RPT flights on the Metro aircraft. Examples of discrepancies from relevant requirements included the following.

- Neither pilot had received a valid special design feature endorsement for the pressurisation system.
- The Transair chief pilot could only provide aircraft endorsements to pilots working for Transair or working under an arrangement with Transair. However, neither pilot was employed by Transair when they completed their aircraft endorsements with the chief pilot.
- Neither pilot had been cleared to line by a check pilot prior to commencing line operations, as required by Transair's procedures and regulatory requirements.
- The pilot in command had not been route checked into Lockhart River for RPT operations by an appropriately qualified pilot, as required by Transair's procedures and regulatory requirements.

Overall, none of these limitations were likely to have had a significant influence on the conduct of the accident flight. However, they were symptomatic of problems in the management of training and checking within Transair, particularly as the same problems also occurred for other pilots (see Sections 2.6.1 and 2.6.2).

There were also limitations with the amount of ground-based instruction provided during the pilot's endorsements (see Section 2.6.1). However, there was no indication the crew's level of knowledge about Metro aircraft systems in general was involved in the actions which led to the controlled flight into terrain.

2.5.5 Lockhart River Runway 12 RNAV (GNSS) approach design

RNAV (GNSS) approaches offer several advantages relative to other types of non-precision approaches. These include being runway aligned straight-in approaches, which are associated with a lower accident rate relative to circling approaches. They also have no ground-based navigation aids, and therefore they can be implemented more widely than previous types of approaches.

However, although their straight-in criteria should make them safer from the missed approach point to the landing, RNAV (GNSS) approaches still have the potential to lead to problems with pilot workload and situation awareness. Responses to the ATSB pilot study indicated that, prior to reaching the missed approach point, RNAV (GNSS) approaches created higher workloads for pilots (relative to most other approaches). Pilots also indicated that these approaches were associated with a higher likelihood of losing situational awareness of the aircraft's position along the approach (relative to most other approaches), and 15 respondents reported that they had descended too early on an approach due to a misinterpretation of their position. High workload and losses of situational awareness were especially a concern for pilots operating Category A and Category B aircraft such as Metros, as these aircraft tended not to have sophisticated automation or vertical guidance systems unlike high capacity airliners, and they tended to operate these approaches outside controlled airspace which respondents indicated also increased workload.

Based on the available research, including the ATSB pilot survey, there were two key aspects of the Lockhart River Runway 12 RNAV (GNSS) approach which would probably have affected the crew's workload and potential for the crew to lose situation awareness:

- distance to the missed approach point; and
- variations from optimal approach design.

Several other aspects of RNAV (GNSS) approach and approach chart design were identified during the investigation, and are discussed in Sections 2.6.6 to 2.6.8 and 2.8.6.

Distance to the missed approach point

RNAV (GNSS) approaches did not have a continuous distance reference to the missed approach point throughout the approach displayed on the GPS. As a result, pilots were required to mentally calculate this distance throughout the approach, until after they passed the final approach fix. Although the approach charts did have a distance/altitude table that can be used to help pilots maintain an appropriate altitude during the approach, it appeared that the crew of the accident flight were not using it and the Transair approach procedures outlined in its operations manual also did not make reference to using these tables.

The problem related to the lack of continuous distance reference to the missed approach point can be overcome with advances in technology in the design of GPS receivers or augmentation to provide vertical guidance.

Variations from optimal approach design

The 'optimal' design criteria included segments of 5 NM between each of the waypoints in the approach, and a constant descent angle of 3 degrees. Due to the layout of the terrain to the north-west of the aerodrome, the Lockhart River Runway 12 RNAV (GNSS) approach had complicated segment spacing, additional altitude limiting steps after the final approach fix, and a slope of more than 3 degrees. This combination added to pilot workload when calculating distances, and increased the likelihood of position confusion during the approach.

There are limited options available to overcome these design problems. However, the overall influence that these variations can have needs to be considered by CASA when evaluating and deciding whether to accept the approach (see Section 2.8.6).

2.5.6 Copilot ability relating to RNAV (GNSS) approaches

The copilot had a low level of experience on multi-crew operations and Metro operations, and he had a low familiarity conducting approaches to or landing at Lockhart River. He also had a low familiarity with RNAV (GNSS) approaches. Given this limited experience, he would have had a high workload during the approach. He may also have had difficulty understanding the approach chart, providing appropriate and timely information to the pilot in command, and detecting any problems regarding the aircraft's position on the approach.

The copilot had only operated on flights into Lockhart River from Bamaga on two occasions prior to the accident flight. Only one of these two flights could have involved a Lockhart River Runway 12 RNAV (GNSS) on 13 April 2005. He was probably the handling pilot on this flight, as his logbook indicated that he was the handling pilot on the other southbound flight into Cairns that day. It was not possible, based on the available evidence, to determine whether IMC existed on the southbound flight to Lockhart River or whether an instrument approach was flown.

Given his limited experience operating into Lockhart River from the north, it is possible that the copilot had limited awareness of the elevation of terrain under the Lockhart River Runway 12 RNAV (GNSS) approach. Furthermore, due to the limited runway offset information on the approach chart (see Section 2.6.8), it is possible that the copilot expected the approach track to be over the valley.

2.5.7 Cockpit layout

Some navigation and warning systems relevant to conducting an instrument approach were not in an optimum position for one or both of the crew in VH-TFU. If a display is not in an optimum position, it can be less likely to attract attention and be more difficult to monitor or attend to, especially in high workload situations. In terms of the accident flight, the location or lack of replication of GPS information, GPWS annunciator and radio altitude indicator were considered by the investigation.

GPS receiver

The location of the GPS display in the cockpit of VH-TFU resulted in the display only being within the pilot in command's primary maximum field-of-view and normal line of sight, and away from his primary flight and navigation instruments. Although the GPS annunciators were located within the pilot in command's primary optimum field-of-view, these alerted the pilot in command that the aircraft was approaching a waypoint. The only source of distance and waypoint identifier information was on the GPS display.

Given the position of the GPS display relative to the pilot in command's normal line of sight, the display size, and turbulence towards the end of the flight, it is possible that the pilot in command would have had a limited ability to easily read the GPS display. As a result, it is likely that he would have had to rely on the copilot to inform him about the aircraft's position on the approach. This, in turn, required both crew to be experienced in RNAV (GNSS) approach procedures and two-crew communication.

Although the position of the GPS display probably increased pilot workload, the magnitude of this influence could not be reliably determined. Even though the position of the GPS display was problematic, the limited panel area available on VH-TFU made a more central positioning of the GPS receiver difficult.

GPWS annunciators

If there was a failure in the GPWS, the 'GPWS INOP' annunciator should have illuminated. The GPWS annunciators were located within the pilot in command's forward line of sight but to the left of the copilot's primary maximum field-of-view and therefore, left of where the copilot's visual attention would have been primarily directed. Accordingly, if the 'GPWS INOP' annunciator became illuminated during the approach, it is possible that the copilot would not have noticed it. Although there was limited space on the instrument panel to centrally place the GPWS annunciators, there was space to allow the annunciators to be replicated on the copilot's side of the cockpit.

Although the position of the GPWS display was not optimal, the aural annunciations should have been salient and available to both crew members.

Radio altitude indicator

Although the radio altitude indicator was located in front of the pilot in command, it was outside of the copilot's primary maximum field-of-view and away from his primary navigation instruments, approach chart, and the GPS display that he would have been referencing. The result was that the copilot would have had to purposely remove his attention away from his primary view in order to read the radio altitude indicator. Accordingly, it is unlikely that rapidly changing numbers on the indicator would have attracted his attention (see also Section 2.4.4).

2.6 Risk controls

Several risk controls were identified as being safety factors. The risk controls included:

- pilot training;
- pilot checking;
- supervision of flight operations;
- standard operating procedures for approaches;
- useability of the *Transair Operations Manual*;
- GPWS alerts and warnings on normal approach;
- RNAV (GNSS) approach waypoint naming convention;

- approach chart layout;
- terrain awareness and warning systems; and
- autopilot.

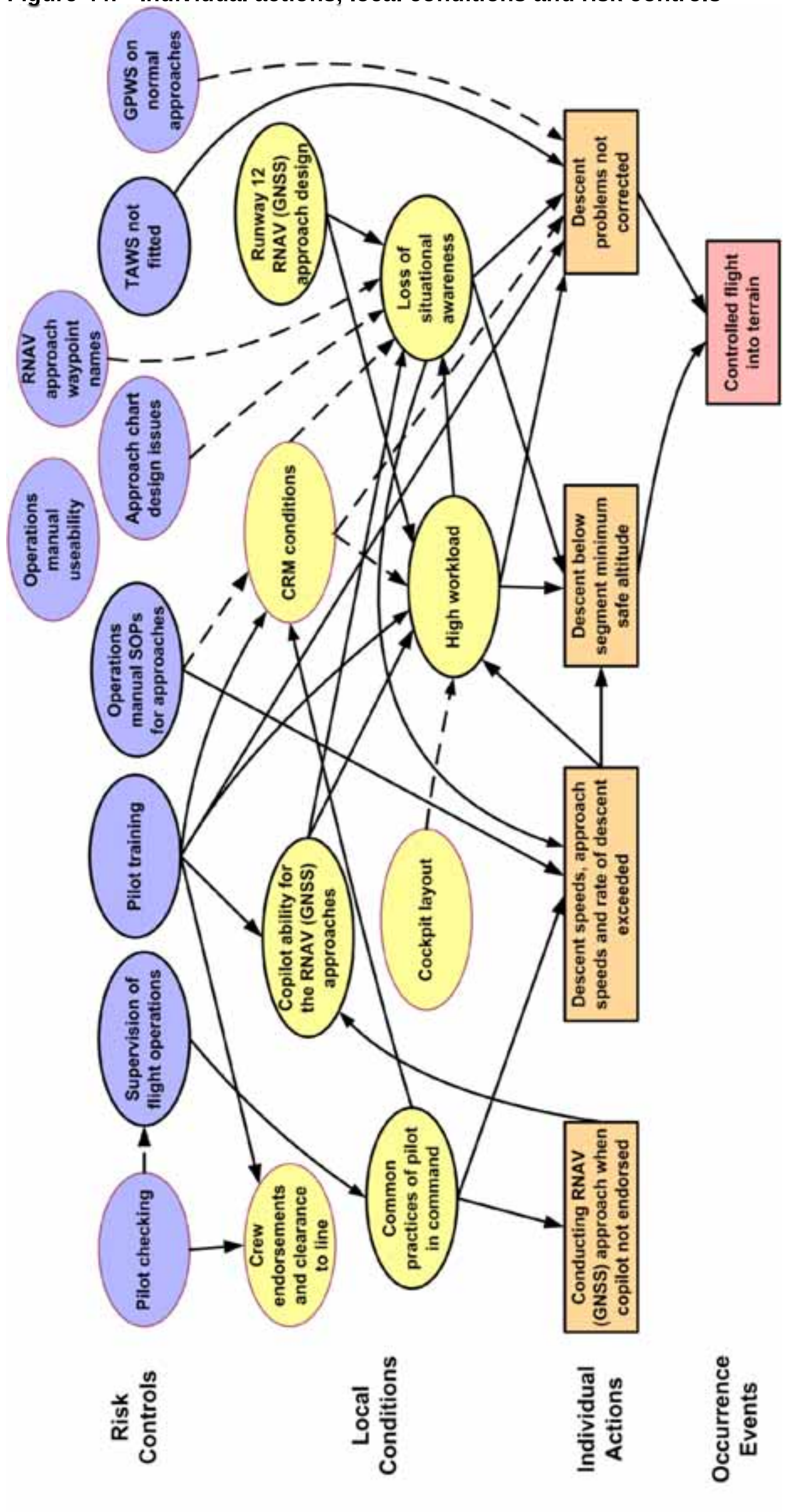
Figure 44 shows the relationship between these risk controls and other safety factors already discussed.

2.6.1 Pilot training

The training and checking organisation and the content of training courses outlined in the *Transair Operations Manual* was approved by the Civil Aviation Safety Authority (CASA), and the inclusion of human factors management (or crew resource management) training in the manual exceeded the regulatory requirements.[22] However, the training that was actually provided to new pilots did not always meet the requirements outlined in the *Transair Operations Manual*. In addition, there were other areas in which the amount of training provided to pilots was less than desirable for RPT operations. The main limitations with the Transair pilot training included the following.

- For many pilots, the ground-based instruction during endorsement training did not include formal classroom training, and was substantially less than that outlined in the *Transair Operations Manual*. Many pilots undertaking endorsements were given the *FlightSafety International SA-227 Pilot Training Manual* for the aircraft and a multiple choice examination as way of completing the ground training component. There were also several reports that new pilots did not have adequate systems knowledge prior to commencing line operations.
- The available evidence indicates that limited training was provided to pilots on stabilised approaches. In addition, no training was provided on the operational aspects of using the GPWS, or other aspects of CFIT prevention to any of the Cairns-based pilots. The *Transair Operations Manual* did not include a requirement for GPWS training. Transair had indicated to CASA that this would be done in 1999.
- No formal training in the operational aspects of using GPS was provided to new pilots (including the copilot), either for en route operations or for approaches. However, RNAV (GNSS) approaches were a pivotal part of operations for the Cairns-based pilots, particularly for operations into Bamaga.

Figure 44: Individual actions, local conditions and risk controls



- There was no formal training in multi-crew operations provided to pilots prior to commencing line operations. Subsequent training was provided during line operations by supervisory pilots, but there was no defined syllabus or required outcomes for this training. There was no regulatory requirement in Australia for flight crew undergoing a type rating on a multi-crew aircraft to be trained in procedures for crew incapacitation and crew coordination. However, this was required under the International Civil Aviation Organization's Annex 1.

- There was no regulatory requirement in Australia for initial or recurrent CRM training for RPT operators, even though CASA released a discussion paper in 2000, and further development and publicity had occurred since that time. Human factors or crew resource management (CRM) training was required in the *Transair Operations Manual* but this training had not been provided to any of the Cairns-based pilots. Transair employed a supervisory pilot who had provided CRM training to the chief pilot as well as to pilots in Trans Air Limited in Papua New Guinea.

- Line training was provided by supervisory pilots, who were not required to have any qualifications or training in the principles and methods of instruction. No training in instructional techniques was provided, even for those supervisory pilots that did not have prior instructor qualifications, such as the pilot in command.

- There was no specified process for monitoring the effectiveness of supervisory pilots.

- There appeared to be no meetings of checking, training and supervisory pilots to discuss standardisation of training activities.

- There was no specified program for the ongoing development of pilots, and no evidence that any such training had been provided in recent years.

For some operators, it may be impracticable to provide extensive training to new pilots in aspects such as multi-crew operations, CRM and CFIT awareness, as the pilots may require some time to consolidate basic skills. However, it is practicable to provide some introductory training in this area, and then have a program to reinforce and expand on this training at a later time. However, there was no evidence that such initial or follow-up training was planned or provided by Transair.

In summary, the training being delivered to pilots by Transair did not provide a high level of assurance that they could effectively operate as part of a multi-crew environment, particularly during high workload, abnormal or emergency situations. Formal training by appropriately-qualified instructors about RNAV (GNSS) approaches would have enabled the copilot to have the skills to adequately participate in a relatively complex approach, such as the Lockhart River Runway 12 RNAV (GNSS) approach. In addition, structured training in stabilised approaches, CFIT awareness and GPWS procedures would have provided the crew with a greater potential for recognising and responding to problems. Formal training in multi-crew operations and CRM also had the potential for reducing workload and optimising the communication and coordination of activities between the two pilots.

2.6.2 Pilot checking

The qualifications and duties of checking personnel, content of proficiency checks and frequency of proficiency checks, as outlined in the *Transair Operations Manual*, had been approved by CASA. However, in practice the checks were not being conducted as required by the *Transair Operations Manual*. The main limitations with the Transair pilot proficiency checking included the following.

- The proficiency base checks were only being conducted once a year, not twice a year as required by regulations. This meant that pilot proficiency on important aspects such as emergency procedures and instrument approaches, included in base checks, was not being checked as frequently as required.
- Although base checks were conducted by CASA-approved check pilots, the initial check to line and subsequent flight proficiency line checks were typically not conducted by check pilots.
- Route check certifications were not completed for any of the RPT routes operated by the Cairns-based pilots. This included the pilot in command.
- The copilot did not have the 10 hours flight time operating the Metro, as required by the *Transair Operations Manual*, before operating as a copilot on a revenue flight.
- The briefings or debriefings provided by some of the pilots conducting checks, including the chief pilot, were reportedly not comprehensive.

In summary, there were a number of limitations with the checking system which restricted the ability of Transair to be assured that its pilots were proficient in important aspects of its operations. The reduced frequency of the proficiency checks influenced the level of supervision of flight operations (see Section 2.6.3). However, it is unclear whether an increased frequency of proficiency checks would have necessarily detected problems associated with the pilot in command's normal operating practices.

2.6.3 Supervision of flight operations

In addition to checking pilot proficiency, it is also important that the routine performance of pilots is monitored on an ongoing basis to ensure compliance with relevant requirements and that flight operations maintain company standards.

With ancillary bases, there is an inherent difficulty in ensuring appropriate monitoring of flight operations. However, a variety of mechanisms can be used to obtain relevant information. Transair had appointed a base manager at Cairns, whose duties outlined in the *Transair Operations Manual* included ensuring operations were conducted in accordance with the manual, and supervising the activities of the line pilots at the base.

There was also a requirement for Transair to conduct base checks and line checks on each pilot on a regular basis. However, there were limitations associated with each of these mechanisms, and a series of other limitations associated with the way flight operations were monitored. These limitations included the following.

- Flight proficiency base and line checks not done as frequently as required, which limited the opportunities for management to monitor operations at the Cairns base.

- Flight proficiency line checks were not always conducted by CASA-approved check pilots as required, which limited the quality or reliability of such checks. For many of the line checks, the Cairns base pilots were effectively checking themselves.
- The flight proficiency base checks and line checks that were conducted by a check pilot were almost all done by the chief pilot, who also provided most of the pilots' initial training. This meant that there were almost no independent evaluations of operational standards by another appropriately qualified check pilot.
- When independent evaluations of Transair's operations were conducted by the contractor check pilot, problems with the standard of operations and level of system knowledge were identified but there was no evidence of any response by the chief pilot about these concerns.
- The *Transair Operations Manual* did not prescribe minimum qualifications or training for the Cairns base manager. The pilot in command was appointed to this role on the basis of seniority, and no training was provided to ensure he could conduct the required duties effectively. There was no specified process to monitor or review the base manager's performance in that role.
- The chief pilot reported that he visited the Cairns base about every 3 months. Although he stated that he used these visits to discuss issues with pilots, the Cairns-based pilots reported that the chief pilot did not use these visits to proactively discuss operational standards with them.
- The tracking of instrument approach recency was left up to individual pilots and an update was given to the main Transair office once a month via the Cairns base manager. Transair did not track recency for RNAV (GNSS) approaches.

The process of obtaining information about flight operations at the Cairns base appeared to rely on the pilots reporting concerns. Several pilots reported that they had not received satisfactory responses to concerns raised with the chief pilot. However, the chief pilot did not recall these concerns being reported to him. The investigation was not able to reliably determine the extent to which the chief pilot was aware of the pilot in command's undesirable operating practices.

In summary, the processes used to monitor flight operations were passive, not as frequent as they should have been, and not as independent as they could have been. The nature of the supervision processes used fundamentally limited the prospect of management detecting problems with operational standards in a timely manner. More proactive, frequent and independent monitoring processes would have been more likely to detect problems with the approach speeds being used during instrument approaches, and the conduct of instrument approaches when crew were not appropriately qualified.

2.6.4 Standard operating procedures

Standard operating procedures (SOPs) are specified to ensure that an operator's flight operations are conducted in a consistent and safe manner and are resistant to crew error. Effective crew coordination and crew performance depend upon the crew having a shared mental model of each task. That mental model, in turn, is founded on SOPs. SOPs should be clear, comprehensive, and readily available in the manuals used by crew members.[220]

There were several deficiencies with the standard operating procedures outlined in the *Transair Operations Manual*, which included the following.

- The manual did not clearly specify the speeds to be used during approaches.
- The *Transair Operations Manual* did not advise when to carry out aircraft configuration changes during the approach.
- The *Transair Operations Manual* did not provide standard calls that could be used by crew members to challenge the other crew member when errors were detected and not corrected.
- The criteria for a stabilised approach were not clearly specified in the *Transair Operations Manual*, and there was no procedure requiring the initiation of a missed approach following an approach becoming unstable.

SOPs that covered these areas, together with robust training, checking and supervision, should have reduced the approach speeds used on the accident flight and may have resulted in the non-handling pilot calling for a missed approach to be conducted. Good knowledge of, and adherence to, clearly defined multi-crew SOPs should also reduce pilot workload through assisting crew coordination and communication.

CASA had produced advisory material on the content of an operations manual in the form of a Civil Aviation Advisory Publication (CAAP). This was not as comprehensive as the guidance provided by other agencies such as the International Civil Aviation Organization and the UK Civil Aviation Authority in areas such as multi-crew operations and stabilised approach criteria. The inclusion of this content in the *Transair Operations Manual* would have reduced the risks to its operations.

2.6.5 Useability of the *Transair Operations Manual*

Effective crew coordination and crew performance on the accident flight depended upon the crew having a shared mental model of each crew members' tasks, which in turn relied on SOPs outlined in a useable and comprehensive operations manual. Some of Transair's pilots, including the copilot, were only ever supplied with the CD-ROM version of the *Transair Operations Manual* and the paper copy held in the Cairns base crew room did not incorporate the latest amendments.

Transair pilots reported the electronic format of the manual was difficult to use, and this was reported by a supervisory pilot as contributing to many of the copilots having limited knowledge of Transair's procedures. Presenting the operations manual in a difficult-to-use format may have also diminished the authority line pilots gave to the manual.

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220 Federal Aviation Administration, Advisory Circular 120-71A *Standard Operating Procedures for Flight Deck Crewmembers*, 27 February 2003.

2.6.6 GPWS alerts and warnings on normal approaches

Honeywell simulations of the Lockhart River Runway 12 RNAV (GNSS) approach predicted that GPWS mode 2A alerts and warnings should occur when a Category B or Category C aircraft, with approach flap extended, was flying the approach. The mode 2A alerts and warnings should occur either on the recommended constant angle descent profile or using a step-down approach. These simulations were confirmed by an operator of Category B and Category C aircraft.

If an instrument approach leads to GPWS annunciations most of the time, then it can affect flight safety in two ways. Firstly, pilots may avoid that approach or fly the approach in a non-optimal manner (such as higher than the optimum profile) in order to avoid GPWS annunciations. Secondly, when pilots expect a GPWS annunciation, they could consider them to be nuisance alerts and warnings that they can then ignore while continuing the approach. However, ignoring an expected GPWS annunciation can lead to a controlled flight into terrain if it occurs when a crew is unaware that they are low on an approach.

Accordingly, approaches should not be designed so that GPWS alerts and warnings are annunciated when an aircraft is flown on the recommended profile with a configuration and speed appropriate for Category B or C aircraft. The CASA instrument approach validation process did not include an evaluation of GPWS annunciations (see Section 2.8.6).

2.6.7 RNAV (GNSS) approach waypoint naming conventions

The Australian convention for waypoint names for RNAV (GNSS) approaches was for waypoint names to consist of five capital letters only differing by the final letter. Responses from the ATSB pilot survey showed that some pilots found this confusing, and that waypoints could be misidentified on the GPS receiver and/or chart as a result. The final letter varied in a consistent way for each RNAV (GNSS) approach to help enhance pilot situational awareness. However, the positioning of the pertinent information at the end of the identifier, and the lack of significant variation in the format of the characters (a result of using all capital letters and no numbers), reduced the effectiveness of this scheme. Furthermore, displaying redundant information in full size fonts (the first four characters of the waypoint identifier) and capital letters added to clutter on GPS displays and approach charts.

The waypoint convention used in Australia was unique to Australia. Although there was no international waypoint naming convention, aspects of the naming conventions used in some other countries were less prone to the problems described above.

Although the waypoint naming conventions were problematic, the extent to which they influenced the crew's workload and situational awareness on the accident flight could not be reliably determined.

2.6.8 Approach chart layout

In addition to problems associated with the design of RNAV (GNSS) approaches, there were also limitations associated with the way approach charts presented information to pilots. In the case of the Jeppesen charts such as those being used by the crew of VH-TFU, these limitations were associated with distance information, alignment between plan-view and profile-view, use of font, offset depiction, and terrain depiction. The extent to which any of these specific issues influenced the crew's workload and situational awareness on the accident flight could not be reliably determined.

Distance information on charts

The distance information depicted on RNAV (GNSS) approach charts was referenced to the next waypoint to be consistent with the distance displayed on the GPS receiver. That information was needed by pilots to be able to cross-reference to the GPS display.

On Jeppesen charts, there was only one distance reference beyond the next waypoint. This was the distance from the intermediate fix (IF) to the runway threshold, which was depicted under the profile diagram (see Figure 2 on page 2). However, given the results of the ATSB pilot survey, it was possible that the lack of salient distance-to-run information on RNAV (GNSS) approach charts did not maximise the likelihood that pilots' awareness of distance from the missed approach point was maintained, and/or ensure that pilot workload was minimised.

Alignment between plan-view and profile-view

The Jeppesen Lockhart River Runway 12 RNAV (GNSS) approach chart used by the pilots could facilitate position confusion if a pilot was visually scanning between the plan-view and profile-view diagrams. This was due to the absence of the approach segment from the initial approach fix to the intermediate fix being depicted on the profile diagram, and the coincidental alignment between the intermediate fix on the plan-view and the final approach fix on the profile diagram (see Figure 35 on page 152). This problem also existed on other Jeppesen RNAV (GNSS) approach charts.

Discrimination between waypoint identifiers

After passing LHRWF, the crew needed to monitor their position in relation to the missed approach point (LHRWM) and the two intermediate altitude limiting steps ('5.0 NM' and '3.6 NM'), all of which had an 'M' at the end of the position or waypoint identifier (see Figure 35 on page 152). During high workload situations such as during an instrument approach, pilots needed to divide their attention between numerous visual tasks, only one of which involved the approach chart. As a result, it could be expected that the crew would be referencing the information on the chart using momentary glances. As the pilots needed to focus on the final letter of each waypoint identifier, and because the 'M' was the same font size and type in each position, this could lead to misidentification.

Offset depiction

Jeppesen RNAV (GNSS) approach charts, including the Lockhart River runway 12 approach, did not depict the offset in degrees between the final approach track and the runway centreline. The only indication of a non-alignment with the runway centreline was a slight angular difference between the small runway symbol and the approach track. For a pilot not familiar with the RNAV (GNSS) approach, but aware of the valley between South Pap and Mount Tozer that was roughly runway aligned, the absence of the offset information could lead the pilot to believe that the final approach track was over the valley.

Terrain depiction

The Jeppesen Lockhart River runway 12 approach chart depicted terrain information as spot heights on the plan-view diagram. However, the chart did not depict the terrain under the approach track. The profile-view diagram also did not show the terrain elevations below the descent path. For a pilot not familiar with the runway 12 RNAV (GNSS) approach, the absence of any terrain information under the flight path being depicted on the approach chart could lead the pilot to believe there was no significant terrain under the flight path.

In 1998, the Flight Safety Foundation recommended that regulatory authorities should support the development of coloured contour depictions on plan-view diagrams and terrain depiction under profile-view diagrams on approach charts. In 2001, ICAO Annex 4 required that instrument approach charts shall display plan-view contour lines, contour values, and layer tints printed in brown in addition to the spot heights when there was very high terrain in the general vicinity of the aerodrome or high terrain (higher than 500 ft) causing a steeper than optimum final approach or missed approach procedure. The Lockhart River Runway 12 RNAV (GNSS) approach qualified for contours under this ICAO requirement based on the 3.49-degree final approach gradient.

Although Australia had not notified ICAO of a difference with the Annex 4 standard 11.7.2, there was no Australian regulatory requirement for contour lines to be depicted on instrument approach charts.

The criteria used by Jeppesen to determine if contour lines and colour were to be used on the plan-view diagram of instrument approach charts was based on the highest terrain in the vicinity of the approach, but did not consider the terrain clearance under the approach path that made the final approach steeper than the 3-degree optimum.

Comparison with Airservices approach chart layout

Airservices instrument approach charts did not depict terrain contours on plan-view diagrams. As with the Jeppesen instrument approach charts, Airservices charts also did not depict the terrain profile on the profile-view diagrams, although they did depict the segment minimum safe altitudes.

The RNAV (GNSS) approach charts produced by Airservices did not include other limitations associated with the Jeppesen charts. More specifically, the Airservices charts showed the following.

- The profile-view diagram displayed the same number of segments (and waypoints) as the plan-view diagram.
- The distance to the missed approach point was displayed under the profile-view diagram for two waypoints prior to the final approach fix and all intermediate altitude limiting steps.
- Intermediate altitude limiting steps were displayed on the profile-view diagram through shading indicating altitude limits but not by a position identifier in the same position and font as the waypoint identifiers.
- The offset between the final approach track and the runway centreline was depicted in degrees separately in a final approach track/runway orientation diagram in large type.

2.6.9 Terrain awareness and warning systems

Laboratory simulations by the GPWS manufacturer predicted that a terrain awareness and warning system (TAWS) should have provided a 'caution terrain' alert at about 32 seconds before impact, and a 'terrain terrain' alert followed by repetitive 'pull up' warning during the final 28 seconds before impact. In contrast, laboratory simulations for the standard GPWS, as fitted to VH-TFU, predicted that a single 'terrain terrain' alert of about 1-second duration at about 25 seconds before impact, followed by a second 'terrain terrain' alert and then a repetitive 'pull up' warning for the final 5 seconds of the flight.

TAWS provided further advantages compared with standard GPWS, including an improved situational awareness of the terrain due to the provision of visual information prior to aural alerts or warnings, and continuous aural warnings with a longer duration. The forward looking terrain alerting feature does not rely on the radio altimeter.

In summary, TAWS has many design advantages over GPWS. Given these advantages, and their history of service to date, it is probable that had a TAWS been fitted to VH-TFU and been operating, the accident would not have occurred.

In accordance with CAO 20.18, up to the end of June 2005, it was acceptable for VH-TFU to be fitted with standard GPWS. After that time, VH-TFU would have been required to have been fitted with a TAWS. Given the inherent risk of the environment in which Transair was operating, Transair could have elected to fit a TAWS prior to the required date (see also Section 2.7.2).

2.6.10 Autopilot

An autopilot has the capacity to significantly reduce crew workload. Most pilots of autopilot-equipped aircraft interviewed by the investigation, and respondents to the ATSB pilot survey operating Category B and C aircraft with autopilots installed, indicated that they normally used the autopilot when conducting an RNAV (GNSS) approach.

An autopilot was not installed in VH-TFU. There was also no regulatory requirement for an autopilot to be installed on an aircraft engaged in RPT operations with two pilots.

An autopilot can significantly reduce crew workload during the cruise and descent phases of flight, therefore assisting the crew to conduct approach planning and briefings. However, for an autopilot to be useful during a non-precision instrument approach, it has to be of sufficient capability. Operators have reported that the autopilots available for Metro aircraft are limited in capability. In addition, some of the pilots interviewed with experience using autopilots on the Lockhart River Runway 12 RNAV (GNSS) approach indicated that the turbulence sometimes resulted in the autopilot being unable to maintain effective control of the aircraft.

Therefore, it is likely that an autopilot, if it was installed on VH-TFU, would not have been used by the crew during the latter phase of the instrument approach on the accident flight. However, it may have been useful in allowing the crew to be better prepared for the approach.

2.6.11 Other risk controls

GPS receiver display design

The GPS unit fitted to VH-TFU had several limitations compared with more recent models. These included the limited usefulness of the moving map display because of the vertical size of the LCD screen size, the lack of an option to display a distance to the missed approach point throughout the approach, and the lack of any form of vertical advisory guidance.

There was no regulatory requirement for an operator to continually upgrade the GPS system fitted to an aircraft and, given the rapid pace of technological change, it was unreasonable to expect operators to do so.

Certified air/ground service

The aerodrome did not have a Certified Air/Ground Service nor was this service required by the relevant aviation regulations. If such a service had been available, it may have provided the crew with an additional source of weather information during the accident flight.

However, the crew were aware of the weather conditions at Lockhart River, based on weather forecasts, and their previous approach and landing at Lockhart River less than 2 hours prior to the accident. Given this awareness, it is unlikely that the presence of a Certified Air/Ground Service would have affected the crew's decision to conduct the Lockhart River Runway 12 RNAV (GNSS) approach.

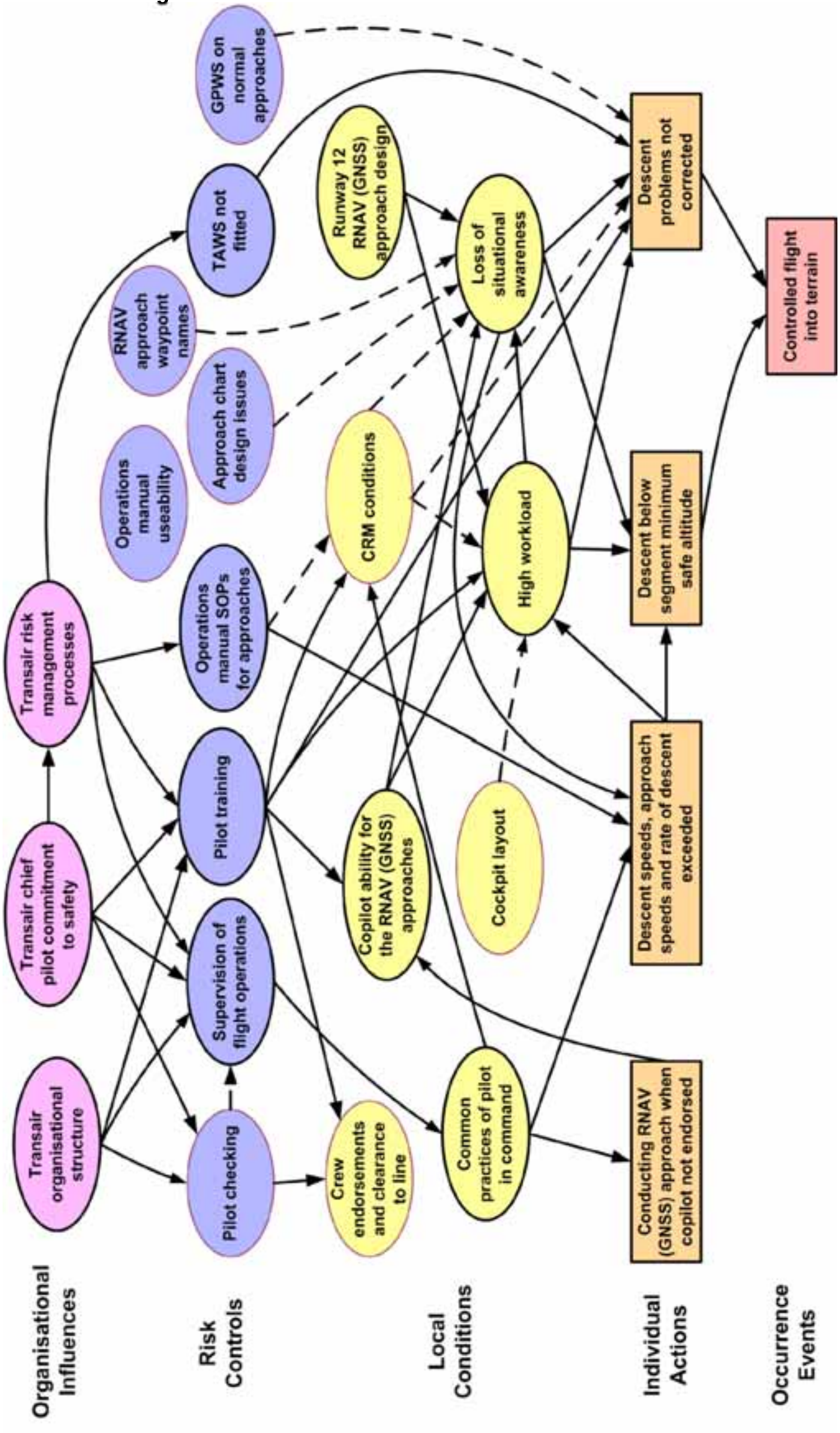
2.7 Organisational influences – Transair

As noted in Section 2.6, there were limitations with several of Transair's risk controls related to assuring the safety of its flight operations. The investigation identified reasons for these limitations in terms of:

- organisational structure;
- risk management processes; and
- demonstrated management commitment to safety.

The relationship betweens these factors and other safety factors identified during the investigation is shown in Figure 45.

Figure 45: Individual actions, local conditions, risk controls and Transair organisational factors



2.7.1 Organisational structure

Transair had grown, under the same chief pilot, from a charter operator since 1989 to a regular public transport (RPT) operator in 2001, followed by a major expansion of RPT passenger operations in New South Wales during 2004. By 2005, the organisation had five operational bases, 25 pilots (including about 15 Metro pilots), and a diverse range of commercial operations. Despite this size and complexity, the organisational management structure had not changed since February 2000, when the maintenance controller was employed.

Throughout this time, one person held three key management positions: chief pilot, head of training and checking, and managing director (chief executive officer). The chief pilot was supported by two other management personnel; a maintenance controller who was also the safety manager from late 2001, and an office-based operations manager who provided administrative support to the chief pilot.

In addition to the duties associated with his three management roles, the chief pilot's work demands were increased by the following duties and factors.

- The chief pilot conducted most of the Metro and Citation endorsement training conducted by Transair, which involved about 12 endorsements a year. This number of endorsements, conducted on a one-to-one basis and to an appropriate standard for pilots with no previous turbine experience, would require about 12 weeks work a year. As noted in Section 2.6.1, the chief pilot did not spend as much time conducting this training as specified in the *Transair Operations Manual*, although it still would have represented a significant workload.

- The chief pilot conducted most of the base checks and about half of the line checks for the Transair RPT pilots. This should have involved up to 30 base checks per year for the 15 Metro pilots, together with about half of the line checks and checks to line for new pilots. These checks should have required many weeks work (including time for travel). As noted in Section 2.6.2, not all of the required proficiency checks were conducted. However, the checks conducted by the chief pilot still represented a significant workload.

- According to the *Transair Operations Manual*, the chief pilot was supported in his duties by a deputy chief pilot. This position was filled to satisfy CASA's concern that there was no one to perform the chief pilot's role during his absences. However, the deputy chief pilot reported that he never conducted the check and training duties outlined in the *Transair Operations Manual*, and the chief pilot never delegated his duties to the deputy chief pilot in his absence. In effect, the deputy chief pilot appeared to be a position on paper only and did little, if anything, to reduce the chief pilot's workload.

- The *Transair Operations Manual* listed another check and training pilot for the Metro fleet, who was employed on a contractual as-needed basis. However, this contractor reported that he had minimal involvement in Transair's check and training system.

- The chief pilot also conducted check and training work for other Australian operators. In addition, he was a shareholder and director of an affiliated company, Trans Air Limited in Papua New Guinea. This involved visits to PNG, estimated to be between six to 12 times a year.

There were three main problems associated with the organisational structure and the minimal delegation of training and checking tasks.

- It was difficult for the chief pilot to conduct all of his required or selected duties to an appropriate standard, frequency or duration. The task demands could explain the problems with the duration of the ground component of endorsement training, the extent of supervision and other duties.
- Most of the key operational decisions, and the training and checking, were done by the same person. This resulted in few independent reviews of flight operational standards by, and professional feedback and input from, a CASA-approved check pilot. CASA conducted a small number of en route flight inspections, but these were limited in their ability to detect problems as the inspectors were not seated in the cockpit and were generally not familiar with the operator's procedures or were not endorsed on the aircraft type.
- There were limited options available for pilots to report concerns regarding operational matters. Problems could either be reported to the chief pilot or the safety manager, who had a maintenance background and reported to the chief pilot. If a pilot reported concerns to the chief pilot, but was not satisfied with the response, there were effectively no other avenues to address the problem with Transair. Several pilots reported that they had not received satisfactory responses to concerns raised with the chief pilot.

In summary, the organisational structure of Transair was significantly less than optimal, and this reduced the capacity of the operator to train, check, and monitor the quality of flight operations.

Limitations in Transair's organisational structure also appeared to exist in the area of maintenance control. The maintenance controller reported that his workload led him to be 'stretched' at times. Problems with his workload had been noted by CASA in the August 2004 audit report.

2.7.2 Risk management processes

Transair introduced an aviation safety manual in September 2003, which outlined a process for identifying hazards and analysing the risk associated with those hazards. The safety manual referred to two means of identifying hazards; employee hazard / incident reports and audits. Reported hazards and incidents were entered into a computer database and a risk value assigned, based on likelihood and consequences, by the safety manager, who then followed up on any issue that he assessed as warranted.

There were limitations associated with the way the risk management process was outlined in the Transair manual and implemented in practice. These limitations included the following.

- The Transair process primarily focussed on identifying hazards through pilot reports of incidents. Incident reports are a reactive means of identifying problems, and they need to be supplemented by proactive methods.
- The proactive method outlined in Transair's safety manual for identifying hazards with existing operations was through audits. The manual stated that the safety manager was responsible for conducting audits, but there

was no discussion in the manual about the process for doing audits, or the scope of audits. Although audits were reportedly conducted for airworthiness and maintenance-related issues, consistent with the safety manager's background, there was no evidence that any audits or systematic reviews of flight operations were conducted for the Cairns base. A review of flight operations at a New South Wales base occurred in September 2004, but there appeared to be no management response to the problems identified during that review.

- There was no discussion in the safety manual of identifying hazards associated with changes to procedures or the introduction of new operations. There was also no apparent understanding within Transair of the importance or method for reviewing changes to operations to identify potential hazards.
- None of Transair's management, including the safety manager, had received training in risk management, even though such training was widely available.
- The processes in the safety manual were not always followed. In particular, operational incidents reported within the safety program were not forwarded to the Australian Transport Safety Bureau as required by Transair's safety manual, the *Transport Safety Investigation Act 2003* and Transport Safety Investigation Regulations 2003.
- The chief pilot did not appear to have a strong role in promoting the safety program or encouraging the participation of pilots in processes to enhance safety (see also Section 2.7.3). Although the chief pilot needed to delegate some of his responsibilities to help manage his workload, he was still responsible for the safety of Transair's operations. Accordingly, he needed to have an active involvement in the safety program but his limited involvement severely reduced the program's capacity to provide benefit to the flight operations of Transair.

One example of the lack of systematic risk management was the decision to have pilots based in Cairns who did not have RNAV (GNSS) approach qualifications. Supervisory pilots had identified that this represented a hazard, due to the only instrument approaches into Bamaga being RNAV (GNSS) approaches. They had reported this concern to the chief pilot, but there was no evidence that the concern had been systematically assessed, and appropriate feedback provided to the pilots. The *Transair Operations Manual* did contain a requirement that the final (122 NM) route segment into Bamaga was required to be flown into visual conditions. This requirement was not practicable and not adopted by Transair's pilots.

Another key example of the lack of systematic risk management was the initiation of RPT flights into Lockhart River. Transair produced aircraft performance charts and one engine inoperative procedures as required by CASA. However, there was no evidence that there was any systematic attempt to identify potential hazards associated with the operation to Lockhart River. It would have been appropriate for Cairns-based pilots to be involved in such a risk assessment, and for the operations to be reviewed after a period of time. However, there was no evidence that Cairns-based pilots had any involvement in the decision to commence RPT operations to Lockhart River and no evidence of trial flights, systematic analysis of hazards, or discussions with other operators.

Hazards that may have been identified if such a formal risk assessment had been conducted included:

- the relatively complex nature of the runway 12 RNAV (GNSS) approach;
- the proximity of terrain under the runway 12 RNAV (GNSS) approach track;
- intensity of turbulence on the runway 12 RNAV (GNSS) approach;
- the likelihood of GPWS alerts and warnings during a normal approach; and
- an NDB approach requiring circling to land onto runway 12.

Potential risk controls that could have been implemented to mitigate the risks associated with the above hazards could have included not permitting the use of the approach, specified content for additional briefings, increased pilot training and checking on RNAV (GNSS) approaches, installation of TAWS, development of stabilised approach procedures, and specific procedures or minimum pilot qualifications for the Lockhart River approach (or a review of approach procedures in general). These risk controls had not been implemented by Transair.

2.7.3 Demonstrated management commitment to safety

Senior management commitment to safety, and line pilots' perceptions of this commitment, is widely recognised as being one of the most essential factors for improving and maintaining the effectiveness of a safety management system. There are many ways that senior management can demonstrate their commitment. However, in the case of Transair, there was significant evidence to suggest that the chief pilot did not demonstrate a high level of commitment to safety.

- Company practices, conducted by or with the knowledge of the chief pilot, did not comply with the *Transair Operations Manual* or regulatory requirements. These included proficiency checks not being completed at the required frequency, some checks being conducted by pilots who were not CASA-approved check pilots, and not providing CRM training to pilots.
- The ground school training conducted by the chief pilot was generally limited in nature. The resulting level of systems knowledge of new copilots was of concern to supervisory pilots and the contractor check pilot.
- The chief pilot reportedly did not adequately respond to advice about various operational concerns, such as Cairns-based pilots not having an RNAV (GNSS) approach endorsement.
- There was limited supervision of the Cairns base pilots.
- There was a lack of flight standards meetings and internal audits of flight operations at the Cairns base.
- Operation of RPT services into Bamaga and Lockhart River commenced prior to formal AOC authorisation to do so.
- Aircraft were used on RPT services that were either not approved for RPT use or not included on Transair's AOC, even after the chief pilot was specifically directed not to use a particular aircraft on RPT operations.

- The chief pilot did not appear to actively promote the company's safety program, either informally or formally through the safety policy outlined in the safety manual.
- There was no evidence that Transair had advised CASA that it had addressed any of the audit observations raised by CASA during audits.

A higher level of commitment to safety by the Transair chief pilot, in his roles of chief pilot, managing director, and head of training and checking, should have resulted in more attention being applied to risk management and the supervision of flight operations. In addition, the day-to-day flight operations by line pilots were conducted in the context of the safety climate set by the chief pilot. A higher level of demonstrated senior management commitment to safety should have increased the respect among line pilots for the *Transair Operations Manual*, standard operating procedures, and the reporting of hazards and establishing their mitigation.

2.8 Organisational influences – CASA

An Air Operator's Certificate (AOC) holder had a clearly defined responsibility under the *Civil Aviation Act 1988* to ensure the safety of its operations. The regulator, CASA, also had defined responsibilities for oversighting the activities of an AOC holder, through the processes of approving AOC variations and other permissions, as well as conducting surveillance of the activities of the operator.

AOC approval and surveillance processes will always have constraints in their ability to detect problems. There is restricted time available for these activities. Regulatory surveillance is also a sampling exercise, and cannot examine every aspect of an operator's activities, nor identify all the limitations associated with these activities. In addition, to a large extent AOC approval and surveillance processes have to focus on regulatory requirements, which provide legal checks and a minimum standard of safety, rather than safety management processes that can exceed these minimum standards.

Despite these constraints, CASA still had significant interaction with Transair, through the conduct of scheduled audits and a series of approval activities, as well as other activities such as the assessment of a complaint from a company pilot. As a result of these interactions (most notably its audits), CASA identified areas for improvement in Transair's procedures and practices, primarily in the area of maintenance control. However, it did not detect fundamental problems associated with the Transair's management of RPT flight operations, such as the problems with pilot training, pilot checking, supervision of line flight operations, standard operating procedures, operations manual format useability, organisational structure, risk management processes and demonstrated management commitment to safety outlined in Sections 2.6 and 2.7.

Given the significance of the problems within Transair, and the amount of interaction CASA had with the operator, it is reasonable to conclude that some of these problems should have been detected by CASA. In considering the reasons why these problems with Transair were not detected, the investigation identified safety factors in the following areas:

- consistency of oversight activities with CASA policies, procedures and guidelines;

- guidance for evaluating management systems;
- risk assessments for changes in operations;
- regulatory requirements for safety management systems;
- guidance for evaluating the useability of operations manuals; and
- processes for assessing an operator's risk profile.

In addition, limitations were identified with CASA's processes for validating instrument approaches.

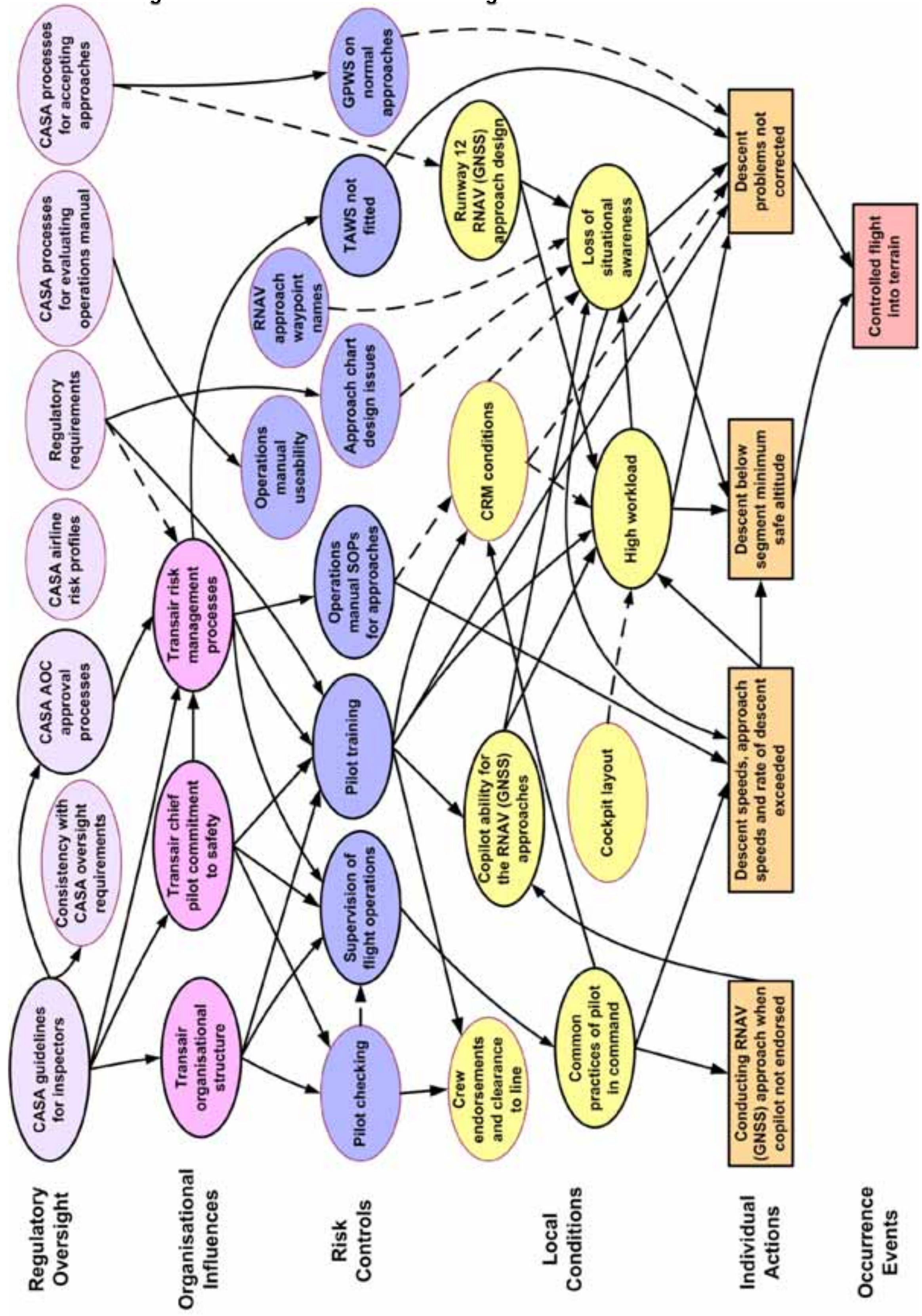
The relationship between these factors and other factors identified during the investigation is shown in Figure 46.

2.8.1 Consistency of oversight activities with CASA policies, procedures and guidelines

There were instances where CASA's oversight of Transair did not appear to be consistent with CASA's own requirements and guidelines.

- The initial approval for Transair to conduct RPT (cargo) operations in October 1999 did not appear to be subject to a full evaluation process consistent with CASA's AOC Manual. More specifically, proving flights and port inspections were not completed before the approval of operations.
- Transair's application to add the Inverell – Brisbane route to its AOC was recommended for approval by the Brisbane airline office on 7 April 2004. However, on 8 April, the airworthiness inspector who had assessed the application recommended that the approval not be processed until Transair demonstrated that it had adequate maintenance control in place. The AOC was issued on 8 April by a delegate in Canberra, and no information addressing the airworthiness inspector's concerns was recorded on file. The extent to which the delegate in Canberra had been made aware of the airworthiness concerns could not be determined.
- The first systems-based audit in December 1999 identified several significant management problems. Transair provided undertakings to address these problems, yet there was no explicit monitoring of Transair's implementation of the agreed improvements. In addition, there was no recorded evidence that CASA completed the activities it proposed to do, such as ensuring that Transair submitted weekly progress reports and conducting a special audit 90 days after the agreement.
- After Transair recommenced RPT operations in September 2001, CASA generally conducted scheduled audits about every 6 months, in accordance with CASA's specified schedule for airline operations. However, the August 2002 audit primarily focussed on Transair's helicopter charter operations. Therefore, there was a period of 15 months between November 2001 and February 2003 when minimal auditing of the operator's RPT passenger operations was conducted.

Figure 46: Individual actions, local conditions, risk controls, Transair organisational factors and CASA organisational factors



- The systems-based audit approach was intended to be conducted with multi-disciplinary audit teams. However, three of the seven audits after September 2001 were conducted with only one inspector.
- There was no indication on CASA files that Transair had responded to any of the audit observations raised by CASA since it started systems-based audits of the operator in December 1999. Although compliance was not a legal requirement, CASA could have used this pattern of response as a basis for additional surveillance activity, or as an indication of suitability when approving further expansions to Transair's RPT operations. There was no indication that the pattern of response was considered.
- CASA reported that it had been attempting to encourage operators to implement CRM training. However, there was no evidence on the audit files that CASA had examined this issue or discussed this issue with Transair. If CASA had identified that Transair was not conducting CRM training as required by the *Transair Operations Manual*, it was unclear what action CASA would have undertaken. Inspectors had different views as to whether to issue requests for corrective action (RCAs) or CAR 215 directions, or to encourage the operator through other means such as audit observations.
- The *Surveillance Procedures Manual* stated that inspectors should attempt to identify the 'root causes' of any deficiencies identified. This did not seem to occur in many cases reviewed by the investigation. For example, one audit identified that load sheets were not being left in Gunnedah, while Cairns-based pilots revealed to the investigation that they had no process in place to leave load sheets in Bamaga. Other examples include findings dealing with specific instances in the August 2004 audit that were then repeated in the February 2005 audit at a different location (dealing with passenger briefings, exit row passengers and stowage of carry-on luggage).

There may have been many reasons for these inconsistencies with internal requirements and guidelines. Possible reasons include resource limitations and a perception that Transair was not a high-risk operator, based on inspectors' views of the piloting and training skills of the chief pilot and/or the May 2003 safety trend indictor (STI) score (see also Section 2.8.3).

Even if CASA had fully met its own requirements and guidelines, there was insufficient evidence to conclude that it would have detected and corrected the fundamental problems with Transair's operations as outlined above.

2.8.2 Guidance for evaluating management systems

The introduction of systems-based surveillance in 1999 significantly enhanced CASA's potential for identifying underlying problems with how operators manage safety. Assessments of an organisation's management systems necessarily involve the use of professional judgement by inspectors. To ensure that such judgements were appropriate, CASA needed to ensure that its inspectors had the appropriate skills to make judgements on management systems, or had an appropriate amount of guidance material to assist them in making these judgements.

CASA had not developed robust guidance material to assist inspectors with their evaluations of management systems, or included personnel on systems-based audits with significant expertise in safety management systems. Although some CASA inspectors probably had sufficient background and skills to conduct assessments in these areas, the guidance provided did not ensure that all of the airline inspectors had these competencies.

In other words, CASA had not provided itself with assurance that key components of an operator's management systems were able to be effectively examined by its inspectors. In the context of Transair, there were limitations in guidance evident in the following areas:

- evaluating organisational structure and staff resources;
- evaluating the suitability of key personnel;
- evaluating organisational change; and
- evaluating risk management processes.

There also appeared to be limitations in the guidance provided for obtaining information from operational personnel during oversight activities.

In late 2004, CASA had recognised the limitations of the competencies of its inspectors to conduct assessments of system safety issues. However, efforts to address these limitations had not taken effect by the time of the accident.

Guidance for evaluating organisational structure and staff resources

Section 28 of the *Civil Aviation Act 1988* outlined a number of conditions that an operator had to meet before being issued with an AOC, including the organisation having an appropriate chain of command and having a sufficient number of suitably qualified and competent personnel. CASA's AOC Manual and *Surveillance Procedures Manual* each contained requirements for inspectors to consider whether an organisation had an appropriate structure and sufficient personnel to carry out the required functions of the organisation.

Despite the obvious importance of ensuring an organisation had an appropriate number of personnel, and that the workload of key personnel was not excessive, CASA provided minimal guidance to its inspectors on how to evaluate these requirements. In terms of the suitability of an organisation's structure, the manuals provided a minimal amount of guidance, such as the preference stated in the AOC Manual for having different people for the chief pilot and head of training and checking roles 'where economies of scale permit'. However, there was no discussion of what size of organisations should have two separate people, and no detailed guidance on factors to consider when assessing the suitability of an organisation's structure, or whether an individual had excessive workload.

Organisations can vary greatly in terms of their size, structure and complexity, and it would be impracticable to provide detailed guidance about every specific situation that CASA inspectors may encounter. However, it would seem practicable to provide case examples of what was and was not considered appropriate, as well as a list of criteria to consider when making evaluations. Such guidelines could be developed based on CASA's past experience, the experience of other regulatory agencies, discussion with key industry groups, and findings from research into organisational behaviour in a variety of fields.

Some CASA staff noted that judgements about the adequacy of an organisation's resources are difficult. The fact that they are difficult judgements would support the importance of providing guidelines to assist inspectors with making assessments in these areas.

CASA had detected that the Transair chief pilot was 'stretched a bit thin' in 1998 and 1999, and it appeared some inspectors had concerns after this period. However, CASA had not apparently detected any further problems related to the structure of the organisation, and the resulting effect on the workload of the chief pilot, particularly during the expansions of operations in 2001 and 2004.

Had CASA provided more detailed guidance to its inspectors for assessing organisational structures and staff resources, it would be reasonable to expect that the problems associated with Transair's organisational structure and chief pilot workload after Transair commenced RPT operations would probably have been identified.

Guidance for evaluating the suitability of key personnel

The specified processes for evaluating the suitability of a chief pilot candidate focused on the candidate's abilities to fly an aircraft, and had minimal focus on the person's abilities to manage operations and manage safety. For airline operations in particular, a more detailed, structured focus on the candidate's safety management abilities is needed.

In the case of the Transair chief pilot, he was appointed in 1989 as the chief pilot of a charter operator. The evaluation process at that time would have been more limited with regards to management abilities. The fact that the chief pilot of a charter operator can move into airline operations in the same position, without being reassessed in a structured manner as to his or her suitability, was a significant limitation with the approval processes.

A structured re-approval process, with more emphasis on safety management, when upgrading to RPT passenger operations had a significant potential to identify areas where further development was required in the case of the Transair chief pilot.

Guidance for evaluating organisational change

Transair had two periods of significant growth and change in operations: the introduction of RPT operations in north Queensland in 2001, and then the growth in RPT passenger operations into new routes in New South Wales in 2004. In both of these periods, CASA was required to conduct assessments of a series of applications for variations to Transair's AOC.

Each of these decisions needed to consider the merits of the relevant application by the operator. Although the CASA inspectors involved in making these decisions were presumably aware of other recent approvals that had been given, there was no mechanism that required them to review the impact of a series of recent decisions as a whole, or guidance on how to conduct such an evaluation.

In summary, a series of incremental changes could be made to an organisation's activities, each with the approval of CASA. Each change by itself may be justified as having minimal impact, but overall may have had a significant impact. The inherent problem in considering each change in isolation has been termed the ‘tyranny of small decisions’.[221] If the overall pattern of change of Transair’s activities in either 2001 or 2004 had been taken as a whole, then different decisions may have been made about the suitability of the organisation’s structure, resources and systems.

By not making such decisions at the approval stage, the regulator was relying on its surveillance processes to detect and rectify any problems. The *Surveillance Procedures Manual* advised that organisational changes should be considered when developing the scope of an audit, and it appeared that CASA did focus on Transair’s new operations in New South Wales during 2004 and 2005. However, the guidance on examining an organisation’s change management processes was limited to a small number of general questions, and these focussed on identifying what changes had occurred rather than the adequacy of an organisation’s processes to manage the changes.

Guidance for evaluating risk management processes

It is widely agreed that, in safety-critical industries, organisations need structured processes for identifying hazards, analysing risks, treating risks and evaluating the effect of treatments. However, the ability of an operator to develop and implement these processes was not required to be evaluated during the process of approving variations to an AOC. CASA’s *Surveillance Procedures Manual* provided a small number of general questions for examining an organisation’s risk management processes during audits, but these questions focussed on detecting whether there were processes in place, rather than evaluating the quality or effectiveness of the processes, or the relevant competencies of the personnel who were managing or conducting the processes.

Although risk management processes were examined in some audits of Transair, these examinations did not appear to be of sufficient depth to identify problems with the quality or effectiveness of the operator’s processes.

An Australian Standard on risk management has existed since 1994, and CASA has promoted the use of risk management as part of its safety management educational materials since 1998. It would seem appropriate to use this material, and the available expertise in industry, to develop a detailed set of criteria or questions to use when evaluating the quality and effectiveness of an operator’s risk management processes.

Guidance for obtaining information from operational personnel

Basic audit methodology includes obtaining information from a variety of sources, including the personnel who are required to conduct the activities being audited. However, CASA’s approval and surveillance processes appeared to primarily focus on obtaining information from management personnel. A more robust process would involve regularly obtaining information from other personnel, including those fulfilling an important role in facilitating and monitoring operational standards, such as deputy chief pilots, check and training pilots, and base managers. A more robust process would also include guidance for obtaining information from operational personnel in a structured manner, as well as

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221 Odum, W. E. (1982). Environmental degradation and the tyranny of small decisions. *BioScience, 32*, 728-729.

mechanisms to encourage such personnel to provide information on management processes and operational standards.

Conducting discussions with samples of operational personnel takes time, and it is possible that some information obtained through such discussions would be malicious or difficult to substantiate. However, such discussions have a real potential for identifying problems that would not be detected through discussions with senior management, reviews of documentation or product inspections.

Had structured discussions with line personnel been conducted over the period when Transair was conducting RPT operations, it is reasonable to conclude that some of the problems associated with the operator's management systems that were identified during the ATSB investigation would have become apparent to CASA.

2.8.3 Risk assessments for changes in operations

The process for an AOC holder to apply to CASA to vary its AOC involved the AOC holder making an application to CASA. The variation could be for the addition or removal of aircraft, operating routes, and facilities. CASA conducted an assessment of whether Transair had the appropriate processes and resources to undertake the requested change. The processes used by CASA did not appear to involve a structured and/or comprehensive risk assessment of the proposed change. In particular, there was no procedural requirement for CASA inspectors to consider the suitability of an operator's procedures, training and equipment for conducting instrument approaches at new ports.

CASA could require an operator to supply further technical information than what was provided in an operator's application before approving the request. However, there was no requirement for operators to provide a formal risk assessment or safety case for significant changes in its operations. A requirement for a formal risk assessment or safety case, and an appropriate assessment of this by CASA, would help ensure that an operator considered and mitigated potential risks before a new AOC was issued by CASA.

2.8.4 Regulatory requirements for safety management systems

Although CASA released a discussion paper in 2000, and further development had occurred since then, there was no regulatory requirement for operators to have a safety management system. The lack of specific regulatory requirements for safety management systems meant that CASA had less capacity to issues RCAs to effect changes in operator's processes in areas such as risk management or change management.

However, there were still general regulatory requirements for CASA to ensure that an AOC holder could conduct operations safely. In addition, the use of audit observations was a mechanism to facilitate improvements by organisations, providing that responses to such observations were actively monitored and used to help to determine an operator's overall suitability.

Transair's safety program was in effect a safety management system. However, as discussed in Section 2.7, there were significant limitations with the quality of Transair's system. The extent to which specific regulatory requirements in this area would have improved the quality of the system, without effective regulatory oversight from CASA, could not be determined.

2.8.5 Processes for assessing an operator's risk profile

The safety trend indicator (STI) was a tool that was introduced by CASA to determine the relative risk level of operators. The last STI score in May 2003 was markedly better than previous scores, all of which had indicated that Transair was a 'high risk' operator. The reason for a significant reduction in STI score could not be determined but there had been no substantial change in Transair's operations since the previous STI assessment in October 2002. Had further STIs been conducted by a range of CASA inspectors, they may have indicated that Transair had returned to a 'high risk' operator status due to a range of issues such as the significant expansion of operations during 2004.

When the decision was made to only use STIs for general aviation operators, it meant that CASA was left with less potential to measure and track risk levels for airline operators, or identify when to conduct special audits or spot checks based on the assessed risk of an operator. CASA has been developing new methods of evaluating the risk levels of airline operators. However, no such method had been implemented at the time of the accident. Financial viability assessments had also not been conducted on Transair.

Any risk rating method would require data inputs from multiple data sources, including previous audit findings and occurrence reports. In the case of Transair, there were limitations in both of these types of data. Consequently, it is unclear whether a systematic process for assessing the risk level of airline operators would have identified Transair as an operator requiring increased surveillance activity.

2.8.6 Guidance for evaluating the useability of operations manuals

CASA did not provide any guidance to its staff on how to evaluate an operations manual in electronic format. This lack of guidance meant that it was possible for operators to produce electronic manuals with limited useability. Any factor that decreased the level of useability of an operations manual directly reduced the level of safety originally intended to be provided by the manual.

It is probable that many more operators will change to an electronic operations manual in the future. Therefore, CASA inspectors need to have guidance material to ensure that they can effectively evaluate the suitability of such manuals.

2.8.7 Processes for validating instrument approaches

CASA's procedure for accepting an instrument approach involved a validation flight. During the validation process for the Lockhart River Runway 12 RNAV (GNSS) approach, the CASA officer who accepted the Airservices design ticked the 'fly-ability' check box on the validation form. However, the validation flight process did not attempt to replicate normal approach checks and procedures, did not exceed Category B speed limits, was in visual meteorological conditions and used a highly experienced pilot. As a result, the workload of the validation process would have been considerably lower than that experienced by the accident crew.

In addition, the validation process did not systematically consider other hazards associated with the approach. For example, a systematic assessment of the hazards of the Lockhart River Runway 12 RNAV (GNSS) approach should have identified factors such as GPWS annunciations when flying the published approach (see Section 2.6.6), the turbulence routinely generated by the wind flowing over the South Pap ridge line, nature of terrain information provided on the chart, steeply rising terrain under the approach giving reduced time to respond to any altitude deviation, the lack of any indication on the approach chart of the South Pap ridge directly under the flight path, and an expectation of terrain close to the approach path that could desensitise pilots to abnormal proximity to terrain. These factors could have then been considered in deciding whether to accept the approach, or to introduce appropriate risk mitigators if required.

When RNAV (GNSS) approaches were first introduced in Australia, there was an industry consultation period. However, no such feedback was actively sought when new approaches were introduced, or after they had been in place for a period of time. The chief pilot stated that he reported to CASA that the Lockhart River Runway 12 RNAV (GNSS) approach was particularly difficult but was told that, as it was within the PANS-OPS criteria, there was nothing that could be done.

Overall, CASA's process for accepting an instrument approach did not involve a systematic risk assessment of pilot workload, activation of the GPWS, and other potential hazards.

2.8.8 Other issues

There may have been many others reasons why specific problems in Transair's operations were not detected during CASA surveillance activities. For example, CASA's audits examined flight crew training issues on several occasions, but did not detect the problems associated with the frequency of proficiency checks, and that some line checks were being conducted by pilots who were not approved check pilots. The detail on the audit files was not sufficient to determine in some cases what aspects of flight crew training were examined. It appears that at least one inspector did not have an appropriate understanding of some of the requirements. An increased use of available checklists, or the development of more detailed checklists, may also have improved the chances of detecting the problems with Transair's training and checking processes.

As already discussed in Section 2, regulatory requirements were limited or non-existent in areas such as CRM training, crew coordination training and procedures, required endorsements to conduct instrument approaches, and safety management systems. Guidance information provided by CASA on the contents of the operations manual was also limited. Had some of these requirements or guidance material been in place, then CASA inspectors may have focussed more attention in these areas, and been more likely to identify limitations in Transair's procedures and practices.

3 FINDINGS

3.1 Context

Weather conditions in the Lockhart River area were poor and necessitated the conduct of an instrument approach procedure to attempt any arrival at the aerodrome. The cloud base was probably between 500 ft and 1,000 ft above mean sea level and the terrain to the west of the aerodrome was probably obscured by cloud. The aircraft overflew some of this terrain during the Lockhart River Runway 12 RNAV (GNSS) approach. The aircraft encountered turbulence during the final stage of this approach.

As the copilot was making the CTAF transmissions and other communications during the flight, including at the start of the approach, it is very likely that the pilot in command was the pilot flying the aircraft. The practice of the non-flying pilot making the radio broadcasts was reflected in the *Transair Operations Manual* and the operator's normal practices, and was consistent with industry practice worldwide.

A safety factor is an event or condition that increases risk. The safety factors identified during the investigation were classified as either 'contributing safety factors' or 'other safety factors' (see page xviii). It is possible that 'other safety factors', such as inadequate crew resource management, contributed significantly to the accident, but the investigation had insufficient evidence to make this determination. Some factors will never be known due to the absence of cockpit voice recorder information and witnesses, as well as the destruction of the aircraft.

For the purposes of enhancing safety, 'other safety factors' may be just as important as contributing safety factors or more so. Safety factors of both types can be classified as 'safety issues'. Safety issues are the safety factors that should be addressed to enhance the safety of future transport operations. Consistent with ICAO recommendations, safety issues identified during an investigation that are found not to have been contributing factors should also be addressed in the final investigation report.

3.2 Contributing safety factors

A 'contributing safety factor' is defined as a safety factor that, if it had not occurred or existed at the relevant time, then either:

- the occurrence would probably not have occurred;
- the adverse consequences associated with the occurrence would probably not have occurred or have been as serious; or
- another contributing safety factor would probably not have occurred or existed.

In this context, the term 'probably' is defined as meaning a likelihood of more than 66 per cent.

3.2.1 Contributing factors relating to occurrence events and individual actions

- The crew commenced the Lockhart River Runway 12 RNAV (GNSS) approach, even though the crew were aware that the copilot did not have the appropriate endorsement and had limited experience to conduct this type of instrument approach.
- The descent speeds, approach speeds and rate of descent were greater than those specified for the aircraft in the *Transair Operations Manual*. The speeds and rate of descent also exceeded those appropriate for establishing a stabilised approach.
- During the approach, the aircraft descended below the segment minimum safe altitude for the aircraft's position on the approach.
- The aircraft's high rate of descent, and the descent below the segment minimum safe altitude, were not detected and/or corrected by the crew before the aircraft collided with terrain.
- The accident was almost certainly the result of controlled flight into terrain.

3.2.2 Contributing factors relating to local conditions

- The crew probably experienced a very high workload during the approach.
- The crew probably lost situational awareness about the aircraft's position along the approach.
- The pilot in command had a previous history of conducting RNAV (GNSS) approaches with crew without appropriate endorsements, and operating the aircraft at speeds higher than those specified in the *Transair Operations Manual*.
- The Lockhart River Runway 12 RNAV (GNSS) approach probably created higher pilot workload and reduced position situational awareness for the crew compared with most other instrument approaches. This was due to the lack of distance referencing to the missed approach point throughout the approach, and the longer than optimum final approach segment with three altitude limiting steps.
- The copilot had no formal training and limited experience to act effectively as a crew member during a Lockhart River Runway 12 RNAV (GNSS) approach.

3.2.3 Contributing factors relating to Transair processes

- Transair's flight crew training program had significant limitations, such as superficial or incomplete ground-based instruction during endorsement training, no formal training for new pilots in the operational use of GPS, no structured training on minimising the risk of controlled flight into terrain, and no structured training in crew resource management and operating effectively in a multi-crew environment. (*Safety Issue*)
- Transair's processes for supervising the standard of flight operations at the Cairns base had significant limitations, such as not using an independent approved check pilot to review operations, reliance on passive measures to

detect problems, and no defined processes for selecting and monitoring the performance of the base manager. (*Safety Issue*)

- Transair's standard operating procedures for conducting instrument approaches had significant limitations, such as not providing clear guidance on approach speeds, not providing guidance for when to select aircraft configuration changes during an approach, no clear criteria for a stabilised approach, and no standardised phraseology for challenging safety-critical decisions and actions by other crew members. (*Safety Issue*)
- Transair had not installed a terrain awareness and warning system, such as an enhanced ground proximity warning system, in VH-TFU.
- Transair's organisational structure, and the limited responsibilities given to non-management personnel, resulted in high work demands on the chief pilot. It also resulted in a lack of independent evaluation of training and checking, and created disincentives and restricted opportunities within Transair to report safety concerns with management decision making. (*Safety Issue*)
- Transair did not have a structured process for proactively managing safety-related risks associated with its flight operations. (*Safety Issue*)
- Transair's chief pilot did not demonstrate a high level of commitment to safety. (*Safety Issue*)

3.2.4 Contributing factors relating to the Civil Aviation Safety Authority's processes

- CASA did not provide sufficient guidance to its inspectors to enable them to effectively and consistently evaluate several key aspects of operator management systems. These aspects included evaluating organisational structure and staff resources, evaluating the suitability of key personnel, evaluating organisational change, and evaluating risk management processes. (*Safety Issue*)
- CASA did not require operators to conduct structured and/or comprehensive risk assessments, or conduct such assessments itself, when evaluating applications for the initial issue or subsequent variation of an Air Operator's Certificate. (*Safety Issue*)

3.3 Other safety factors

An 'other safety factor' is defined as a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report.

3.3.1 Other factors relating to local conditions

- There was a significant potential for crew resource management problems within the crew in high workload situations, given that there was a high trans-cockpit authority gradient and neither pilot had previously demonstrated a high level of crew resource management skills.

- The pilots' endorsements, clearance to line operations, and route checks did not meet all the relevant regulatory and operations manual requirements to conduct RPT flights on the Metro aircraft.
- Some cockpit displays and annunciators relevant to conducting an instrument approach were in a sub-optimal position in VH-TFU for useability or attracting the attention of both pilots.

3.3.2 Other factors relating to instrument approaches

- Based on the available evidence, the Lockhart River Runway 12 RNAV (GNSS) approach design resulted in mode 2A ground proximity warning system alerts and warnings when flown on the recommended profile or at the segment minimum safe altitudes. (*Safety Issue*)
- The Australian convention for waypoint names in RNAV (GNSS) approaches did not maximise the ability to discriminate between waypoint names on the aircraft global positioning system display and/or on the approach chart. (*Safety Issue*)
- There were several design aspects of the Jeppesen RNAV (GNSS) approach charts that could lead to pilot confusion or reduction in situational awareness. These included limited reference regarding the 'distance to run' to the missed approach point, mismatches in the vertical alignment of the plan-view and profile-view on charts such as that for the Lockhart River runway 12 approach, use of the same font size and type for waypoint names and 'NM' [nautical miles], and not depicting the offset in degrees between the final approach track and the runway centreline. (*Safety Issue*)
- Jeppesen instrument approach charts depicted coloured contours on the plan-view of approach charts based on the maximum height of terrain relative to the airfield only, rather than also considering terrain that increases the final approach or missed approach procedure gradient to be steeper than the optimum. Jeppesen instrument approach charts did not depict the terrain profile on the profile-view although the segment minimum safe altitudes were depicted. (*Safety Issue*)
- Airservices Australia's instrument approach charts did not depict the terrain contours on the plan-view. They also did not depict the terrain profile on the profile-view, although the segment minimum safe altitudes were depicted. (*Safety Issue*)

3.3.3 Other factors relating to Transair processes

- Transair's flight crew proficiency checking program had significant limitations, such as the frequency of proficiency checks and the lack of appropriate approvals of many of the pilots conducting proficiency checks. *(Safety Issue)*
- The *Transair Operations Manual* was distributed to company pilots in a difficult to use electronic format, resulting in pilots minimising use of the manual. (*Safety Issue*)

3.3.4 Other factors relating to regulatory requirements and guidance

- Although CASA released a discussion paper in 2000, and further development had occurred since then, there was no regulatory requirement for initial or recurrent crew resource management training for RPT operators. (*Safety Issue*)
- There was no regulatory requirement for flight crew undergoing a type rating on a multi-crew aircraft to be trained in procedures for crew incapacitation and crew coordination, including allocation of pilot tasks, crew cooperation and use of checklists. This was required by ICAO Annex 1 to which Australia had notified a difference. (*Safety Issue*)
- The regulatory requirements concerning crew qualifications during the conduct of instrument approaches in a multi-crew RPT operation was potentially ambiguous as to whether all crew members were required to be qualified to conduct the type of approach being carried out. (*Safety Issue*)
- CASA's guidance material provided to operators about the structure and content of an operations manual was not as comprehensive as that provided by ICAO in areas such as multi-crew procedures and stabilised approach criteria. (*Safety Issue*)
- Although CASA released a discussion paper in 2000, and further development and publicity had occurred since then, there was no regulatory requirement for RPT operators to have a safety management system. (*Safety Issue*)
- There was no regulatory requirement for instrument approach charts to include coloured contours to depict terrain. This was required by a standard in ICAO Annex 4 in certain situations. Australia had not notified a difference to the standard. (*Safety Issue*)
- There was no regulatory requirement for multi-crew RPT aircraft to be fitted with a serviceable autopilot. (*Safety Issue*)

3.3.5 Other factors relating to CASA processes

- CASA's oversight of Transair, in relation to the approval of Air Operator's Certificate variations and the conduct of surveillance, was sometimes inconsistent with CASA's policies, procedures and guidelines.
- CASA did not have a systematic process for determining the relative risk levels of airline operators. (*Safety Issue*)
- CASA's process for evaluating an operations manual did not consider the useability of the manual, particularly manuals in electronic format. (*Safety Issue*)
- CASA's process for accepting an instrument approach did not involve a systematic risk assessment of pilot workload and other potential hazards, including activation of a ground proximity warning system. (*Safety Issue*)

3.4 Other key findings

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

- It was very likely that both crew members were using RNAV (GNSS) approach charts produced by Jeppesen.
- The cockpit voice recorder did not function as intended due to an internal fault that had developed sometime before the accident flight and that was not discovered or diagnosed by flight crew or maintenance personnel.
- There was no evidence to indicate that the GPWS did not function as designed.
- There would have been insufficient time for the crew to effectively respond to the GPWS alert and warnings that were probably annunciated during the final 5 seconds prior to impact with terrain.

4 SAFETY ACTIONS

This report identifies a range of safety issues. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than release formal safety recommendations.

All of the responsible organisations for the safety issues identified in the investigation were given a draft report in December 2006 and were given 60 days to respond to the draft. As part of this process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The section below details the safety actions communicated to the ATSB during the investigation and in response to the draft report. Where safety action was not forthcoming or not considered sufficient, the ATSB has issued additional safety recommendations.

This section also includes safety recommendations that were released during the investigation prior to the publication of this report, including those based on safety issues identified in the ATSB Aviation Safety Research and Analysis report *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches*. This section also details the responses provided and actions taken by organisations to these recommendations to date that have been advised to the ATSB.

4.1 Transair

A number of serious safety issues identified during the investigation related to Transair. It would normally be expected that an operator would undertake safety actions to address such issues as a result of its own initiatives or as a result of ATSB recommendations.

However, at the request of Transair, the Civil Aviation Safety Authority cancelled the Air Operator's Certificate issued to Lessbrook Propriety Limited, trading as Transair, on 4 December 2006. Transair ceased all operations from that date.

The ATSB has therefore not issued any safety recommendations to Transair.

4.2 Civil Aviation Safety Authority

The Civil Aviation Safety Authority (CASA) provided advice to the ATSB on 23 November 2006, prior to the release of the draft report, of safety action it had undertaken. CASA further advised the ATSB on 23 March 2007 of additional safety action.

CASA also provided responses on 6 March 2007 to recommendations from the ATSB Aviation Safety Research and Analysis Report 20050342 *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches*.

4.2.1 Approach to surveillance

On 23 November 2006, CASA advised the ATSB of the following.

> The surveillance focus has been substantially expanded from a concentration on compliance audits applied in a similar way to all industry sectors, regardless of relative risk, to one where risk is the key determinant of the level and nature of surveillance. There has also been a change in use of personnel, from a situation where inspectors could spend 60%-70% of their total time on administrative issues, for example, planning for and recording the results of the audit, to a more effective use of time by being in the field conducting a range of surveillance activities. Moreover, a reduced concentration on compliance audits has allowed resources to be directed to identifying broad industry system or management trends.
>
> Towards the end of 2004, CASA began development of a risk based approach to surveillance. During 2005 total surveillance was progressively increased through the use of less administratively intense surveillance tools – the 'time on the tarmac' concept – and the development of Operational Surveillance methods. From that time surveillance of the air transport sector has consisted of a combination of traditional audits and significantly increased operational surveillance (an average increase of around 60% from 2004 to 2006). CASA continues to develop refinements to surveillance of the air transport sector based on more effective risk assessment.
>
> In the latter part of 2005, having determined that the regional airline sector represented the highest air transport risk, work was undertaken to identify the highest risk passenger carrying operators, and a program of additional surveillance of them was initiated.

4.2.2 Guidance for evaluating management systems

Safety issue

CASA did not provide sufficient guidance to its inspectors to enable them to effectively and consistently evaluate several key aspects of operator management systems. These aspects included evaluating organisational structure and staff resources, evaluating the suitability of key personnel, evaluating organisational change, and evaluating risk management processes.

Response from Civil Aviation Safety Authority

Date received: 23 November 2006

> We have been addressing a clear requirement to enhance CASA's 'frontline' surveillance workforce capability. The need to assess the safety related decisions taken by industry management meant we needed people with management or safety management expertise and experience to support those with technical experience as a pilot or engineer. This requirement was enhanced by the increasing use of safety management systems (SMS) in aviation worldwide and the impending mandating of SMS for Australian aviation. CASA deployed its first safety system specialists in mid 2006, a capability that will have a particular focus on assessing regional airline safety management capability.

Date received: 23 March 2007

> CASA has, and continues to provide substantial guidance material in all aspects of surveillance. Inspectors are highly experienced and call upon professional judgement in assessing effectiveness of operators. Inspectors are recruited on the basis of this experience and professional judgement and are required to carry out their duties in accordance with surveillance guidance material provided by CASA.

ATSB assessment of response

The ATSB acknowledges CASA's actions to recruit safety systems specialists and the importance of professional judgement in performing regulatory oversight. However, the ATSB still believes that guidance material provided to CASA inspectors was and is inadequate.

ATSB Safety Recommendation R20070002

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority undertake further work to address this safety issue.

4.2.3 Risk assessments for changes in operations

Safety issue

CASA did not require operators to conduct structured and/or comprehensive risk assessments, or conduct such assessments itself, when evaluating applications for the initial issue or subsequent variation of an Air Operator's Certificate.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> Risk assessment concepts continue to be developed in CASA. Risk assessment training has been provided to staff with the emphasis now changing to incorporate safety management principles. The AS/NZS-4360:2004 standard on risk assessment is referenced in the Surveillance Procedures Manual.
>
> Additionally, work has commenced on a new CASA Surveillance IT system to be incorporated into Aviation Industry Regulatory System. This system will include a risk module. Such a system should significantly improve CASA's governance, risk identification and reporting capability leading to more effective surveillance of the industry.

ATSB assessment of response

The ATSB acknowledges CASA's on-going development of risk assessment concepts. However, the safety issue also relates to the lack of a regulatory requirement for operators to conduct and provide a risk assessment of initial issue or subsequent renewal of an AOC, as well as CASA's ability to evaluate such risk assessments.

ATSB safety recommendation R20070003

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority undertake further work to address this safety issue.

4.2.4 Processes for assessing an operator’s risk profile

Safety issue

CASA did not have a systematic process for determining the relative risk levels of airline operators.

This issue was discussed in the analysis section of the draft report but was not listed as a safety issue. However, it has now been included as a safety issue following assessment of comments on the draft report.

ATSB assessment

ATSB safety recommendation R20070004

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority address this safety issue.

4.2.5 Guidance for evaluating the useability of operations manuals

Safety issue:

CASA’s process for evaluating an operations manual did not consider the useability of the manual, particularly manuals in electronic format.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> CASA is currently undertaking a project to evaluate and implement the Joint Airworthiness Requirements – Operations (European Union Regulations) philosophy of Operations Manuals. Whilst it is not intended that the format will be prescribed, appropriate guidance material will be introduced.

ATSB assessment of response

The ATSB acknowledges CASA’s intention to address this safety issue.

As a result of this advice of proposed safety action by CASA, the ATSB will continue to monitor its progress until evidence is received of the implementation of the proposed safety action.

4.2.6 Processes for validating instrument approaches

Safety issue

CASA’s process for accepting an instrument approach did not involve a systematic risk assessment of pilot workload and other potential hazards, including activation of a ground proximity warning system.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> CASA's current processes for periodic revalidation of instrument approaches specifically address pilot workload and other potential hazards.
>
> The approach design and validation methodology adopted in Australia is ICAO compliant (see Doc 8071 – in which Australia participated in the development) and uses GPS United States Federal Aviation Administration TSO receivers. These standards have all been subject to international (risk assessment) review and acceptance during their development, and are therefore not included in the approach validation process.
>
> The validation requirements do necessitate the consideration of other potential hazards (refer Doc 8071 and MOS). This process is part of the overall procedure design and implementation methodology as defined by ICAO.

ATSB assessment of response

The ATSB acknowledges that although CASA may consider pilot workload and potential hazards during instrument approach revalidation, it does not intend to include such assessments in the original validation process. In addition, hazards currently assessed in the flight validation are very limited. In particular, the flight validation process does not systematically consider hazards such as GPWS activation, potential influence of turbulence, the nature of terrain information provided on the approach chart, and the nature of terrain close to the approach path.

ATSB safety recommendation R20070005

The ATSB recommends that the Civil Aviation Safety Authority address this safety issue.

4.2.7 Regulatory requirements for crew resource management training

Safety issue

Although CASA released a discussion paper in 2000, and further development had occurred since then, there was no regulatory requirement for initial or recurrent crew resource management training for RPT operators.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> Regulations mandating Crew Resource Management (CRM) for RPT operators are in development. However, operators have all been strongly encouraged to adopt CRM training through a variety of methods and industry consultation.
>
> CASA has current projects to enhance guidance material on standard operating procedures, Human Factors (HF) / CRM and crew cooperation in multi-crew operations. CASA has used material (HF and CRM) from the draft Civil Aviation Safety Regulation Part 121 in order to develop appropriate advisory material (see http://rrp.casa.gov.au/casrcreate/121.asp for more information on Part 121).

ATSB assessment of response

The ATSB notes that CASA is working towards implementing the Civil Aviation Safety Regulation Part 121 and is implementing measures in the interim to encourage and help operators to establish crew resource management training.

The ATSB acknowledges CASA's intention to address this safety issue. As a result of this advice of proposed safety action by CASA, the ATSB will continue to monitor its progress until evidence is received of the implementation of the proposed safety action.

4.2.8 Regulatory requirements for multi-crew training

Safety issue

There was no regulatory requirement for flight crew undergoing a type rating on a multi-crew aircraft to be trained in procedures for crew incapacitation and crew coordination, including allocation of pilot tasks, crew cooperation and use of checklists. This was required by ICAO Annex 1 to which Australia had notified a difference.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> Regulations are currently being developed to mandate these requirements and when enacted will result in a withdrawal of the notified difference.

ATSB assessment of response

The ATSB acknowledges CASA's intention to address this safety issue. As a result of this advice of proposed safety action by CASA, the ATSB will continue to monitor its progress until evidence is received of the implementation of the proposed safety action.

4.2.9 Regulatory requirements for instrument approach qualifications

Safety Issue

The regulatory requirements concerning crew qualifications during the conduct of instrument approaches in a multi-crew RPT operation was potentially ambiguous as to whether all crew members were required to be qualified to conduct the type of approach being carried out.

ATSB safety recommendation R20060002

Date issued: 24 January 2006

> The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review and clarify the legal requirements concerning the qualifications for two-crew (pilot) operation during the conduct of instrument approaches in air transport operations. The review should assess the safety benefit arising from ensuring that when an instrument approach is conducted in an aircraft required to be operated by a two-person flight crew, both flight crew members are qualified to conduct the type of approach being carried out.

Response from Civil Aviation Safety Authority

The Civil Aviation Safety Authority advised the ATSB on 3 April 2006 that it has amended Civil Aviation Order 40.2.1, Instrument Ratings, to clarify the requirement for all instrument rating holders to hold an endorsement for any navigation aid being used to navigate an aircraft (including instrument approaches of which they are a crew member. The amendment does, however, provide an exemption for copilot crew members who do not hold an endorsement but have received equivalent training and demonstrated proficiency in the use of the navigation aid while participating in an operator's cyclic training and proficiency programme. The amendment became effective on 25 March 2006.

On 23 November 2006 CASA also advised the following:

> Following reviews by CASA following the Lockhart River accident, and supported by information contained in the ATSB interim factual report of December 2005, CASA amended the regulatory requirements relating to the qualifications for two pilot instrument approaches in air transport operations. Instructions have been issued to CASA field staff regarding instrument rating requirements and practices for smaller regional airline operators.

ATSB assessment of response

Recommendation Status: Closed - Accepted

4.2.10 Guidance for content of an operations manual

Safety issue

CASA’s guidance material provided to operators about the structure and content of an operations manual was not as comprehensive as that provided by ICAO in areas such as multi-crew procedures and stabilised approach criteria.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> Guidance material in the form of an advisory circular on multi-crew operations, which includes such contemporary safety issues as threat and error management and stabilised approaches, is in its final stages of development.

> Australia remains active on the ICAO Operations Control Panel with regards to global standards and recommended procedures including those that apply to subjects such as operations manuals, multi-crew procedures and stabilised approaches.

ATSB assessment of response

While the ATSB acknowledges CASA's intention to issue an advisory circular on multi-crew operations, the safety issue relates more broadly to the structure and content of operations manuals.

ATSB safety recommendation R20070006

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority address this safety issue.

4.2.11 Regulatory requirements for safety management systems

Safety issue

Although CASA released a discussion paper in 2000, and further development and publicity had occurred since then, there was no regulatory requirement for RPT operators to have a safety management system.

International Civil Aviation Organization requirements

On 17 July 2006, ICAO amended Annex 6 to include requirements for safety management systems. The Annex stated that, as of 23 November 2006:

> States should require, as part of their safety programme, that an operator implements a safety management system acceptable to the State of the Operator that, as a minimum:
>
> a) identifies safety hazards;
>
> b) ensures that remedial action necessary to maintain an acceptable level of safety is implemented;
>
> c) provides for continuous monitoring and regular assessment of the safety level achieved; and
>
> d) aims to make continuous improvements to the overall level of safety.

The Annex also stated that, from 1 January 2009, the recommendation would become a standard.

Response from Civil Aviation Safety Authority

Date received: 23 March 2007

> CASA recommends that operators have safety management systems in place at the entry control point. At present, the only head of power for CASA to ensure an operator conducts its operations with a reasonable degree of care and diligence is a general provision in section 28BE of the *Civil Aviation Act 1988*, which provides, relevantly:

(1) The holder of an AOC must at all times take all reasonable steps to ensure that every activity covered by the AOC, and everything done in connection with such an activity, is done with a reasonable degree of care and diligence.

(2) If the holder is a body having legal personality, each of its directors must also take the steps specified in subsection (1).

Regulation changes are planned to more specifically require Safety Management Systems.

CASA has led the field globally, with the Safety Management Systems concept in 2000. Since then, CASA has contributed significantly to ICAO developments which led to the amendment of Annex 6 in November 2006, which deals specifically with this subject.

Despite the regulatory requirement not yet being introduced, operators have been strongly encouraged, through a variety of methods including publication of educational material, to adopt Safety Management Systems. Safety Management Systems were also discussed at a major industry conference, called Flight Crew Licensing, Operations and Training (FLOT), sponsored by CASA for the aviation industry in March 2003. The FLOT conference was attended by 300 industry representatives and 729 people viewed the presentation on-line.

The CASA Corporate Plan 2006-07 to 2008-09 demonstrates CASA's developmental work in this area with a specific initiative to introduce Safety System Specialists and Air Transport Inspectors.

In June 2006, CASA's operational workforce capability was enhanced with the recruitment of three Safety System Specialists. These staff have been employed, not because they are technical specialists (pilots or engineers), but rather because they have specific knowledge and experience in the assessment of safety systems and their associated issues. In addition, a number of Air Transport Inspectors with system safety backgrounds are currently being recruited (March and April 2007).

ATSB assessment of response

The ATSB acknowledges CASA's international role in this area and notes that CASA is working towards implementing the Civil Aviation Safety Regulation Part 119 and is implementing measures in the interim to encourage operators to establish safety management systems.

The ATSB acknowledges CASA's intention to address this safety issue. As a result of this advice of proposed safety action by CASA, the ATSB will continue to monitor its progress until evidence is received of the implementation of the proposed safety action.

4.2.12 Regulatory requirements for terrain depiction on approach charts

Safety issue

There was no regulatory requirement for instrument approach charts to include coloured contours to depict terrain. This was required by a standard in ICAO

Annex 4 in certain situations. Australia had not notified a difference to the standard.

ATSB assessment

ATSB safety recommendation R20070007

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority address this safety issue.

4.2.13 Regulatory requirements for autopilot fitment

Safety issue

There was no regulatory requirement for multi-crew RPT aircraft to be fitted with a serviceable autopilot.

ATSB safety recommendation R20060003

Date issued: 20 January 2006

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the adequacy of current legislation and regulations:

- to assess the safety benefit that could be achieved from the fitment of a serviceable autopilot to all aircraft currently on the Australian civil aircraft register, engaged on scheduled air transport operations;
- with a view to ensuring that all aircraft placed on the Australian civil aircraft register after a specified date and intended to be engaged on scheduled air transport operations are equipped with a serviceable autopilot.

Response from Civil Aviation Safety Authority

Date Received: 16 August 2006

> CASA has conducted a preliminary review of Civil Aviation Order (CAO) 20.18 and examined the history of changes as they relate to fitment of autopilot equipment. The relevant current provisions in CAO 20.18 have existed since about 1960 and are consistent with current provisions of the US Federal Aviation Administration (FAA) and the European Joint Aviation Authorities (JAA).
>
> A review of CASA data to identify the 'population' of RPT Operators and aircraft that are affected revealed a total of 52 aircraft, 80 per cent of which are the Metro SA227. Some feedback indicates that the standard autopilot approved for this aircraft type is widely known within the aviation industry to be unreliable old technology and expensive. This may account for the fact that few Metro SA227 aircraft are fitted with autopilots. All Australian aircraft operating in high capacity regular public transport operations have approved autopilots fitted.
>
> CASA will consult industry through the Standards Consultative Committee (SCC) before deriving a conclusion on the matter.

Furthermore, CASA has extracted relevant Crew Resource Management/training and Human Factors material out of draft Civil Aviation Safety Regulation Part 121A and is developing a Civil Aviation Advisory Publication. This material is currently with CASA senior managers for comment.

Date received: 23 March 2007

CASA has conducted a review of CAO 20.18 and examined the history of changes as they relate to the fitment of autopilot equipment. The relevant current provisions in CAO 20.18 have existed since about 1960 and are consistent with current provisions of the US FAA and the European Joint Aviation Authorities (JAA).

A comprehensive review of this segment of the industry has revealed a total of 52 aircraft, 80% of which are the Metro SA227. Feedback indicates that the standard autopilot approved for this aircraft type is widely known within the aviation industry to be unreliable technology and expensive. This may account for the fact that few Metro SA227 aircraft are fitted with autopilots.

The Standards Consultative Committee (SCC) concurs with CASA's view that the cost of mandatory fitment of such equipment to this type of aircraft would be prohibitive. However, CASA continues to keep the subject under active consideration.

All Australian aircraft operating in high capacity regular public transport operations have approved autopilots fitted.

ATSB assessment of response

Recommendation status: Monitor

4.2.14 Ground proximity warning system alerts and warnings on normal approaches

Safety Issue

Based on the available evidence, the Lockhart River Runway 12 RNAV (GNSS) approach design resulted in mode 2A ground proximity warning system alerts and warnings when flown on the recommended profile or at the segment minimum safe altitudes.

This safety issue was not listed in the draft report but was identified during assessment of comments on the draft report. CASA was formally advised of this safety issue on 20 March 2007.

ATSB assessment

ATSB safety recommendation R20070008

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority address this safety issue.

4.2.15 Maintenance requirements for on-board recorders

Safety recommendation R20060005

Date issued: 10 February 2006

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the maintenance requirements for cockpit voice recording systems and flight data recording systems against international standards such as EUROCAE ED-112 and ICAO Annex 6 with the aim of improving their reliability and increasing the availability of data to investigators.

Response from Civil Aviation Safety Authority

Date Received: 16 August 2006

> The maintenance and testing requirements for flight data recorders (FDR) and cockpit voice recorders (CVR) are not explicitly defined in Australian regulations. ICAO Annex 6 requirements are accepted as the minimum requirement to be met by operators when submitting Schedules of Maintenance for CASA approval. ICAO Annex 6, Part 1, Attachment D, Flight Recorders, provides guidance for pre-flight checking, inspection and calibration of flight data recording and cockpit voice recording systems.
>
> CASA guidance in relation to flight data recorder maintenance is set out in CAAP 42L-4(0), and includes reference to ICAO Annex 6 and EUROCAE ED-112.
>
> In light of this recommendation, CASA will review the maintenance requirements for flight data recorders and cockpit voice recorders against the relevant international standards, and will consider in particular whether minimum requirements for such maintenance should be prescribed.
>
> In the interim, CASA will review the existing guidance material with a view to providing more specific maintenance interval guidelines.
>
> CASA will be providing additional training in the maintenance of FDR/CVR systems for airworthiness personnel. This will enhance their knowledge in these systems and will assist them when evaluating aircraft systems of maintenance.

Date received: 23 March 2007

> CASA has completed additional training in maintenance of Flight Data Recorder/Cockpit Voice Recorder systems for airworthiness personnel. This has enhanced knowledge in these systems and will assist when evaluating aircraft systems of maintenance.

ATSB assessment of response

Recommendation status: Monitor

4.2.16 Pilot workload and situational awareness on RNAV (GNSS) approaches

Safety issue from ATSB Aviation Research Report B20050342

Date issued: 15 December 2006

Pilot workload was perceived as being higher, and reported losses of situational awareness were reported as more common, for the area navigation global navigation satellite system (RNAV (GNSS)) approach than all other approaches except the non-directional beacon (NDB) approach, which involved similar workload and situational awareness levels.

This was especially a concern for pilots operating Category A and Category B aircraft. Further research into pilot workload and losses of situational awareness associated with RNAV (GNSS) approaches is warranted.

ATSB Safety Recommendation R20060019

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority address this safety issue.

Response from Civil Aviation Safety Authority

Date Received: 6 March 2007

> In respect of recommendation 2006019, CASA will have the findings of this report considered by the Australian Strategic Air Traffic Management Group (ASTRA), consult with regulators overseas and review research findings from other studies (particularly a recent one by Leeds University in the UK). It would be helpful, however if the ATSB would provide further clarification on the additional research that it recommends be undertaken into pilot workload (especially given the low response rate and limited available data cited in the present study).

Date Received: 23 March 2007

> This has been subject of Flight Safety Australia articles and the CASA Safety Promotions Section has developed a GNSS booklet and instructor pack on this topic for general release.

ATSB assessment of response

The ATSB formally responded to CASA on 12 March 2007.

In response to this recommendation CASA noted that there was limited available data cited in the ATSB report concerning pilot workload. The ATSB study was based on subjective estimates of workload and other factors by pilots and the results suggest that follow-up research with objective measures of workload is warranted. As we point out in our report, there have been very few other studies conducted on this matter, and the few that have been published tend to restrict their focus to high capacity RPT operations, where workload issues may be substantially different from those faced by pilots in other operational categories and/or single pilot operations (typically Category A and Category B aircraft). ATSB therefore holds the view that additional research on this topic is warranted to extend the knowledge gained from our own research, and particularly to better understand the differences in workload and time pressures faced by pilots of Category A and Category B aircraft compared with other instrument approaches and pilots of high capacity, multi-crew airline operations.

The ATSB acknowledges that CASA has developed important and useful educational material to assist pilots with the transition to RNAV (GNSS) approaches, and that this information was recently updated and reissued. The ATSB also notes that CASA touched on this issue in an article in a recent edition of Flight Safety Australia.

Further response from Civil Aviation Safety Authority

Date received: 26 March 2007

In regard to R20060019, CASA will continue to monitor developments in this area, particularly in the United Kingdom. To this end, CASA will be meeting staff of the UK CAA shortly to discuss recent work done by them on RNAV (GNSS) approaches. The issues raised in your report have also been raised at the recent ICAO Navigation Systems Panel. At the present time, however, it is unlikely that CASA will be in a position to commission specific research, either from universities or in-house.

ATSB assessment of response

Recommendation status: Monitor

4.2.17 Additional safety actions by CASA

In addition to the safety actions outlined above, on 23 November 2006 CASA advised the ASTB of the following additional safety actions. [Emphasis in original.]

Other safety actions conducted by CASA:

- A **data recorder course**, including Flight Data Recorders (FDR) and Cockpit Voice Recorder (CVR) has been attended by selected airworthiness inspectors. More staff will be attending the course in the future.
- A **safety research and analysis capability** has been established and reporting directly to the Deputy CEO Operations.
- The Air Transport Operations Group (ATOG) has introduced **Operational surveillance** to complement planned surveillance activities.

- ATOG has also issued **instructions** to field staff about instrument rating requirements and practices relating to smaller RPT operators.

- The General Aviation Operations Group have introduced the **'General Aviation Safety Assessment Program'** to target high risk passenger carrying operations.

- A number of operational training courses for the CASA inspectorate have been conducted since the accident.

- CASA conducted a Metro aircraft training course and workshop for Flying Operations Inspectors and industry operators. The increased use of simulators for enhancing training was a theme of the workshop. Similar workshops will be conducted on an annual basis.

- In accordance with the provisions of CAR 179A, CASA issued revised instructions relating to the use of Global Positioning System (GPS) equipment.

- CASA has developed a Global Navigation Satellite System (GNSS) Instructor Pack which will assist general aviation and smaller RPT operators to educate staff.

- Minor amendments have been made to the ATOG Pentana Tracker system to provide enhanced audit report writing and RCA follow up capability.

Safety actions in progress:

- CASA has extracted material (Human Factors and Cockpit Resource Management) from the draft CASR Part 121A with a view to using it to develop a Civil Aviation Advisory Publication (CAAP).

- A review of the adequacy of the current legislation with respect to autopilots has commenced and was posted on the SCC Forum for industry discussion and input. The SCC concurs with CASA's view that the cost and fitment of equipment to this type of aircraft would be prohibitive. However, CASA continues to have the subject under active consideration.

- Work has commenced on the new CASA Surveillance IT system to be incorporated into Aviation Information Regulatory System (AIRS). This system is expected to include a risk module.

- Draft CAAPs about Standard Operating Procedures and Aircraft Performance are being developed by ATOG.

- Ten joint CASA – Industry workshops on aircraft performance for smaller air transport operators and service providers were conducted by CASA between February and September 2006. In addition, Civil Aviation Advisory Publication 235 was produced which enhances performance planning guidance particularly in the case of engine out performance.

- CASA has commenced work on transitioning higher risk operators from its General Aviation Operations Group to its Air Transport Operations Group, to ensure maximum consistency of surveillance practices.

4.3 Jeppesen Sanderson

4.3.1 Jeppesen RNAV (GNSS) approach chart design

Safety issue

There were several design aspects of the Jeppesen RNAV (GNSS) approach charts that could lead to pilot confusion or reduction in situational awareness. These included limited reference regarding the ‘distance to run’ to the missed approach point, mismatches in the vertical alignment of the plan-view and profile-view on charts such as that for the Lockhart River runway 12 approach, use of the same font size and type for waypoint names and ‘NM’ [nautical miles], and not depicting the offset in degrees between the final approach track and the runway centreline.

Response from Jeppesen Sanderson Inc.

Date received: 12 February 2007

> **Approach transitions**
>
> The profile view supplements the plan view on Jeppesen charts with a side-view depiction of the final approach segment. Emphasis is intentionally placed on the all-important final approach segment and related airspace fixes / stepdown points, minimum or recommended altitudes, horizontal distances, and vertical descent information.
>
> In order provide maximum space to achieve the best possible side-view depiction of the final approach, Jeppesen does not include approach transitions from the profile view. The profile is a schematic depiction, not drawn to scale. This is intended to illustrate important details for legibility that might otherwise be compromised when trying to draw the profile true to-scale, or limiting the amount of available space by including multiple transition routes in the profile.
>
> Steps are taken during the preparation of approach charts to ensure compatibility between the plan view and profile views, including the point at which approach transitions join the final approach course.
>
> The approach plan view and profile view are chart features that were invented by Capt. Elrey Jeppesen and have been adopted by aeronautical cartographers worldwide.
>
> **Distance Information**
>
> Horizontal distance information from each airspace fix / stepdown point to the Missed Approach Point (MAP) is provided in the profile view.
>
> Alignment between plan-view and profile view
>
> The plan view and profile view on Jeppesen charts are independent graphical portrayals. The plan view is to scale and the profile view is not. There is no alignment of these two graphics and none is intended nor possible. Any spatial correlation between the placement of information in the plan view and the profile (e.g. airspace fixes) is merely coincidental.

Font

According to Jeppesen production specifications waypoints and fixes labels in the profile view are depicted using big bold type. Big bold type was introduced on Jeppesen charts in March 1995 to enhance chart readability. On the Lockhart River RNAV (GNSS) Rwy 12 Jeppesen chart step down fixes 5.0 NM and 3.6 NM and their minimum altitudes are critical fixes on the final approach segment and are depicted in big bold type.

Offset depiction

Straight in approaches that have a Final Approach course not in alignment with the runway centerline are depicted graphically in the plan view on the Jeppesen chart. The numerical value of the angular difference is not charted.

ATSB assessment of response

The ATSB acknowledges the information provided by Jeppesen in relation to the chart design philosophy of its approach charts. However, the ATSB believes that the safety issue still exists.

ATSB safety recommendation R20070009

The Australian Transport Safety Bureau recommends that Jeppesen Sanderson Inc. address this safety issue.

4.3.2 Jeppesen approach chart terrain depiction

Safety issue

Jeppesen instrument approach charts depicted coloured contours on the plan-view of approach charts based on the maximum height of terrain relative to the airfield only, rather than also considering terrain that increases the final approach or missed approach procedure gradient to be steeper than the optimum. Jeppesen instrument approach charts did not depict the terrain profile on the profile-view although the segment minimum safe altitudes were depicted.

Response from Jeppesen Sanderson Inc.

Date received: 12 February 2007

Jeppesen introduced the depiction of terrain contours in June of 1994. Jeppesen depicts terrain contour information when terrain within the approach chart plan view exceeds 4000 feet above the airport elevation, or when terrain within 6 nautical miles of the airport reference point rises to at least 2000 feet above the airport elevation, or by customer request. These standards were adopted by the FAA National Aeronautical Charting Organization (NACO) and ICAO.

> Prior to implementation of Jeppesen's colored, shaded terrain contours, this criteria and depiction was reviewed and endorsed by the US Air Transport Association's Chart & Data Display Committee. Implementation of terrain contours was also made in response to industry-wide recommendations related to preventative measures for reducing CFIT accidents. After our implementation Flight Safety International presented Jeppesen with a safety award in February of 1996 for improving flight crew situational awareness with the introduction of the airport qualification service and addition of colored terrain contour information on approach charts.
>
> Jeppesen has opposed the concept of depicting terrain in profile because of distortion due to profile views are not to scale. Also, as the width of the various approach segments vary terrain cannot be realistically nor meaningfully be displayed in profile.

ATSB assessment of response

The ATSB acknowledges the information provided by Jeppesen in relation to its protocols for depicting terrain on its approach charts. However, Jeppesen's criteria for including contour lines on approach charts does not fully meet the requirements of the International Civil Aviation Organization Annex 4 standard in paragraph 11.7.2. Accordingly, the ATSB believes that the safety issue still exists.

ATSB safety recommendation R20070010

The Australian Transport Safety Bureau recommends that Jeppesen Sanderson Inc. address this safety issue.

4.4 Airservices Australia

4.4.1 Airservices Australia's approach chart terrain depiction

Safety issue

Airservices Australia's instrument approach charts did not depict the terrain contours on the plan-view. They also did not depict the terrain profile on the profile-view, although the segment minimum safe altitudes were depicted.

ATSB assessment

ATSB safety recommendation R20070011

The Australian Transport Safety Bureau recommends that Airservices Australia address this safety issue.

4.4.2 RNAV (GNSS) approach chart design and interpretability

Safety issue from ATSB Aviation Research Report B20050342

Date issued: 15 December 2006

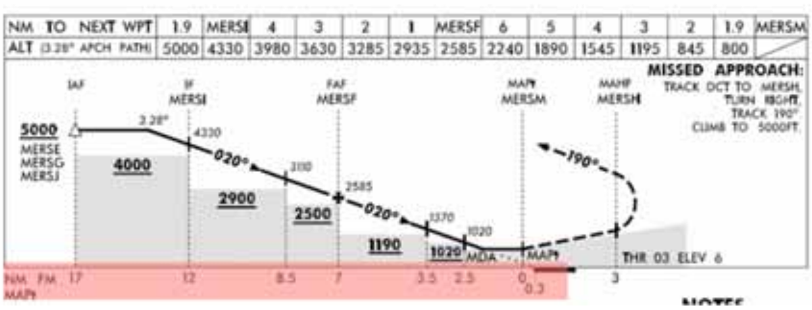
The most common concern identified by respondents about the design of RNAV (GNSS) approaches was that the charts did not use references for distance to the missed approach point throughout the approach on the global positioning system (GPS) or flight management system (FMS) displays, and distance references on the approach charts were inadequate. Approach chart interpretability was assessed as more difficult for the RNAV (GNSS) approach than all other approaches by respondents from all aircraft performance categories. Respondents considered that the information presented on RNAV (GNSS) approach charts, including distance information, may not be presented in the most useable way, and consequently may lead to loss of situational awareness.

ATSB Safety Recommendation R20060020

The Australian Transport Safety Bureau recommends that Airservices Australia address this safety issue.

Response from Airservices Australia

Date Received: 8 March 2007

> This recommendation is borne of three findings:
>
> 1. No ranging to Missed Approach Point (MAPt) throughout the approach on GPS or FMS displays:
>
> The matter of distance to the MAPt being shown by the navigation equipment is outside the scope of Airservices Australia's responsibility and should be directed to equipment manufacturers and database coders.
>
> 2. Distance references on charts inadequate:
>
> All Australian DAP RNAV (GNSS) instrument approach charts produced by Airservices Australia have distance to the MAPt reference from the Initial Approach Fix (IAF) to the MAPt below the profile view of the procedure (see Fig 1 below). The distances shown below the profile are in a similar format to existing conventional procedures.
>
> 
>
>
> Fig 1 – Merimbula, Rwy 03 RNAV (GNSS) approach plate profile – Distance-to-go highlighted below the profile
>
> 3. Data on charts not presented in the most usable way:
>
> The charts are produced to agreed international standards in a format that is similar to other States that have RNAV procedures.

> One factor that that could be addressed to facilitate interpretation of the charts is to realign the waypoint named as the Missed Approach waypoint, with the runway threshold. Historically, for coding purposes, the MAPt could not be at the threshold as there would then be one geographical point with two different functions. This is no longer an issue and all procedures could be redesigned to have the MAPt at the threshold. However, whilst removing one possible cause of confusion for some pilots, all pilots would require further training/notification as the 'standard' had changed. There would also need to be some research on the effect of procedures that require the MAPt to be sited prior to the threshold for obstacles located in the Missed Approach segment and how to correctly design the procedure and chart it accordingly.
>
> The recommendation is partly not accepted (1 and 2 above). In relation to the other aspect of the recommendation, the issue of the positioning of the MAPt, Airservices Australia will liaise with CASA to determine to what extent the pilot community will need re-education. Regarding the design considerations, Airservices Australia, in conjunction with CASA, will consult the ICAO Obstacle Clearance Panel, sponsors of ICAO Doc 8168 PANS-OPS, which describes the design criteria that Airservices must adhere to under our Civil Aviation Safety Regulations Part 173 certification (173.085).

ATSB assessment of response

The ATSB will discuss with Airservices Australia alternative ways of presenting distance information on approach charts in an effort to determine whether improvements to the current design, particularly from a user's (pilot's) perspective, might be possible.

Recommendation status: Monitor

4.4.3 Sub-optimal RNAV (GNSS) approach design

Safety issue from ATSB Aviation Research Report B20050342

Date issued: 15 December 2006

The 21.5 per cent of Australian area navigation global navigation satellite system (RNAV (GNSS)) approaches deviate from the optimum design parameters (short and irregular segments less than 5 NM and/or multiple steps within segments, and/or multiple minimum segment altitude steps) due to the vicinity of high terrain. This was identified as a major concern by many pilots. A review to determine whether designs closer to the optimum approach profile could be developed, within the ICAO Pans-Ops limitations, was considered appropriate.

ATSB Safety recommendation R20060021

The Australian Transport Safety Bureau recommends that Airservices Australia address this safety issue.

Response from Airservices Australia

Date Received: 8 March 2007

> Approach procedures in areas of high terrain can be more complex. The example shown, Merimbula 03 RNAV (GNSS) procedure, has one 'non-ideal' segment length, the final approach segment of 7nm. By inspection and well inside the capabilities of pilots to calculate, the distance is 17nm (5+5+7) from the initial approach fix to the MAPt (clearly shown below the profile view on the chart – see Fig 1).
>
> There is no other approach to this runway end. Using existing navigation aids to this runway end the PANS-OPS criteria would only allow an approach that was of no operational benefit. An RNAV approach design closer to the optimum, in this instance changing one segment, would raise the minima.
>
> The task of designers is to balance the complexity of the design against operationally acceptable minima. The complexity is limited by the criteria in ICAO PANS-OPS Vol II, and the Civil Aviation Safety Regulations and associated Manual of Standards Part 173 that describes the design criteria to which Airservices must adhere.
>
> A review of procedures to give standard segments lengths would raise minima and then the question of operational acceptability would be raised.
>
> This recommendation is not accepted.

ATSB assessment of response

The ATSB will be consulting further with Airservices on this matter.

Recommendation status: Open

4.4.4 RNAV (GNSS) approach waypoint naming convention

Safety Issue

The Australian convention for waypoint names in RNAV (GNSS) approaches did not maximise the ability to discriminate between waypoint names on the aircraft global positioning system display and/or on the approach chart.

Safety issue from ATSB Aviation Research Report B20050342

Date issued: 15 December 2006

The naming convention of using five capital letters for waypoint names, with only the final letter differing to identify each segment of the approach, was reported to cause clutter on the charts and GPS and FMS displays, and also increase the chance of a pilot misinterpreting a waypoint. This can lead to a loss of situational awareness.

With the growing body of international experience using RNAV (GNSS) approaches, it may be timely to review the naming convention.

ATSB Safety recommendation R20060022

The Australian Transport Safety Bureau recommends that Airservices Australia address this safety issue.

Response from Airservices Australia

Date Received: 8 March 2007

Waypoint naming has some guidance in internationally agreed criteria and is constrained by what the flight management computer can handle. PANS-OPS Vol II, Chapter 31, paragraph 31.1.2 states that```:

> 'Each fix shall be published as a waypoint……………………with an alphanumeric identifier.'

The database constraint and requirement for the waypoint to have a unique identifier has posed certain problems.

- There are not enough unique ICAO 5-letter pronounceable identifiers to cover the number of new waypoints generated by RNAV procedures.
- To avoid confusion in the database, each waypoint needs a unique name (certain database coders talk of proliferation of one waypoint name e.g. Final fix Runway 36 - FFR36).

To counter this, various five character alphanumeric protocols have been developed globally, but essentially they all have the same function. They provide the following:

- Uniqueness
- Attributes to a particular aerodrome
- Hierarchy
- General guidance to the pilot to aid situational awareness.

The Australian naming convention for waypoints used on Airservices Australia GNSS charts was devised by CASA and was endorsed by the industry GPS Implementation Team in the mid 1990s. This waypoint naming convention is specified in the Manual of Standards Part 173 paragraph 8.9.3 Drafting Conventions. The naming convention is designed on the following principles:

- RNAV (GNSS) waypoints shall be named using a unique five letter code.
- The first three letters will be the last three letters of the airport Y code identifier (e.g.; SCB for YSCB).
- The fourth will be the direction from which the procedure approaches the airport (e.g.; N, S, E, or W).
- The fifth will identify the procedure fix type (I for the IF, F for the final approach fix, M for the MAPt, T for the MATF and H for the MAHF). NB: MATF - Missed approach turning fix. MAHF - Missed approach holding fix.
- For IAFs the letter will commence with A and will progress alphabetically, excepting 'O', to each IAF, noting that the identifiers for the succeeding fixes (IF, final approach fix, etc) shall not be used.

Any review of a naming convention must have global application as pilots from outside Australia must be able to grasp the principles of what is being applied. Internationally there is still debate over the naming convention, but there is a consistent logic behind the Australian RNAV waypoint naming.

> In light of the above, Airservices Australia, in conjunction with CASA, will consult the ICAO Obstacle Clearance Panel and Operations Panel to ascertain the international perspective with regard to waypoint naming to prior to reviewing the Australian naming convention.

ATSB assessment of response

The ATSB acknowledges the safety actions proposed by Airservices Australia.

Recommendation status: Monitor

4.5 Department of Transport and Regional Services

4.5.1 Cockpit voice recorder maintenance

ATSB Safety recommendation R20060006

Date issued: 10 February 2006

The Australian Transport Safety Bureau recommends that the Department of Transport and Regional Services, with the assistance of the Civil Aviation Safety Authority, pursues further the development of proposals to amend the provisions of Part IIIB of the *Civil Aviation Act 1988*. While recognising the need to have protections to prevent inappropriate disclosure and use of Cockpit Voice Recorder information, the proposals to amend the Act should take into account the need to enable approved maintenance organisations to replay in-flight Cockpit Voice Recorder data for legitimate maintenance and testing purposes.

Response from Department of Transport and Regional Services

Date Received: 24 February 2006

> In relation to R20060006, I understand that the Australian Transport Safety Bureau (ATSB) is already working on this issue.[222] The Aviation Operations Branch within the Department of Transport and Regional Services is prepared to assist the ATSB as necessary.

ATSB assessment of response

Recommendation status: **Monitor**

Response from Civil Aviation Safety Authority

Date Received: 16 August 2006

> CASA notes that this recommendation is primarily directed to DOTARS [Department of Transport and Regional Services], which is responsible for administration of Part IIIB of the Civil Aviation Act 1988. In accordance with the recommendation, CASA will cooperate with the Department in the development of any proposals to amend the provisions of Part IIIB.

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222 At the date of publication of this report, the Australian Government Office of Parliamentary Counsel was preparing a draft of amendments to the *Civil Aviation Act 1988*.

However, CASA notes that there may be no need for a maintenance check of the CVR to be conducted by actually listening to the tape. It is likely that a functional system check can confirm the fidelity of the equipment rather than actually needing to listen to the tapes.

ATSB assessment of response

Recommendation status: Monitor

4.6 Australian Transport Safety Bureau

4.6.1 Regional airline study

Detailed information on regional airline safety in Australia is provided in the Bureau of Air Safety Investigation 1999 research report *Regional Airline Safety Study Project Report*.[223] The study covered all aspects of regional airline operations, including training, flight operations, maintenance, publications, selection and qualification of personnel, support facilities, air traffic services, and regulation and surveillance. Since the release of that report there have been a number of changes within the regional airline industry and there have been several accidents and incidents involving regional aircraft. The ATSB will be conducting a further safety study into the Australian regional airline industry during 2007.

4.6.2 Threat and error management

The ATSB sponsored an industry project in 2005-2006 to develop and distribute threat and error management training material to general aviation and regional airline training organisations.

4.6.3 Report distribution

Copies of this investigation report will be forwarded to all Australian operators conducting fare-paying passenger operation in aircraft with more than nine passenger seats. It will also be published on the ATSB website.

223 The Bureau of Air Safety Investigation (BASI), *Regional Airline Safety Study Project Report*, May 1999. BASI became part of the newly formed Australian Transport Safety Bureau (ATSB) on 1 July 1999.

APPENDICES

Appendix A:	**Flight Data Recorder Technical Analysis Report**
Appendix B:	**Cockpit Voice Recorder Technical Analysis Report**
Appendix C:	**Extract from Honeywell GPWS MK VI Warning System Pilot's Guide**
Appendix D:	**Estimated aircraft weight and balance**
Appendix E:	**Transcript of radio transmissions from VH-TFU**
Appendix F:	**Honeywell GPWS MK VI Simulation**
Appendix G:	**Extracts from Transair's operations manual – GPS non precision approach, descent and GPWS procedures**
Appendix H:	**Summary of CASA oversight of Transair from 1998 to 7 May 2005**
Appendix I:	**Joint Aviation Authorities non-technical skills**
Appendix J:	**Summary of significant CFIT descent approach and landing accidents in Australia**
Appendix K:	**Flight Safety Foundation CFIT Checklist**
Appendix L:	**Flight Safety Foundation approach and landing (ALAR) toolkit, standard operating procedures**
Appendix M:	**Media Release**

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APPENDIX A: FLIGHT DATA RECORDER TECHNICAL ANALYSIS REPORT

Flight Data Recorder Readout and Analysis
SA227-DC VH-TFU
Lockhart River, Qld
7 May 2005

ATSB TECHNICAL ANALYSIS REPORT 21/06

Neil A. H. Campbell
Senior Transport Safety Investigator – Engineering

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

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APPENDIX A CONTENTS

APPENDIX A FACTUAL INFORMATION

Scope

Recorded flight data was read out to assist in the accident investigation. In particular the scope of the factual report (technical analysis report 21/05) was to:

- Document the recovery and downloading of the flight data recorder (FDR)
- Describe the FDR system fitted to the aircraft
- Describe the parameters recorded by the FDR and examine their accuracy
- Produce a graphical representation of the FDR data for the accident flight
- Produce a sequence of events for the accident flight.

The scope of the analysis report (technical analysis report 47/05) was to:

- Describe the technique used to determine the aircraft ground track
- Compare the aircraft altitude profile with the nominal RNAV[1] profile
- Describe the technique used to produce a computer graphics animation of the approach to LHR
- Compare the accident approach with other recorded approaches to LHR[2]
- Comment on aircraft systems serviceability based on FDR data
- Comment on flight control inputs based on control surface parameters recorded by the FDR
- Comment on the turbulence encountered by the aircraft.

This appendix is a combination of the factual and analysis reports.

Flight data recorder (FDR) requirements

Flight data recorder carriage requirements for Australian-registered aircraft are specified in Civil Aviation Order (CAO) 20.18. As the maximum take-off weight of VH-TFU was greater than 5,700 kg, it was required to carry an approved FDR. The FDR fitted to VH-TFU was an approved unit.

The FDR parameters that are required to be recorded (i.e. mandatory parameters) are specified in Appendix I of CAO 103.19[3]. The FDR fitted to VH-TFU was required to record at least the first six parameters listed in Appendix I i.e. time, altitude, airspeed, vertical acceleration, heading and press to transmit for the radio transceivers. The FDR fitted to VH-TFU exceeded this minimum requirement as the six mandatory parameters and an additional 13 parameters were recorded.

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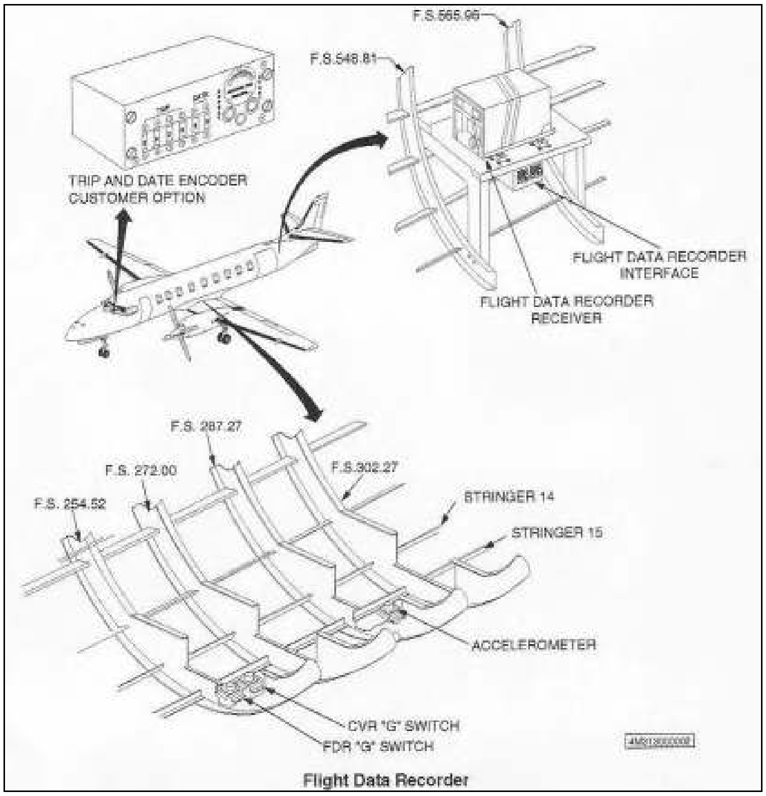
1 Area navigation global navigation satellite system (RNAV (GNSS)) approach.

2 Lockhart River.

3 CAO 103.19 was last updated in 1986.

Aircraft installation

Figure A-1: FDR system diagram[4]



The FDR system was installed in December 1992 during aircraft manufacture. The FDR was located aft of the rear cargo bulkhead between fuselage station (FS) 548.81 and FS 565.96. A G switch was mounted near FS 254 under the passenger centre aisle. The G switch was designed to interrupt power to the FDR and preserve the recording if excessive g[5] force was experienced.

The FDR was powered by 28 VDC via two circuit breakers, one on the left avionics bus and one on the right avionics bus.

4 Fairchild Aircraft SA227 Series Maintenance Manual (Mar 01/02).

5 Acceleration due to gravity. 1 g is 9.80665 m/s^2.

FDR details

The aircraft was equipped with a Loral Data Systems solid-state FDR. Reported details of the FDR were:

Model	F1000
Part number	S703-1000-00
Serial number	00393

When the FDR was recovered the data plate was missing and the serial number could not be confirmed. Examination of the FDR at the ATSB confirmed that the reported model and part number were correct.

FDR system maintenance

Examination of the aircraft maintenance log showed that FDR serial number 00393 was removed on 2 April 2004 after the aircraft FDR circuit breaker repeatedly tripped. The unit was sent to the FDR manufacturer's authorised repair agency in Melbourne. Fault-finding showed that the FDR's aircraft interface circuit board and the power supply circuit board were faulty and they were replaced. A functional test of the FDR, as specified in the manufacturer's component maintenance manual, was successfully completed by the repair agency. The FDR was returned to the operator and re-installed on 21 April 2004.

A maintenance worksheet showed that on 6 April 2005 water was drained from the FDR static pressure line and a leak check carried out.

FDR recovery, transport and download

1. The cockpit voice recorder (CVR) and FDR were recovered from the accident site on 8 May by ATSB investigators.
2. The CVR and FDR were transported between Lockhart River - Weipa - Cairns - Sydney - Canberra accompanied by an ATSB investigator. Liaison with security and airline staff allowed the recorders to travel inside the passenger cabin of the aircraft.
3. The FDR was examined on 9 May and the memory module was visually inspected. The FDR was then stored until the CVR disassembly and initial replay were completed.
4. On 10 May, the FDR was disassembled and the polystyrene foam block containing the memory board was removed from the crash-protected enclosure.
5. Some heat damage was evident on the polystyrene foam block.
6. The manufacturer was sent several digital photos showing the condition of the foam block and subsequently advised that the crash-protected enclosure had

experienced ‘less than 30 minutes at 1,100 degrees C (or some similar combination of lower exposure)’.

7. A new connector was crimped onto the memory board cable at the ATSB FDR laboratory in accordance with Loral Data Systems documentation[6].
8. On 11 May, an ATSB flight recorder specialist hand-carried the memory board to an authorised repair agency of the FDR manufacturer in Melbourne.
9. Under the control of the ATSB flight recorder specialist the memory board was connected to a ‘known good’ FDR. Details of the FDR were:
   - Part number S703-1000-01
   - Serial number 01907
   - Mod. Status 2-14
   - Program Revision R17.
10. An electronic component (described as Q1 on the Flash/Store Interface card) was removed from the known good FDR to prevent any possibility of writing to the memory board from VH-TFU.
11. The data was downloaded using a standard Data Retrieval Unit (DRU) and normal indications were observed during the download.
12. The download was successful and a compressed data file, of size 8,193 kilobytes, was obtained. This file was named TFU.fdt.
13. The download file was decompressed using the manufacturer’s Readout Support Equipment (ROSE) Software Version 3.6 and a TFU.dat file was produced. The file size was 45,721 kilobytes.
14. These two files were transferred to the ATSB flight recorder specialist’s laptop computer and analysed using Insight Analysis Version 1.5.0.50. Analysis showed that the download was successful and that data from the accident flight had been recovered.
15. The two files (TFU.fdt and TFU.dat) were deleted from the authorised repair agency’s computer.
16. The memory board was hand-carried back to Canberra by the ATSB flight recorder specialist.

6 ‘Procedure for Crash Data Recovery for Flight Data Recorder Fairchild Model F1000 with Solid-State Memory’. Document FAR 0389 Revision 4.

Figure A-2: Comparison (undamaged) FDR – Exterior

Figure A-3: Comparison (undamaged) FDR - Interior

Figure A-4: FDR at the accident site

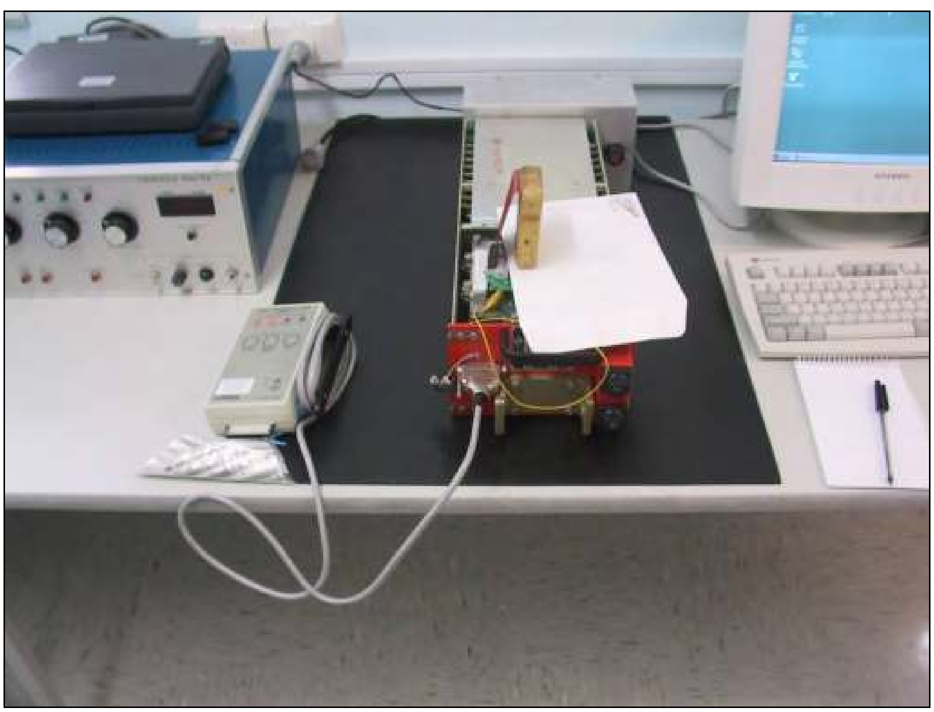
Figure A-5: FDR (foreground) at the ATSB laboratory in Canberra

Figure A-6: FDR with the crash-protected memory module visible

Figure A-7: Crash-protected memory module with a comparison unit

Figure A-8: Polystyrene foam block enclosing the memory board

Figure A-9: Memory board being downloaded using a 'known good' FDR



Rear connectors

The FDR rear connectors (refer to A-10), as well as the raw data, were scrutinized to ensure that all the recorded engineering parameters were detected.

Examination of the rear connector showed that a trip and date encoder was not fitted.

Figure A-10: FDR rear connectors

Figure A-11: Pin numbering

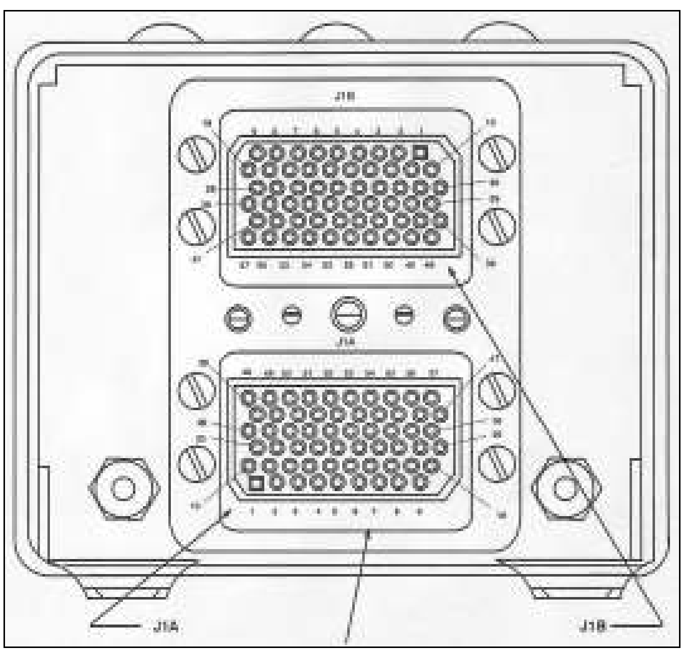
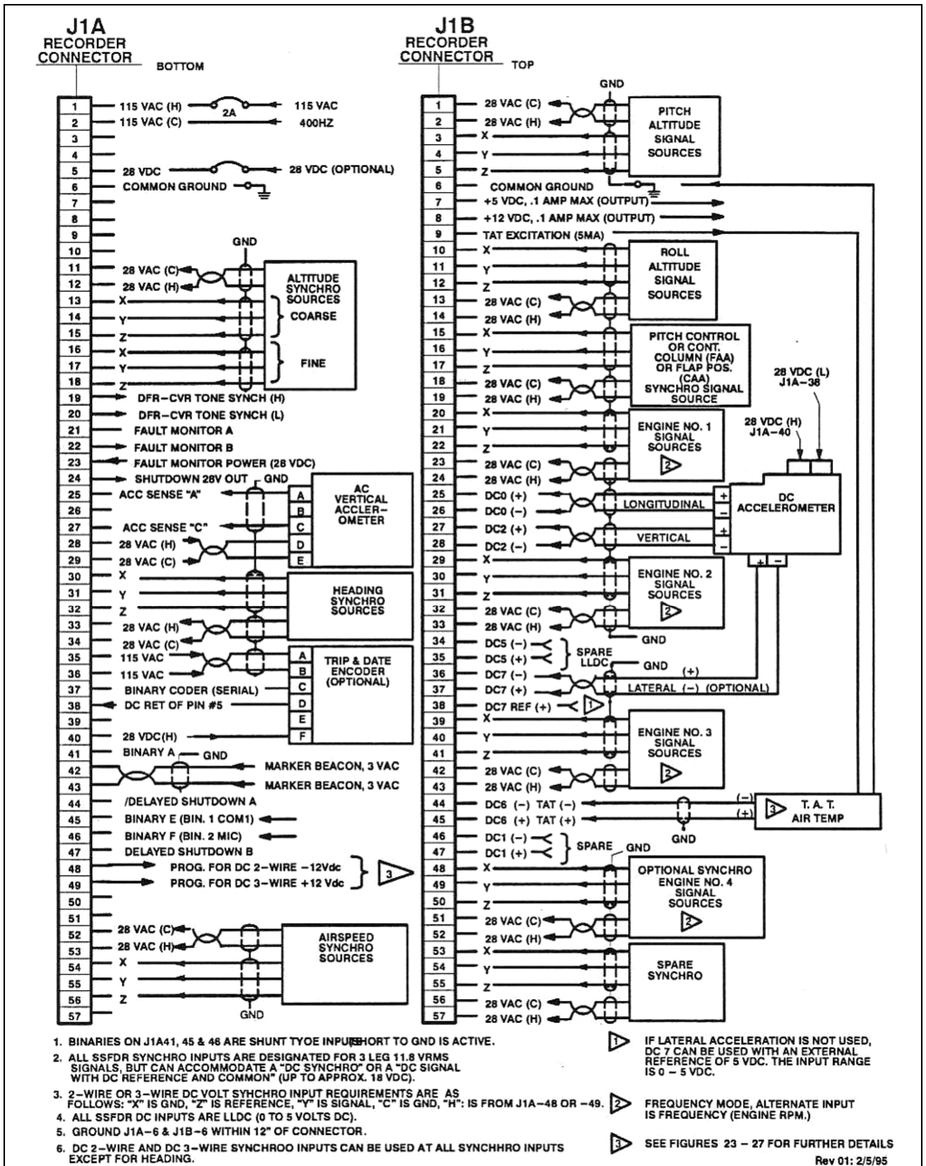


Figure A-12: Pin assignment[7]



ARINC 542A Aircraft Wiring Diagram

Examination of the rear connectors showed no evidence of connections to the following pins:

J1A: 1-4, 7-20, 23-29, 35-37, 39, 44, 47 & 50-57.

J1B: 8-9, 20-21, 29-30, 41, 44-45 & 50.

The observed pin connections were consistent with the FDR installation detailed in the Fairchild Aircraft SA227 Series Maintenance Manual Mar 01/02.

---

7 'Installation and Operation Instruction Manual Fairchild Model F1000' L3 Communications, October 10 1994.

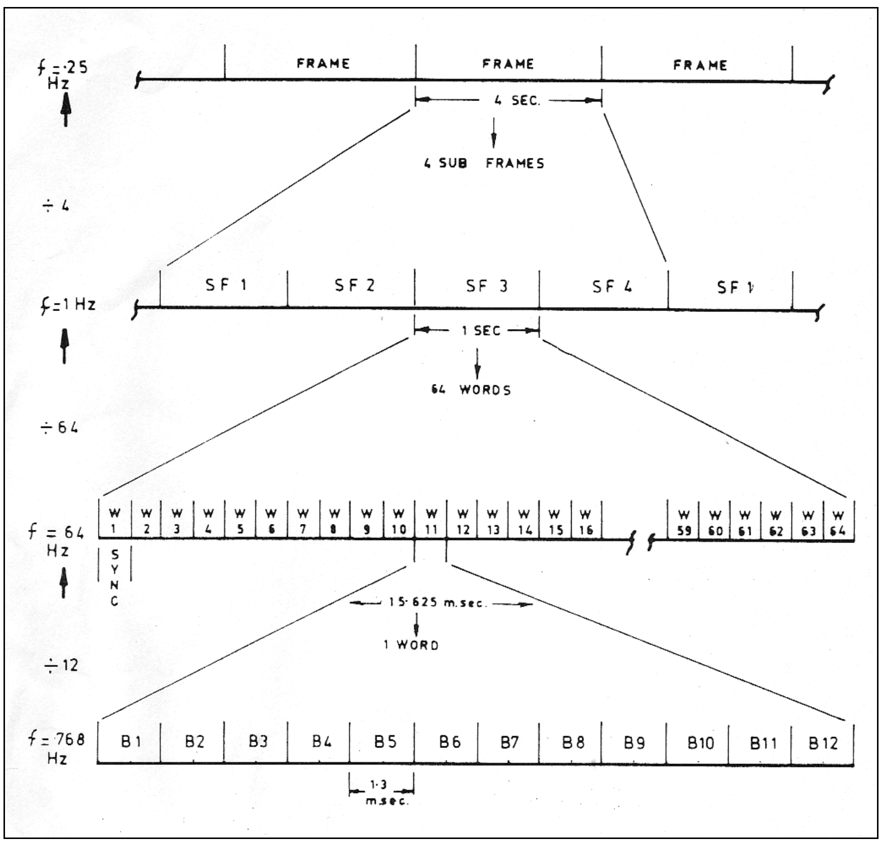
Data frame format

The FDR produces a data stream which is time division multiplexed with parameter identification established by means of position or time (word) slot addresses in the data stream. The data stream is a continuous sequence of four second data frames. Each frame consists of four subframes of 46 x 12 bit words with the first word containing a unique 12 bit synchronization (sync) word identifying it as subframe 1, 2, 3 or 4. The data stream is ‘in sync’ when successive sync words appear at the correct intervals.

The F1000 P/N S703-1000 FDR assembles 46 (12 bit) words per second and then compresses the data before it is recorded. When the data is recovered, the raw compressed data file (.fdt file extension) needs to be decompressed before it is imported by the analysis software. The decompression software ‘pads out’ the 46 word per second data so that it conforms to the standard 64 word per second format expected by the analysis software (refer to figure A-13). Accordingly zeros are always recorded in these 18 word positions (words 2, 3, 7, 15, 17, 25, 27, 33, 35, 39, 41, 43, 47, 49, 50, 59, 62 & 63).

Parameters can be recorded as multi-bit engineering parameters e.g. pressure altitude or single-bit discrete parameters e.g. microphone keying.

Figure A-13: Data frame format



Parameters

Examination of the data showed that the following aircraft parameters were recorded:

Parameter Name:	Units:	Sampling Interval: (seconds)
Elapsed Time[8]	hh:mm:ss	1
Pressure Altitude[9]	feet (reference 1013.2 hPa)	1
Indicated Airspeed	knots	1
Magnetic Heading	degrees M	1
Pitch Attitude	degrees	0.25
Roll Attitude	degrees	0.5
Horizontal Stabiliser Position	degrees	1
Flap Position	degrees	0.5
Elevator Position	degrees	1
Rudder Position	degrees	1
Aileron Position	degrees	0.25
Right Engine Propeller RPM	%	1
Left Engine Propeller RPM	%	1
Right Engine Torque	%	1
Left Engine Torque	%	1
Vertical Acceleration	g	0.125
Longitudinal Acceleration	g	0.25
Microphone Keying 1	discrete (keyed/not keyed)	1
Microphone Keying 2	discrete (keyed/not keyed)	1

8 Elapsed time from power-up of the FDR – incremented once per second.

9 Pressure altitude and IAS are sensed from a transducer package inside the FDR. The recorded values may differ from those observed by the crew.

For the F1000 P/N S703-1000 FDR, discrete parameters are only recorded in word 11 of each subframe. To ensure that all the recorded discrete parameters were detected all 12 bits of word 11 were scrutinized. This showed that two bits were used for Microphone Keying (bits 1 & 3). These were the only discrete parameters related to aircraft operation that were detected. In addition, four FDR status parameters were recorded:

Parameter Name:	**Units:**	**Sampling Interval: (seconds)**
A/D Fault	discrete (no fault/fault)	1
S/D Fault	discrete (no fault/fault)	1
Altitude/Airspeed Source	discrete (pneumatic/electric)	1
FDR Fault	discrete (no fault/fault)	1

Figure A-14: Operation of the FDR PWR FAIL warning light

The FDR PWR FAIL warning light is located on the pilot's instrument panel. The light remains illuminated for 45 seconds each time power is applied while FDR completes self-diagnostic test. Any one of the three items listed below may cause continued illumination of the FDR PWR FAIL warning light.

(1) Loss of 28 VDC power to FDR.

(2) Loss of 26 VAC magnetic heading excitation to FDR.

(3) Discrepant comparison of FDR altitude and airspeed pneumatic transducer calibration data in FDR memory and the pneumatic transducer calibration data from FDR central processor download during 45 second self-diagnostic test.

(4) To extinguish FDR PWR FAIL light after a comparison test discrepancy, the FDR must be powered OFF and ON at least twice for a minimum of 45 seconds. First to replace data in memory, and second, to complete satisfactory comparison of central processor download.

(5) After completion of 45 second self-diagnostic test, the FDR will continue to record data with FDR PWR FAIL light illuminated except during loss of 28 VDC power.

Pressure altitude

Signal Source:	FDR pneumatic transducer
Signal Type:	Pneumatic
Bits Used:	14
Word Locations:	26 (MSW[10]) 34 (LSW[11])
Resolution:	2 feet

A printed circuit board (PCB) inside the FDR contains the pneumatic transducer and associated electronics for sensing and digitizing altitude and airspeed data. Figure A-15 shows an undamaged PCB while Figure A-16 shows the PCB from VH-TFU.

The transducer measures the difference between static pressure, captured through one or more static port(s), and a reference pressure. The reference conditions for the transducer are standard pressure and temperature (i.e. 1013.25 hPa and 15º Celsius). The static ports are located on the exterior of the aircraft, at locations chosen to detect the prevailing atmospheric pressure as accurately as possible i.e. without any disturbance from the passage of the aircraft.

On Metro 23 aircraft this sensor is connected to the copilot's static system. The raw recorded altitude data is converted to engineering units (i.e. altitude in feet) by a standard polynomial equation supplied by the FDR manufacturer.

10 Most significant word.

11 Least significant word.

Figure A-15: Comparison undamaged pneumatic printed circuit board

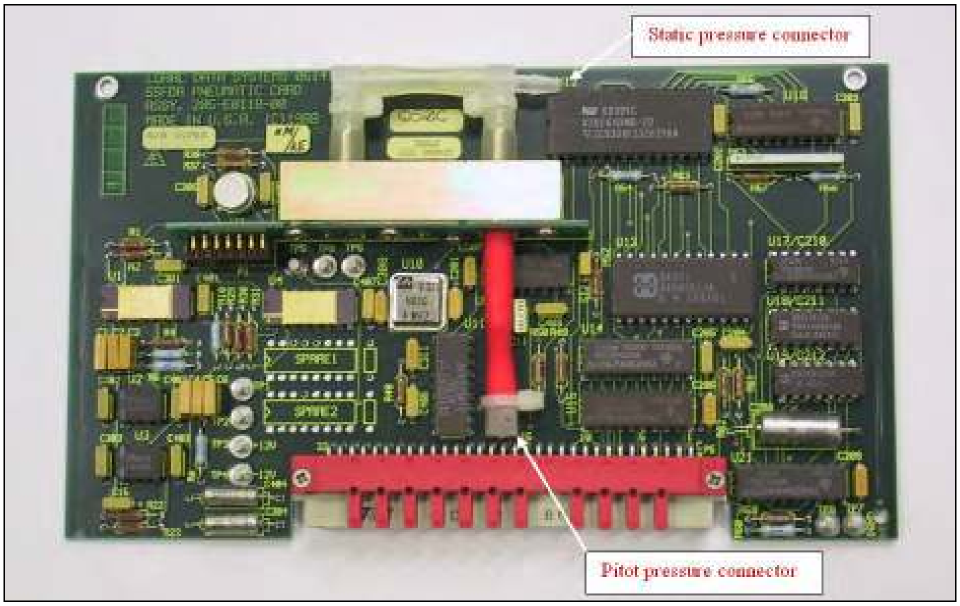
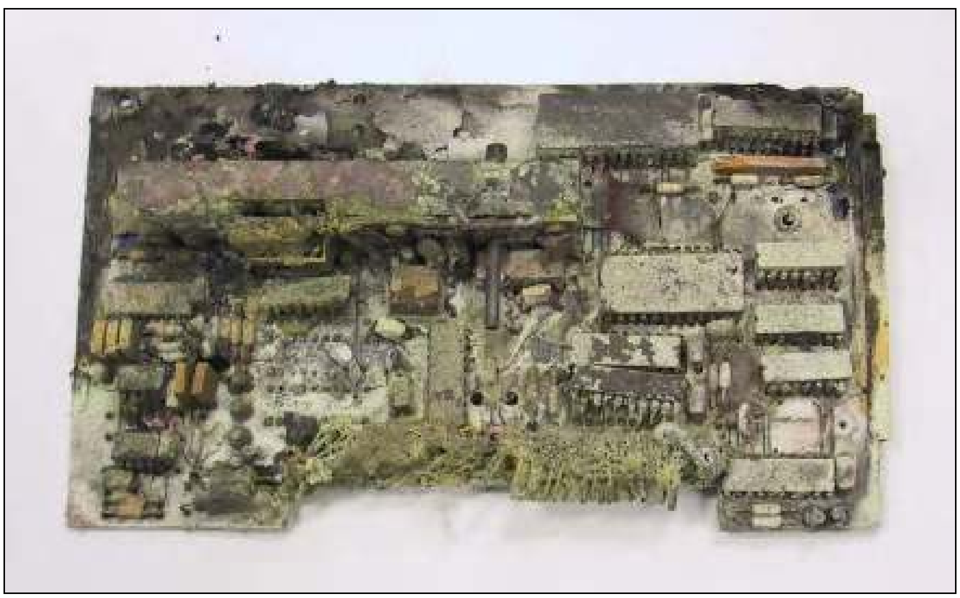


Figure A-16: Pneumatic printed circuit board from VH-TFU



The recorded altitude data was initially processed using the manufacturer's standard polynomial conversion equation. Examination of the results showed that the altitude values were unreasonable i.e. cruise levels did not agree with the cruise flight levels documented in the operator's trip records. The damage to the pneumatic PCB from VH-TFU precluded any direct testing/calibration so recorded radar data was used to calibrate the altitude data recorded by the FDR.

On the day of the accident VH-TFU flew the following sectors:

Cairns - Lockhart River - Bamaga - Lockhart River.

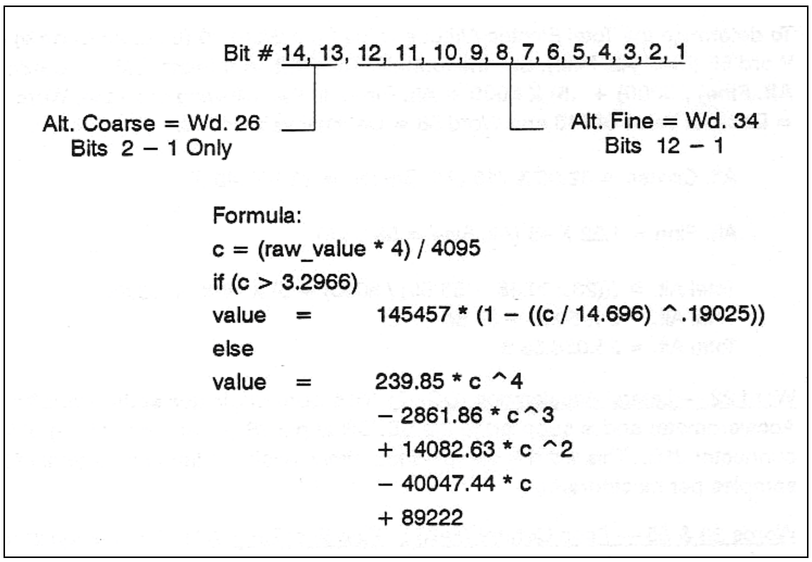
During climb and initial cruise after takeoff from Cairns the aircraft was under radar coverage from the secondary surveillance radar at Redden Creek (16º 51′ 38.7″ South and 145º 44′ 38.7″ East).

Mode C pressure altitude (referenced to 1013 hPa) was recorded by the radar system at intervals of 3.7 seconds while the aircraft was under radar coverage. The Mode C Pressure Altitude data accuracy was determined by the aircraft's encoding altimeter accuracy plus the transponder quantisation of 100 ft.

By comparing radar Mode C altitude with the recorded FDR altitude (Figure A-18) a calibration curve was derived (Figure A-19) i.e. Equation 1.

The standard pressure altitude engineering units were obtained using the equation listed in Figure A-17. Corrected altitude was then obtained by applying Equation 1.

Figure A-17: Standard pressure altitude conversion[12]



Bit # 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1

Alt. Coarse = Wd. 26
Bits 2 – 1 Only

Alt. Fine = Wd. 34
Bits 12 – 1

Formula:
c = (raw_value * 4) / 4095
if (c > 3.2966)
value = 145457 * (1 – ((c / 14.696) ^.19025))
else
value = 239.85 * c ^4
– 2861.86 * c^3
+ 14082.63 * c ^2
– 40047.44 * c
+ 89222

Equation 1:

Corrected altitude = value + correction

i.e. Corrected altitude = $value^3 * 7.0E\text{-}11 + value^2 * 4.0E\text{-}6 + value * 0.9958 + 152.82$

The accuracy of the corrected altitude values was:

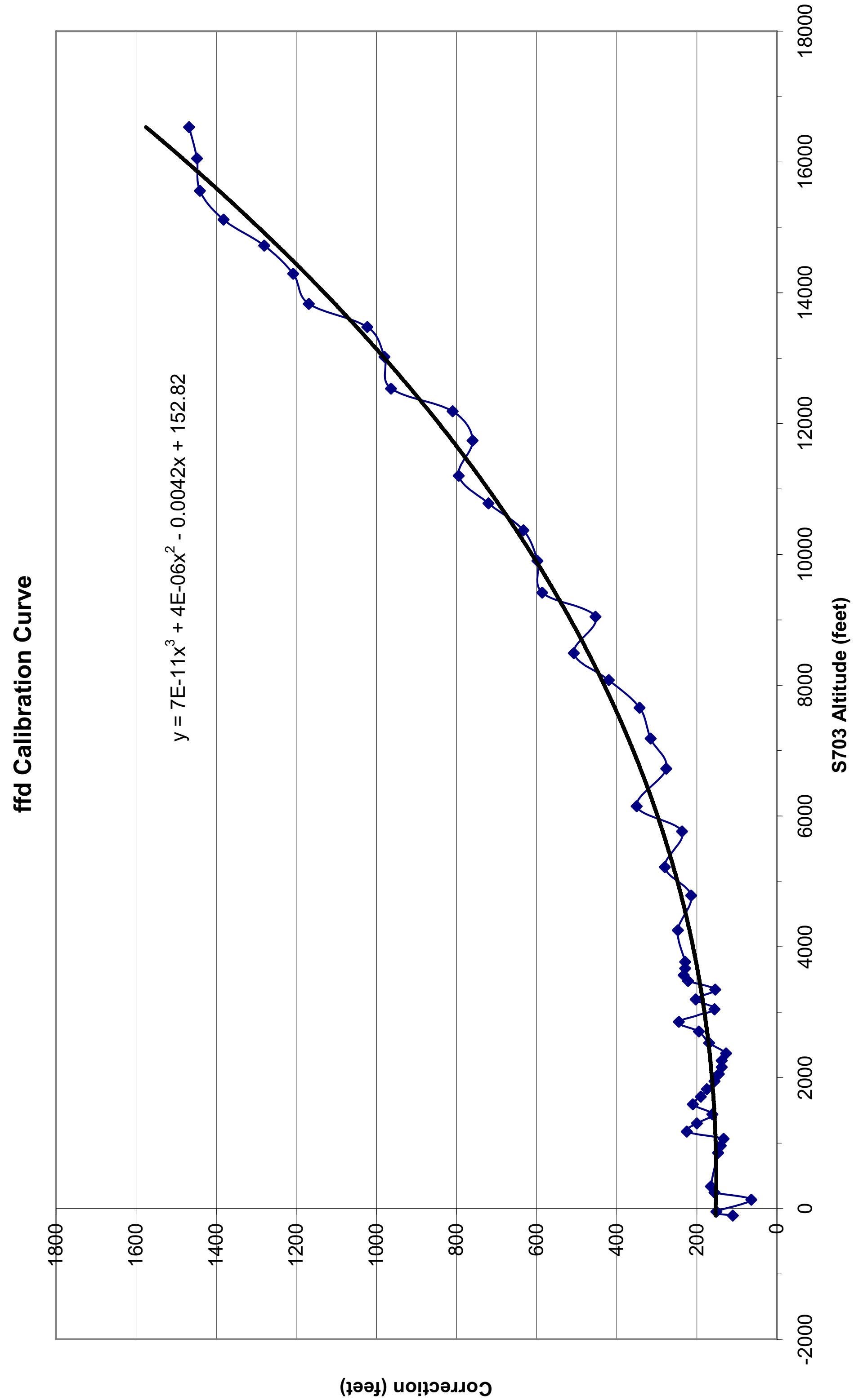
Altitude	Accuracy
3,000 feet	± 100 feet
18,000 feet	± 300 feet
22,000 feet	± 400 feet

12 'Procedure for Crash Data Recovery for Flight Data Recorder Fairchild Model F1000 with Solid-State Memory'. Document FAR 0389 Revision 4, figure 7-1, Page 2.

Figure A-18:

Altitude Calibration - Climb
Mode C Altitude
FDR Altitude
Altitude (feet)
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
Time (seconds)
0
200
400
600
800
1000
1200

Figure A-19:


ffd Calibration Curve
y = 7E-11x3 + 4E-06x2 - 0.0042x + 152.82
Correction (feet)
S703 Altitude (feet)
1800
1600
1400
1200
1000
800
600
400
200
0
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

Indicated airspeed

Signal Source:	FDR pneumatic transducer
Signal Type:	Pneumatic
Bits Used:	12
Word Location:	42
Resolution:	1 knot
Sampling Interval:	1 second

Pneumatic indicated airspeed (IAS) data is sensed by a transducer inside the FDR. The transducer measures the difference between static pressure, captured through one or more static port(s), and dynamic pressure captured through a pitot tube. The static ports are located on the exterior of the aircraft, at locations chosen to detect the prevailing atmospheric pressure as accurately as possible i.e. without any disturbance from the passage of the aircraft. The pitot tube accumulates 'ram air' i.e. air forced against the opening of the tube by the passage of the aircraft. Pitot tubes face forward in the direction of flight.

On Metro 23 aircraft, this sensor is connected to the copilot's pitot-static system. The raw recorded airspeed data is converted to engineering units (i.e. IAS in knots) by a standard polynomial equation supplied by the FDR manufacturer.

The recorded IAS data was initially processed using the manufacturer's standard polynomial conversion equation. Examination of the results showed that the IAS values were unreasonable i.e. cruise speeds did not agree with the cruise speeds documented in the operator's trip records. The damage to the pneumatic PCB from VH-TFU precluded any direct testing/calibration.

To determine IAS the following steps were performed:

1. Determine the aircraft altitude.
2. Determine the static pressure correction required as the same static pressure correction used for pressure altitude was also applied to IAS.
3. Convert this value to an equivalent voltage (i.e. multiply by 4095 and divide by 6).
4. Add this correction to the raw recorded IAS value.
5. Apply the standard polynomial equation for IAS supplied by the FDR manufacturer.

The IAS values obtained from these steps were again examined for reasonableness. In particular the IAS values were compared with expected climb speeds, expected cruise speeds (eg. compared with engine trend monitoring logs) and airspeed limits eg. V_{MO}[13] (246 kts) and V_{FE}[14] for ¼ flap (215 kts), ½ flap (180 kts) and full flaps (165 kts).

---

13 V_{MO}: Maximum operating airspeed.

The examination showed that airspeed values were now reasonable although it was noted that for some flights IAS exceeded V_{MO} during descent. As the exceedances were within the stated accuracy at high speed (± 15 kts), no further correction was considered necessary.

Figure A-20: Standard airspeed polynomial[15]

```
        PNEUMATIC AIRSPEED: 12 bit raw value to knots
temp = raw_value * 6/4095               ( 6 PSI / 5 VDC)
knots = 1479.11 *  ( ((((temp/14.696)+1.) ^ (1/3.5)) - 1.) ^ .5 )
```

The accuracy of the corrected IAS values was:

IAS	Accuracy
60 kts – 150 kts	± 10 kts
> 150kts	± 15 kts

14 V_{FE}: Maximum airspeed for extending the flaps or operating with the flaps extended.

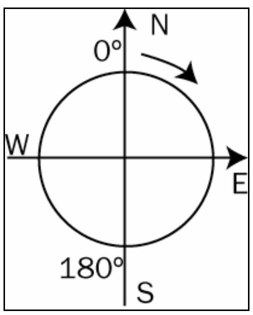
15 'Procedure for Crash Data Recovery for Flight Data Recorder Fairchild Model F1000 with Solid-State Memory'. Document FAR 0389, revision 4, figure 7-1, page 2.

Magnetic heading

On Metro 23 aircraft, magnetic heading data is sensed from the pilot's gyrocompass.

Signal Source:	Gyrocompass
Signal Type:	Synchro
Bits Used:	12
Word Location:	9
Resolution:	0.09º
Sampling Interval:	1 second

Figure A-21: Sign convention



The standard scaling equation for magnetic heading was used and no corrections were applied. A reasonableness check was performed by examining recorded magnetic heading during takeoff and landing versus known magnetic heading of the runway obtained from the AirServices Australia publication 'En Route Supplement Australia'.

Location	Runway Directions	Landing	Takeoff
(7 May 2005)	(ºM)	(ºM)	(ºM)
Cairns	149/329	150.0	151.6
Lockhart River	119/299	119.9	120.8
Bamaga	131/311	129.2	133.3

The recorded headings were obtained at times when the IAS was between 80-100 kts.

The comparison showed that recorded magnetic heading agreed with documented magnetic heading within an accuracy of ± 5º.

Pitch attitude

Signal Source:	Attitude Direction Indicator
Signal Type:	Synchro[16]
Bits Used:	12
Word Locations:	13, 29, 45 & 53
Resolution:	0.09º
Sampling Interval:	0.25 second

Pitch attitude is the angle between the aircraft's longitudinal axis and the horizon ie. the angle of rotation around the aircraft's lateral axis, refer to figure A-52. Zero degrees pitch attitude corresponds to the aircraft's nose being level with the horizon, positive and negative pitch attitude corresponds to the aircraft's nose being above the horizon and below the horizon respectively.

The pitch attitude parameter was unserviceable[17]. Examination of recorded pitch attitude data showed that unreasonable values had been recorded during takeoff, cruise and landing. These values were generally zero with occasional spikes. This was unrealistic behaviour as continuous variations in pitch attitude are expected during flight. This characteristic was evident in all the flights recorded by the FDR, not just the accident flight.

16 A synchro is an AC electrical position sensor.

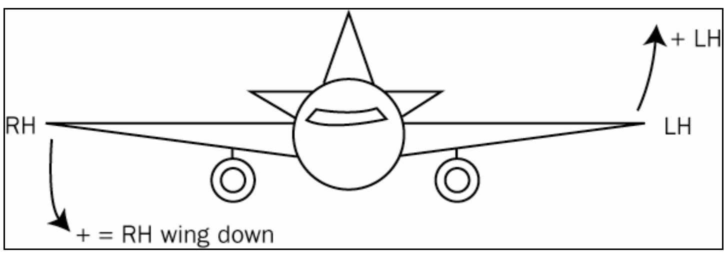
17 ATSB Recommendation 20060005 was issued on 10 February 2006 to address FDR and CVR system serviceability problems.

Roll attitude

Signal Source:	Attitude Direction Indicator
Signal Type:	Synchro
Bits Used:	12
Word Locations:	14 & 46
Resolution:	0.09º
Sampling Interval:	0.5 second

The standard scaling equation for roll attitude was used and no corrections were applied. The sign convention for roll attitude is that positive values correspond to right wing low:

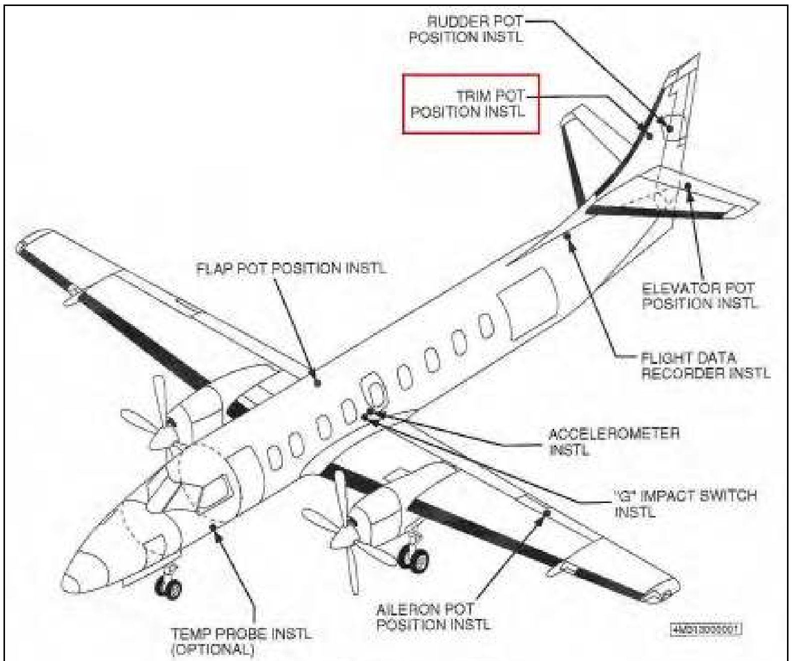
Figure A-22: Sign convention



Horizontal stabiliser position

Signal Source:	Potentiometer
Signal Type:	DC voltage
Bits Used:	12
Word Location:	18
Resolution:	0.04º
Sampling Interval:	1 second

Figure A-23: Trim potentiometer (pot) location



Flight Data Recorder Locator

It has been observed in readouts for other Metro 23 aircraft, prior to the accident involving VH-TFU, that the standard scaling for horizontal stabiliser position resulted in unrealistic values and was incorrect. Neither the aircraft manufacturer nor the FDR manufacturer has been able to provide the correct scaling equation.

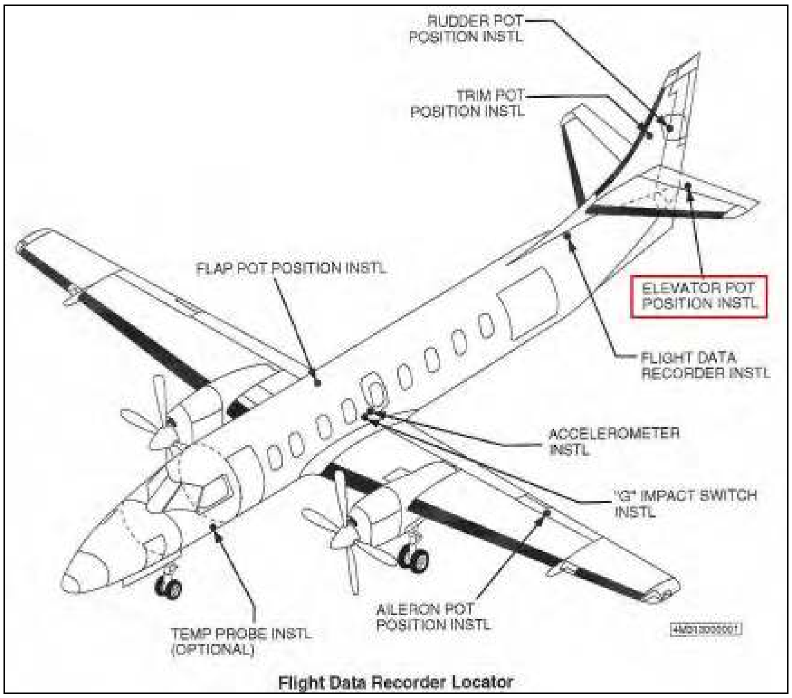
Examination of the raw horizontal stabiliser position data from VH-TFU showed that it behaved in a similar way to other Metro 23 aircraft. Data from VH-TFU and other Metro 23 aircraft were examined to determine the relationship between the raw decimal counts and horizontal stabiliser position.

Horizontal Stabiliser Position	Raw Decimal Counts
Full Nose Up (+7.8º) (Leading Edge Down)	2264
Full Nose Down (-2.4º) (Leading Edge Up)	2017

Elevator position

Signal Source:	Potentiometer
Signal Type:	DC voltage
Bits Used:	12
Word Location:	31
Resolution:	0.08º
Sampling Interval:	1 second

Figure A-24: Elevator potentiometer (pot) location



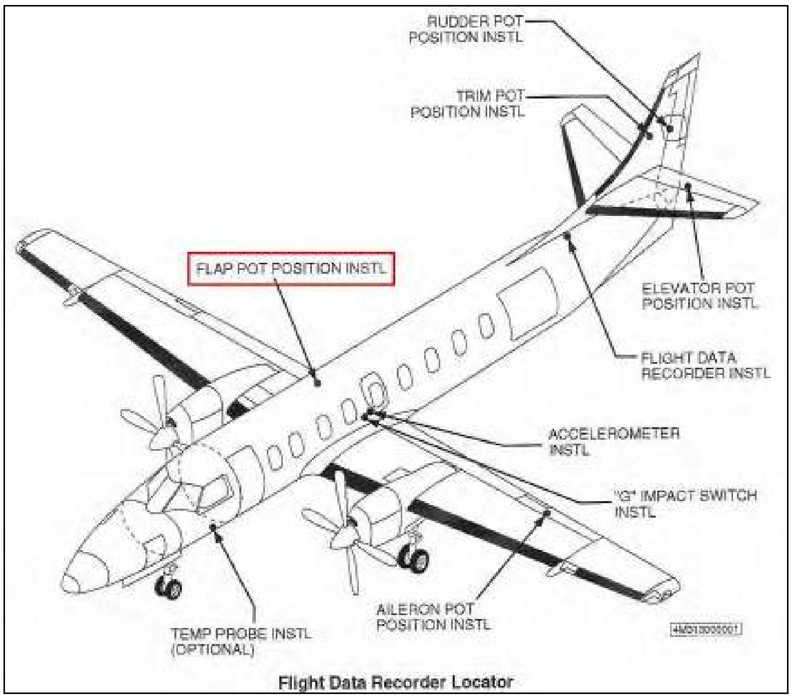
Elevator scaling was derived using Fairchild Aircraft drawing 27K82090 and figure 1-25 (page 40) from the L3 Communications component maintenance manual.

Elevator Position	Raw Decimal Counts
Neutral (0º)	1950
Full Up (+30º)	2434
Full Down (-15º)	1669

Flap position

Signal Source:	Potentiometer
Signal Type:	DC voltage
Bits Used:	12
Word Locations:	23 & 55
Resolution:	0.04º
Sampling Interval:	0.5 second

Figure A-25: Flap potentiometer (pot) location



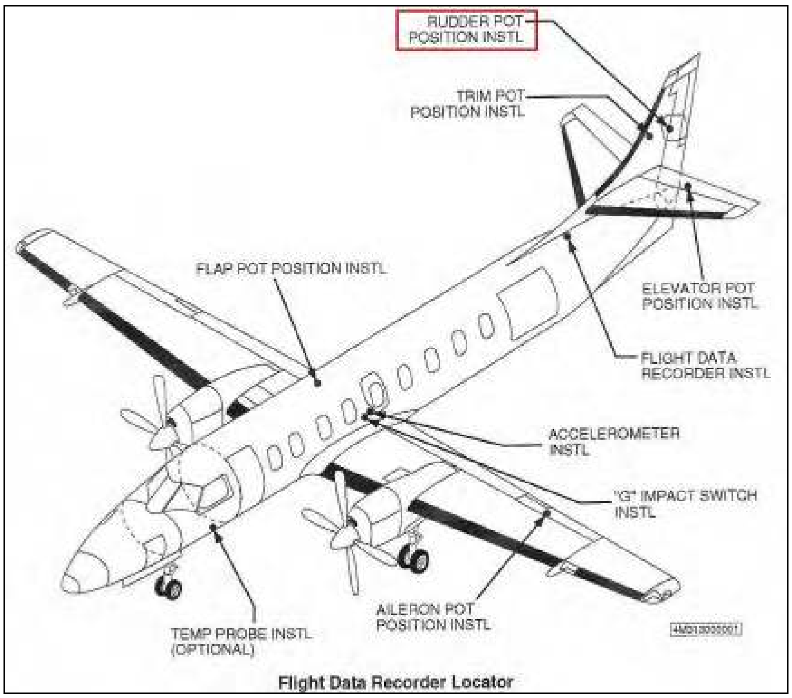
It was observed that the use of the standard scaling for flap position resulted in unrealistic values. The raw data was examined to determine the relationship between the raw decimal counts and flap position.

Flap Lever Detent Position	Flap Position	Raw Decimal Counts
Up	0º	2134 - 2140
¼	9º	1924 - 1944
½	18º	1714 - 1724
Down	36º	1282 - 1338

Rudder position

Signal Source:	Potentiometer
Signal Type:	DC voltage
Bits Used:	12
Word Location:	30
Resolution:	0.04º
Sampling Interval:	1 second

Figure A-26: Rudder potentiometer (pot) location



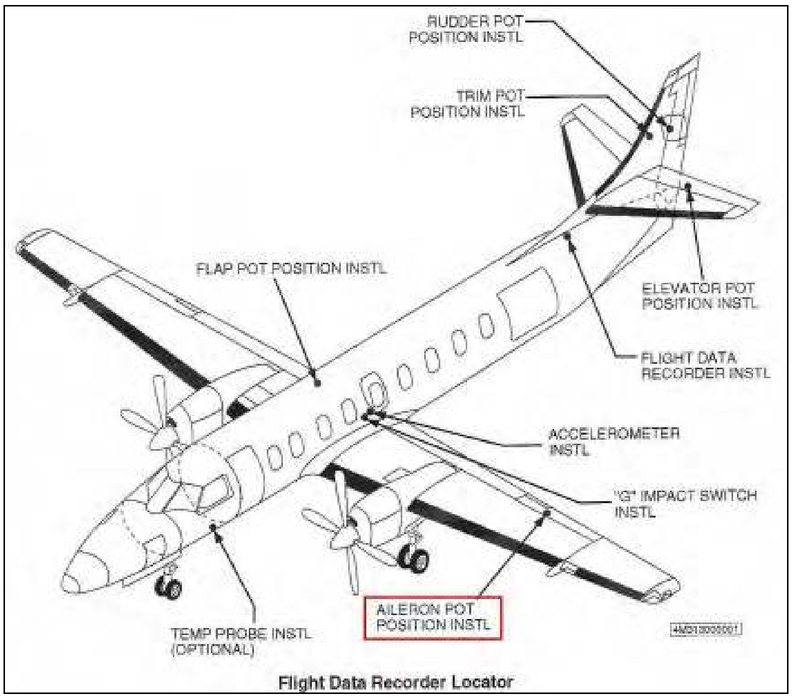
Rudder position scaling was derived using Fairchild Aircraft drawing 27K82090 and figure 1-25 (page 40) from the L3 Communications component maintenance manual.

Rudder Position	**Raw Decimal Counts**
Neutral (0º)	1950
Full Right (+25º)	2597
Full Left (-25º)	1365

Aileron position

Signal Source:	Potentiometer
Signal Type:	DC voltage
Bits Used:	12
Word Locations:	6, 22, 38 & 54
Resolution:	0.07º
Sampling Interval:	0.25 second

Figure A-27: Aileron potentiometer (pot) location



Aileron position scaling was derived using Fairchild Aircraft drawing 27K82090 and figure 1-25 (page 40) from the L3 Communications component maintenance manual.

Aileron Position	**Raw Decimal Counts**
Neutral (0º)	1950
Full Up (+18.5º)	2410
Full Down (-21.5º)	1482

Right engine propeller RPM

Signal Source:	Tacho-generator
Signal Type:	Frequency
Bits Used:	12
Word Location:	40
Resolution:	0.14%
Sampling Interval:	1 second

Right engine propeller RPM is transmitted to the FDR as a frequency signal. The standard scaling for propeller RPM was used and no corrections were applied.

Left engine propeller RPM

Signal Source:	Tacho-generator
Signal Type:	Frequency
Bits Used:	12
Word Location:	8
Resolution:	0.14%
Sampling Interval:	1 second

Left engine propeller RPM is transmitted to the FDR as a frequency signal. The standard scaling for propeller RPM was used and no corrections were applied.

Right engine torque

Signal Source:	Torque transducer (strain-gauge)
Signal Type:	DC voltage
Bits Used:	12
Word Location:	64
Resolution:	0.04%
Sampling Interval:	1 second

The standard scaling equation for torque was used and no corrections were applied.

Left engine torque

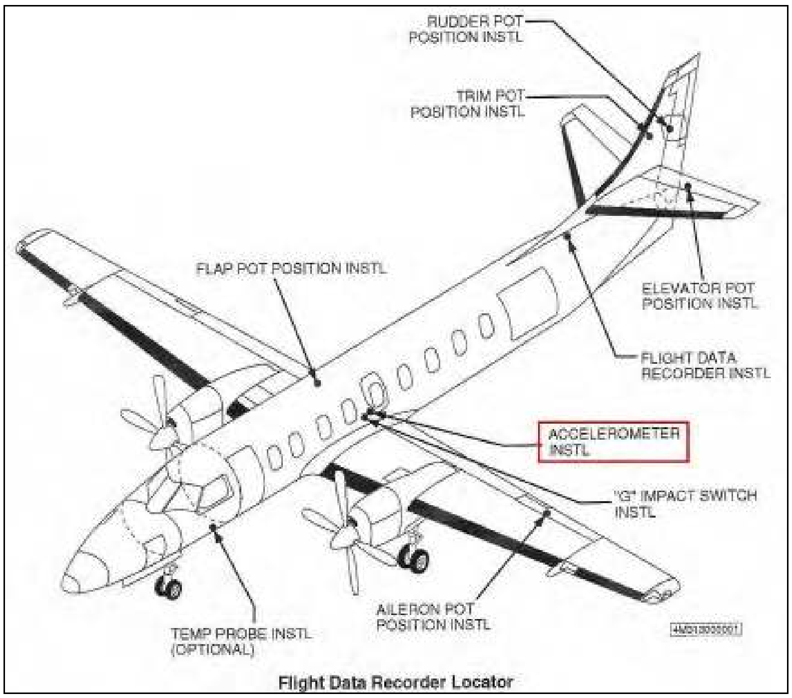
Signal Source:	Torque transducer (strain-gauge)
Signal Type:	DC voltage
Bits Used:	12
Word Location:	32
Resolution:	0.04%
Sampling Interval:	1 second

The standard scaling equation for torque was used and no corrections were applied.

Vertical acceleration

Signal Source:	DC accelerometer
Signal Type:	DC voltage
Bits Used:	12
Word Locations:	4, 12, 20, 28, 36, 44, 52 & 60
Resolution:	0.003 g
Sampling Interval:	0.125 second

Figure A-28: Accelerometer general location



A dual-axis DC accelerometer was fitted to VH-TFU. It provided acceleration information in the aircraft vertical (Z) and longitudinal (X) axes. The standard scaling equation for vertical acceleration was used and no corrections were applied. A reasonableness check was performed by examining recorded vertical acceleration values when the aircraft was on the ground and airborne. Values close to the expected 1 g were recorded on the ground with typical variations observed when the aircraft was airborne.

Figure A-29: Sign convention

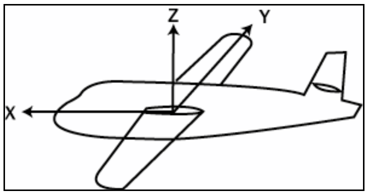
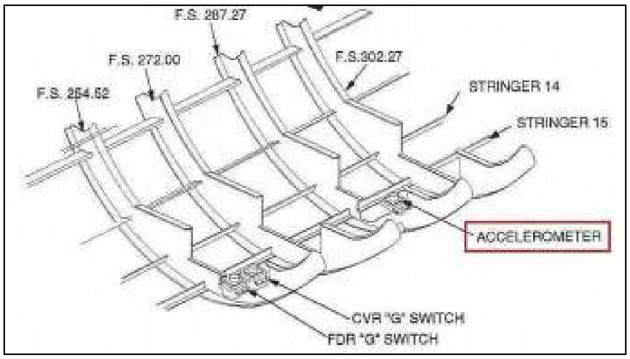


Figure A-30: Accelerometer detailed location



Longitudinal acceleration

Signal Source:	DC accelerometer
Signal Type:	DC voltage
Bits Used:	12
Word Locations:	5, 21, 37 & 53
Resolution:	0.0005 g
Sampling Interval:	0.25 second

The standard scaling equation for longitudinal acceleration was used and no corrections were applied. A reasonableness check was performed by examining recorded longitudinal acceleration values when the aircraft was on the ground and during the takeoff roll. Values close to the expected 0 g were recorded on the ground and the typical increase in longitudinal acceleration was observed as the aircraft accelerated along the runway during takeoff.

Pilot microphone keying (COM 1)

Signal Source:	Pilot's transmitter
Signal Type:	DC voltage
Bits Used:	1
Word Location:	11 (bit 1)
Resolution:	N/A
Sampling Interval:	1 second

This parameter is used for recording the time that a radio transmission was made i.e. the time that a microphone was 'keyed'. It is used to synchronise a voice recording (either a cockpit voice recorder or a ground-based air traffic control audio recorder) with the flight data recorder.

No scaling equation is required for a discrete parameter. A 'zero' corresponds to 'keyed' and a 'one' corresponds to 'not keyed'.

Copilot microphone keying (COM 2)

Signal Source:	Copilot's transmitter
Signal Type:	DC voltage
Bits Used:	1
Word Location:	11 (bit 3)
Resolution:	N/A
Sampling Interval:	1 second

This parameter is used for recording the time that a radio transmission was made i.e. the time that a microphone was 'keyed'. It is used to synchronise a voice recording (either a cockpit voice recorder or a ground-based air traffic control audio recorder) with the flight data recorder.

No scaling equation is required for a discrete parameter. A 'zero' corresponds to 'keyed' and a 'one' corresponds to 'not keyed'.

End of recording

The FDR used solid-state technology (i.e. integrated circuits or memory chips) to store the flight data. The FDR memory board comprised 64 separate flash memory chips numbered 0 to 63. Each chip had a memory capacity of 1 megabit giving a total memory capacity of 64 megabits or 8 megabytes.

When the memory is downloaded for analysis, the resulting file (with file extension of *.fdt*) is an exact memory image of the contents of the flash memory chips. Time sequencing and decompression is performed on the *.fdt* file by proprietary software.

The flash memory chips are organized in pairs and data is ‘stitched’ between chips i.e. one frame (4 seconds or 4 subframes of data) is stored in one chip and the next frame is stored in its ‘buddy’ chip.

A memory analysis report was conducted and the results are shown in Figure A-31.

The break in sequence numbers (shown in the column titled SEQ#) in the memory analysis report shows that the most recent data was being recorded alternately in chips 10 and 11 (shown in the column titled PHY#).

Memory failure and error information was also stored in the flash chips. The memory analysis report showed that there were no memory failure or error indications recorded.

Manual examination of the data showed:

Chip:	Subframe:	FDR Elapsed Time Counter (seconds):
10	1	3020
10	2	3021
10	3	3022
10	4	3023
11	1	3024
11	2	3025
11	3	3026
11	4	3027
10	1	3028
10	2	3029
10	3	3030
10	4	3031
11	1	3032
The last valid parameter recorded was vertical acceleration in word 60 of subframe 1.		

The final data recorded by the FDR was consistent with power being removed from the FDR once only. During the initial accident impact with trees, the G switch[18] is likely to have operated removing power from the FDR. The FDR power supply circuit contains a large capacitor that can power the FDR for a short period in the absence of aircraft power. Once power is removed, the FDR is designed to enter a standby mode and later, if power is not restored, the FDR will shutdown. The standby and shutdown process takes approximately 1 second.

Input data to the FDR is not recorded instantaneously and must occur within 0.5 of a second[19]. In the case of the F1000, the delay (latency) between data being sampled and it being recorded is less than 0.1 of a second.

18 G switches are typically set to trigger in the range of 3 – 4 g and are orientated 45° to the aircraft's longitudinal axis.

19 EUROCAE document ED-55 page 27.

Figure A-31: Memory analysis report

MEMORY DEVICE STATUS

LOGICAL#	PHY#	SEQ#	BAD PAGES	CNTRDCTRY BAD_PGS	CORR'ED BIT_ERRS	UNCORR'ED BIT_ERRS
0	0	2	0	0	0	0
1	1	3	0	0	0	0
2	2	4	0	0	0	0
3	3	5	0	0	0	0
4	4	6	0	0	0	0
5	5	7	0	0	0	0
6	6	9	0	0	0	0
7	7	8	0	0	0	0
8	8	10	0	0	0	0
9	9	11	0	0	0	0
10	10	12	0	0	0	0
11	11	13	0	0	0	0
12	12	206	0	0	0	0
13	13	207	0	0	0	0
14	14	208	0	0	0	0
15	15	209	0	0	0	0
16	16	210	0	0	0	0
17	17	211	0	0	0	0
18	18	212	0	0	0	0
19	19	213	0	0	0	0
20	20	214	0	0	0	0
21	21	215	0	0	0	0
22	22	216	0	0	0	0
23	23	217	0	0	0	0
24	24	218	0	0	0	0
25	25	219	0	0	0	0
26	26	220	0	0	0	0
27	27	221	0	0	0	0
28	28	223	0	0	0	0
29	29	222	0	0	0	0
30	30	224	0	0	0	0
31	31	225	0	0	0	0
32	32	226	0	0	0	0
33	33	227	0	0	0	0
34	34	228	0	0	0	0
35	35	229	0	0	0	0
36	36	230	0	0	0	0
37	37	231	0	0	0	0
38	38	233	0	0	0	0
39	39	232	0	0	0	0
40	40	234	0	0	0	0
41	41	235	0	0	0	0
42	42	236	0	0	0	0
43	43	237	0	0	0	0
44	44	238	0	0	0	0
45	45	239	0	0	0	0
46	46	240	0	0	0	0
47	47	241	0	0	0	0
48	48	242	0	0	0	0
49	49	243	0	0	0	0
50	50	244	0	0	0	0
51	51	245	0	0	0	0
52	52	246	0	0	0	0
53	53	247	0	0	0	0
54	54	248	0	0	0	0
55	55	249	0	0	0	0
56	56	251	0	0	0	0
57	57	250	0	0	0	0
58	58	252	0	0	0	0
59	59	253	0	0	0	0
60	60	254	0	0	0	0
61	61	255	0	0	0	0
62	62	0	0	0	0	0
63	63	1	0	0	0	0
64 DEVICES TOTALS			0	0	0	0

Timing correlation

UTC was not recorded by the FDR, however the FDR did record an elapsed time counter which began when power was applied to the recorder and was incremented once per second. When power was removed and later re-applied, this counter was reset to zero and began incrementing again.

UTC was matched with the recorded FDR elapsed time by correlating the microphone keying discrete parameter with the UTC time stamp from the ATC air/ground voice recording. Using this technique the radio transmission from VH-TFU (‘*Brisbane centre tango foxtrot uniform*’), that was recorded on the ground at 0114:28 UTC, was correlated with the FDR microphone keying parameter at an elapsed time of 1281 seconds. This correlation was accurate to ± 1 second.

Flights landing at Lockhart River

The F1000 model FDR compresses the flight data before it is recorded and as a result the recording duration exceeds the minimum requirement of retaining the most recent 25 hours. In this case 100 hours, 2 minutes and 16 seconds of data was recorded covering the accident flight and 59 previous flights. The oldest data recorded was from the cruise and descent portion of the Lockhart River to Cairns flight on 13 April 2005.

Flights that landed at Lockhart River (LHR) are tabulated below:

VH-TFU Flight Sequence: **(before accident flight)**	**Sector:**	**Date:**	**Landing Runway:**
2	CS-LHR	7 May	12
9	CS-LHR	4 May	12
17	BAM-LHR	30 April	12
19	CS-LHR	30 April	12
28	BAM-LHR	27 April	12
30	CS-LHR	27 April	12
34	CS-LHR	25 April	12
36	BAM-LHR	23 April	12
50	CS-LHR	20 April	12

Sequence of events

The accident flight was examined in detail and relevant parameters plotted (refer to Figures A-32 to A-37)

Table A-1: Sequence of events

UTC	Replay	Pressure	Mag.	Indicated	Elapsed	Elapsed	Event
(from ATC recordings)	Time	Altitude	Heading	Airspeed	Time	Time	
	Counter					Counter	
		(feet)	(degrees)	(knots)	(hh:mm:ss)	(seconds)	
00:53:07	355926	N/A	N/A	N/A	00:00:00	0	FDR power-up. Aircraft was stationary at Bamaga.
01:07:32	356791	N/A	N/A	N/A	00:14:25	865	Right engine start.
01:09:15	356894	N/A	N/A	N/A	00:16:08	968	Left engine start.
01:09:42	356921	N/A	N/A	N/A	00:16:35	995	Takeoff flap selected.
01:10:14	356953	83	107.5	N/A	00:17:07	1027	Microphone keyed - Pilot. Aircraft began to taxi.
01:10:45	356984		25	N/A	00:17:38	1058	Control checks: aileron and elevator.
01:11:09	357008	118	343.3	N/A	00:18:02	1082	Microphone keyed - Pilot.
01:11:54	357053	80	147.4	N/A	00:18:47	1127	Power applied for takeoff on runway 13 at Bamaga.
01:12:19	357078	107	134.3	119	00:19:12	1152	Lift off.
01:12:39	357098	381	131	149	00:19:32	1172	Torque reduced on both engines after takeoff.
01:13:01	357120	866	124.6	147	00:19:54	1194	Microphone keyed - Pilot.
01:13:14	357133	1248	121.4	154	00:20:07	1207	Microphone keyed - Copilot.
01:13:31	357150	1773	120.4	146	00:20:24	1224	Flap selected up.
01:14:28	357207	3360	145.8	153	00:21:21	1281	Microphone keyed - Copilot.
01:14:33	357212	3438	149.2	155	00:21:26	1286	Microphone keyed - Copilot.
01:14:49	357228	3667	151	165	00:21:42	1302	Microphone keyed - Copilot.
01:14:58	357237	3924	149.7	163	00:21:51	1311	Microphone keyed - Copilot.

UTC	Replay	Pressure	Mag.	Indicated	Elapsed	Elapsed	Event
(from ATC recordings)	Time	Altitude	Heading	Airspeed	Time	Time	
	Counter					Counter	
		(feet)	(degrees)	(knots)	(hh:mm:ss)	(seconds)	
01:24:36	357815	14281	142.8	165	00:31:29	1889	Microphone keyed - Copilot.
01:28:32	358051	16977	153.1	169	00:35:25	2125	Top of climb (FL170).
01:32:26	358285	17124	143.3	201	00:39:19	2359	Top of descent.
01:33:06	358325	16130	147.9	226	00:39:59	2399	Microphone keyed - Copilot.
01:33:28	358347	15412	150.5	239	00:40:21	2421	Microphone keyed - Copilot.
01:33:37	358356	15127	150.9	246	00:40:30	2430	Torque reduced on both engines.
01:33:54	358373	14531	153.7	252	00:40:47	2447	Further reduction in torque on both engines.
01:34:31	358410	13067	157.1	248	00:41:24	2484	Microphone keyed - Copilot.
01:35:24	358463	11202	150.7	247	00:42:17	2537	Microphone keyed - Copilot.
01:35:42	358481	10583	147.3	249	00:42:35	2555	Microphone keyed - Copilot.
01:35:48	358487	10376	146.9	250	00:42:41	2561	Microphone keyed - Copilot.
01:36:18	358517	9369	147.6	250	00:43:11	2591	Microphone keyed - Copilot.
01:36:49	358548	8364	149.4	253	00:43:42	2622	Microphone keyed - Copilot.
01:38:44	358663	4305	145.3	243	00:45:37	2737	Torque increased on both engines.
01:39:30	358709	3505	146.8	229	00:46:23	2783	Aircraft reached 3,500 feet and began to climb.
01:39:50	358729	3992	144.6	195	00:46:43	2803	Aircraft levelled at 4,000 feet.
01:39:56	358735	3992	157.1	192	00:46:49	2809	Aircraft began to descend. Microphone keyed - Copilot.
01:40:19	358758	3316	177.7	204	00:47:12	2832	Altitude 3,300 feet.
01:40:26	358765	3457	175.7	197	00:47:19	2839	Microphone keyed - Copilot.

UTC	**Replay**	**Pressure**	**Mag.**	**Indicated**	**Elapsed**	**Elapsed**	**Event**
(from ATC recordings)	**Time**	**Altitude**	**Heading**	**Airspeed**	**Time**	**Time**	
	Counter					**Counter**	
		(feet)	**(degrees)**	**(knots)**	**(hh:mm:ss)**	**(seconds)**	
01:40:28	358767	3513	175.7	197	00:47:21	2841	First stage of flap selected.
01:40:33	358772	3600	177	190	00:47:26	2846	Aircraft levelled at 3,600 feet. Microphone keyed - Copilot.
01:40:46	358785	3596	183.6	181	00:47:39	2859	Torque increased on both engines.
01:41:11	358810	3588	139.4	179	00:48:04	2884	Aircraft left 3,600 feet.
01:41:52	358851	2998	134.8	188	00:48:45	2925	Aircraft levelled at 3,000 feet.
01:42:19	358878	3039	127	180	00:49:12	2952	Second stage of flap selected.
01:42:29	358888	3043	126.9	174	00:49:22	2962	Aircraft left 3,000 feet on descent.
01:43:39	358958	1365	136	157	00:50:32	3032	End of recorded data.

Figure A-32: Plot of flight parameters

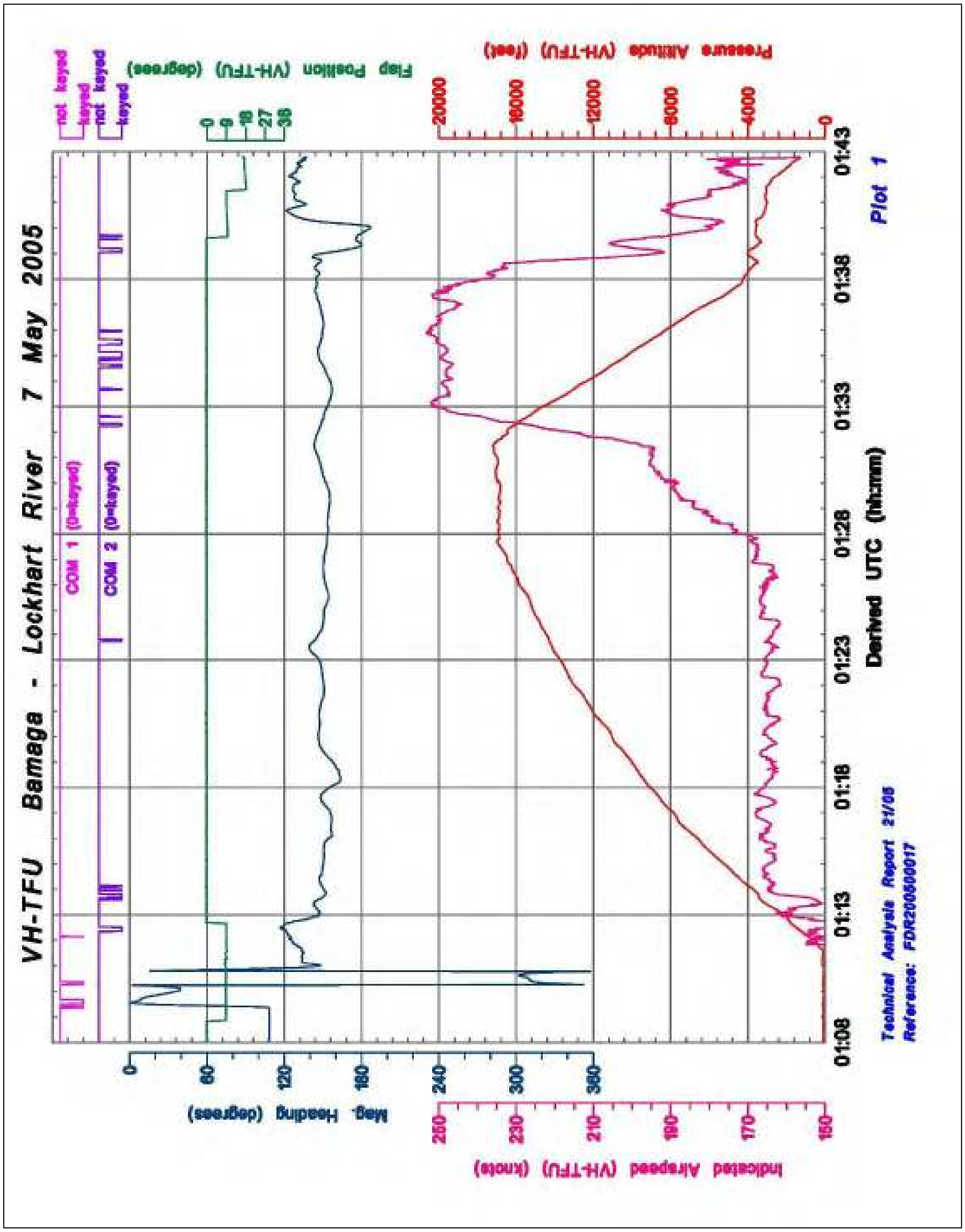


Figure A-33: Plot of engine parameters

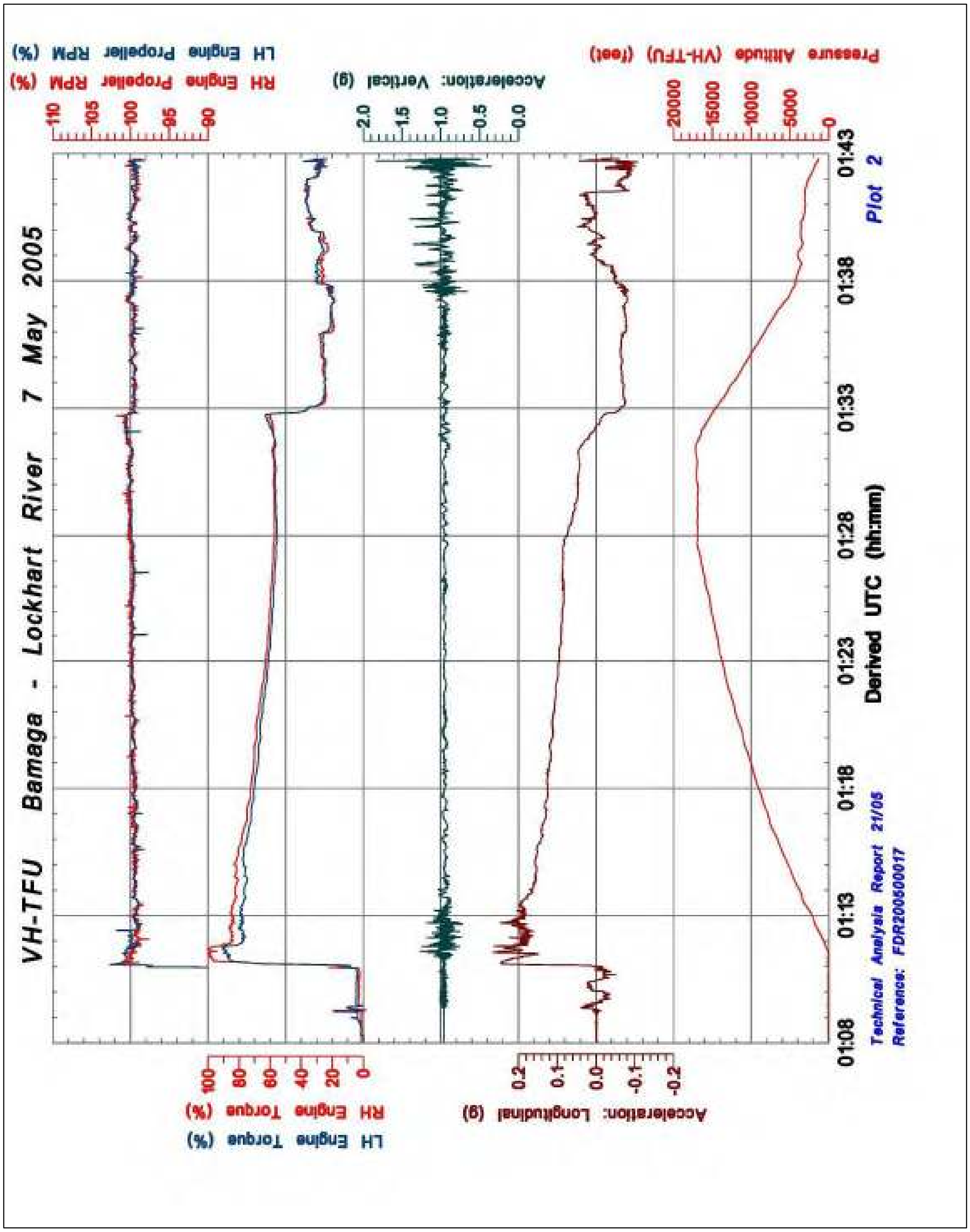


Figure A-34: Plot of control parameters

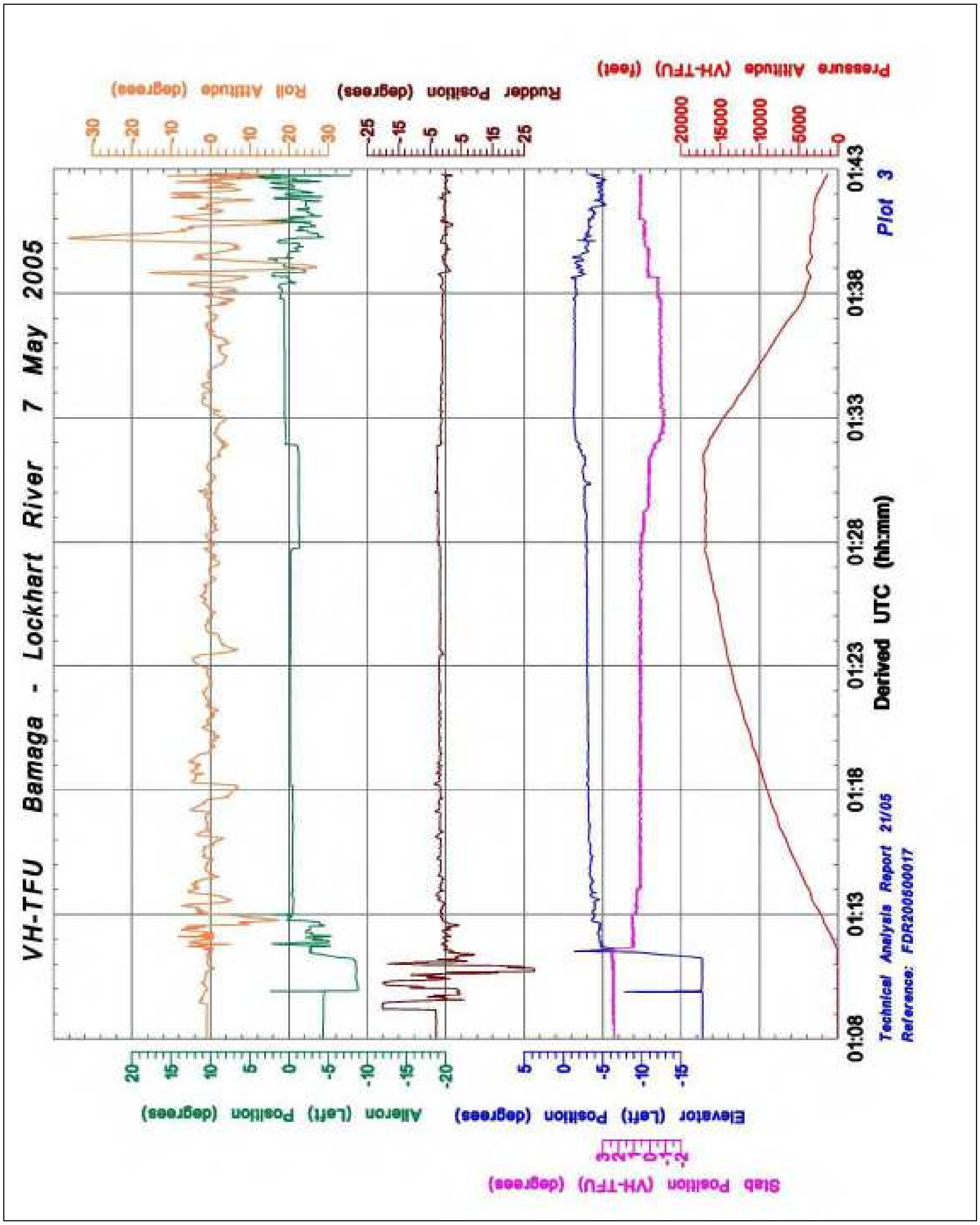


Figure A-35: Plot of flight parameters (last 5 minutes)

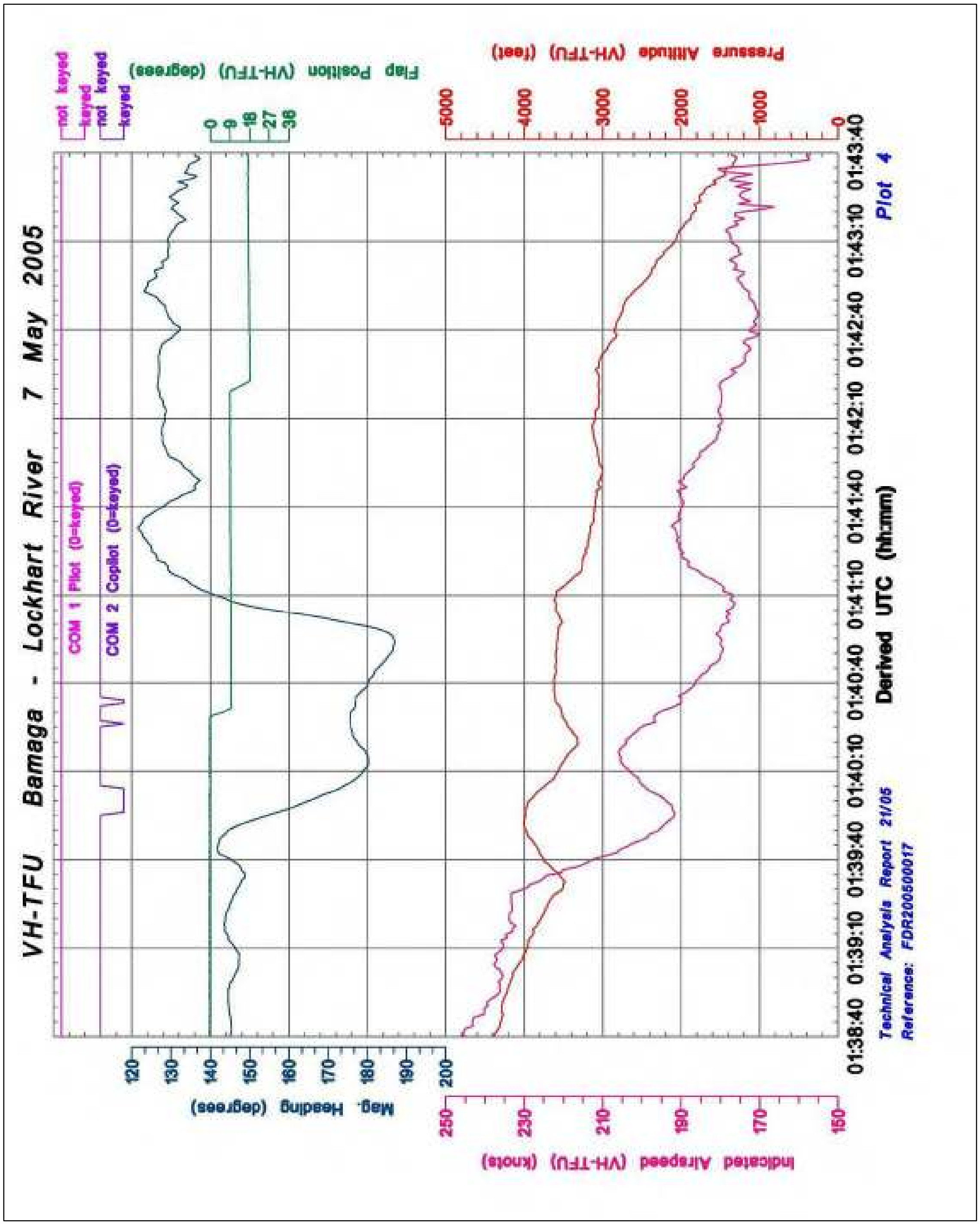


Figure A-36: Plot of engine parameters (last 5 minutes)

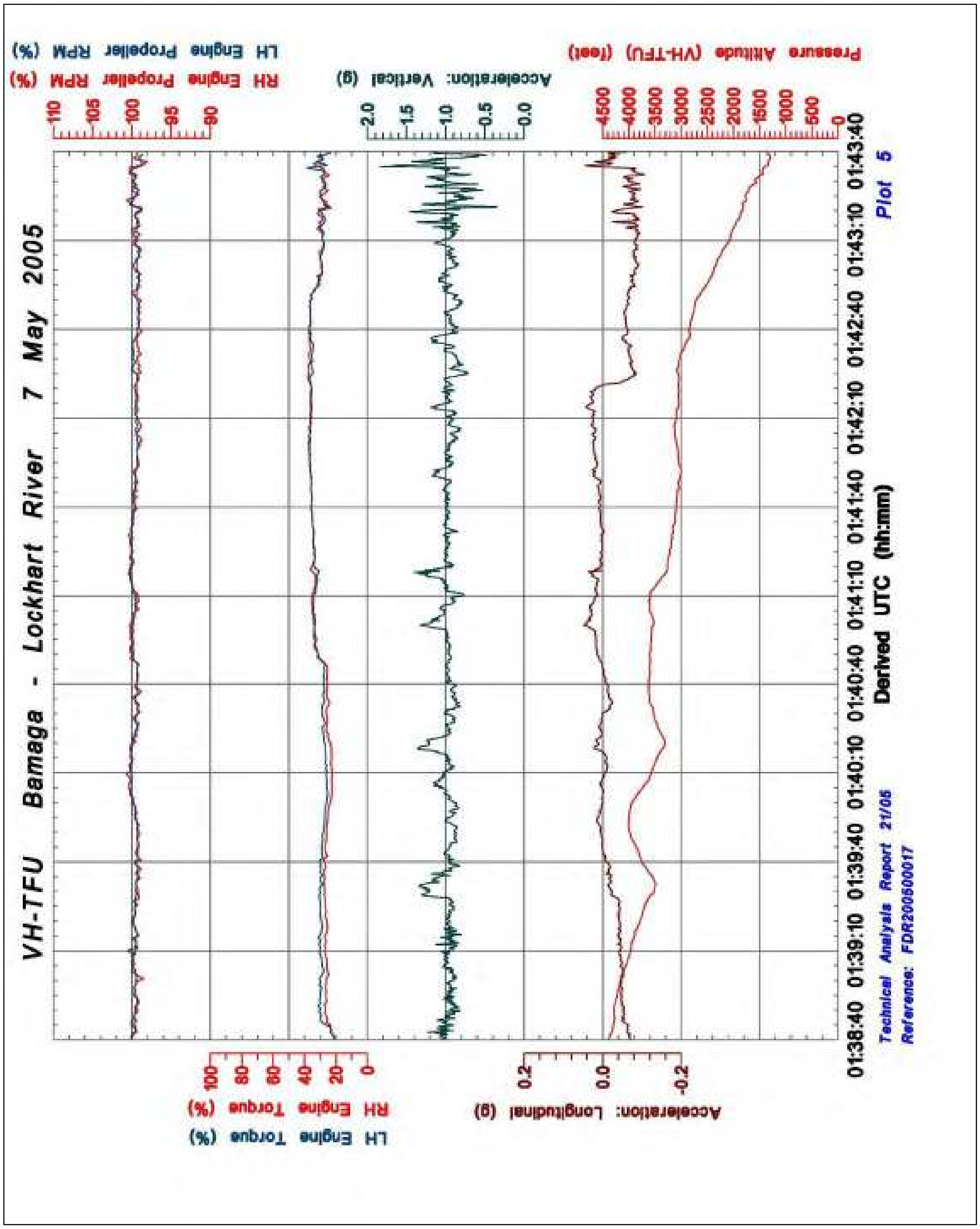
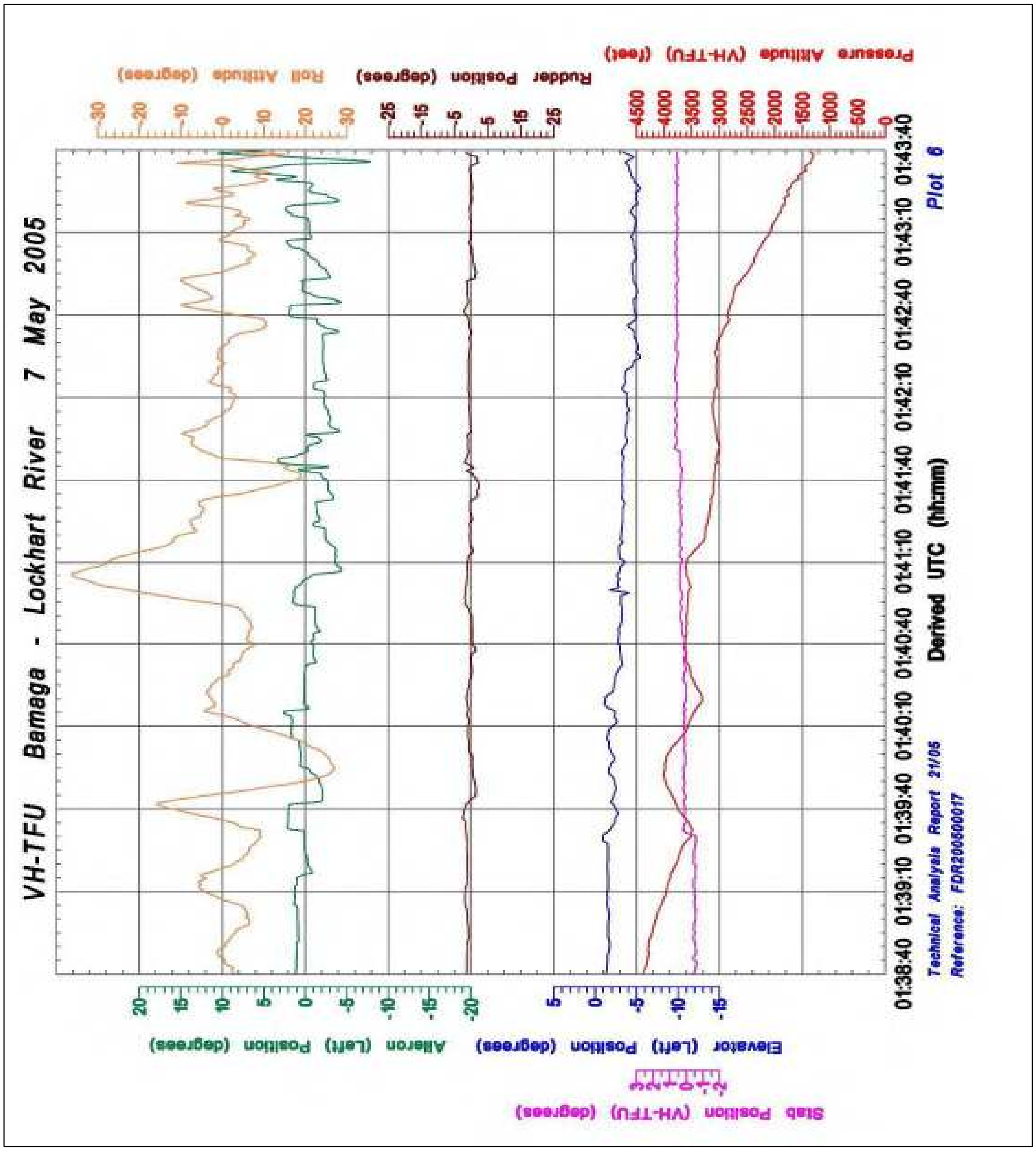


Figure A-37: Plot of control parameters (last 5 minutes)



APPENDIX A ANALYSIS

Pitch parameter unserviceability

Examination of recorded pitch attitude data showed that unreasonable values had been recorded during takeoff, cruise and landing. These values were generally zero with occasional spikes. Refer to figure A-38. This was unrealistic behaviour as continuous variations in pitch attitude were expected during flight, refer to figure A-39. This characteristic was evident in all the flights recorded by the FDR and not just the accident flight.

Examination of the FDR rear connector showed that wires were connected to J1B pins 1-5 as expected. Given that the FDR fault (SSFDR Fault) and synchro/digital (S/D Fault) discrete parameters both indicated *no fault,* then the problem was likely to be with the pitch attitude transmitter, interconnecting wiring or FDR signal interface box and not with the FDR itself.

Examination of the aircraft maintenance log showed that FDR serial number 00393 was removed on 2 April 2004 after the aircraft FDR circuit breaker repeatedly tripped. The unit was sent to the FDR manufacturer's authorised repair agency in Melbourne. Fault-finding showed that the FDR's aircraft interface circuit board and the power supply circuit board were faulty and they were replaced. A functional test of the FDR, as specified in the manufacturer's component maintenance manual, was successfully completed by the repair agency.

The functional test involves supplying test signals to the FDR and checking that they have been correctly recorded. Its purpose is to check that the FDR itself is functioning correctly. It is not a check of the aircraft installation and would not reveal that an aircraft sensor, external to the FDR, was unserviceable.

For the FDR to record useful data, the entire FDR system must be functioning correctly. The FDR system comprises the FDR itself, aircraft sensors, crash sensor (i.e. G switch) and associated wiring. To check the entire FDR system, a complete flight needs to be downloaded and analysed. Currently, there is no CASA requirement for this periodic check to be performed on Australian-registered aircraft. Refer to ATSB Recommendation R20060005 dated 10 February 2006:

<http://www.atsb.gov.au/publications/recommendations/2006/R20060005.aspx>

Figure A-38: Pitch attitude data

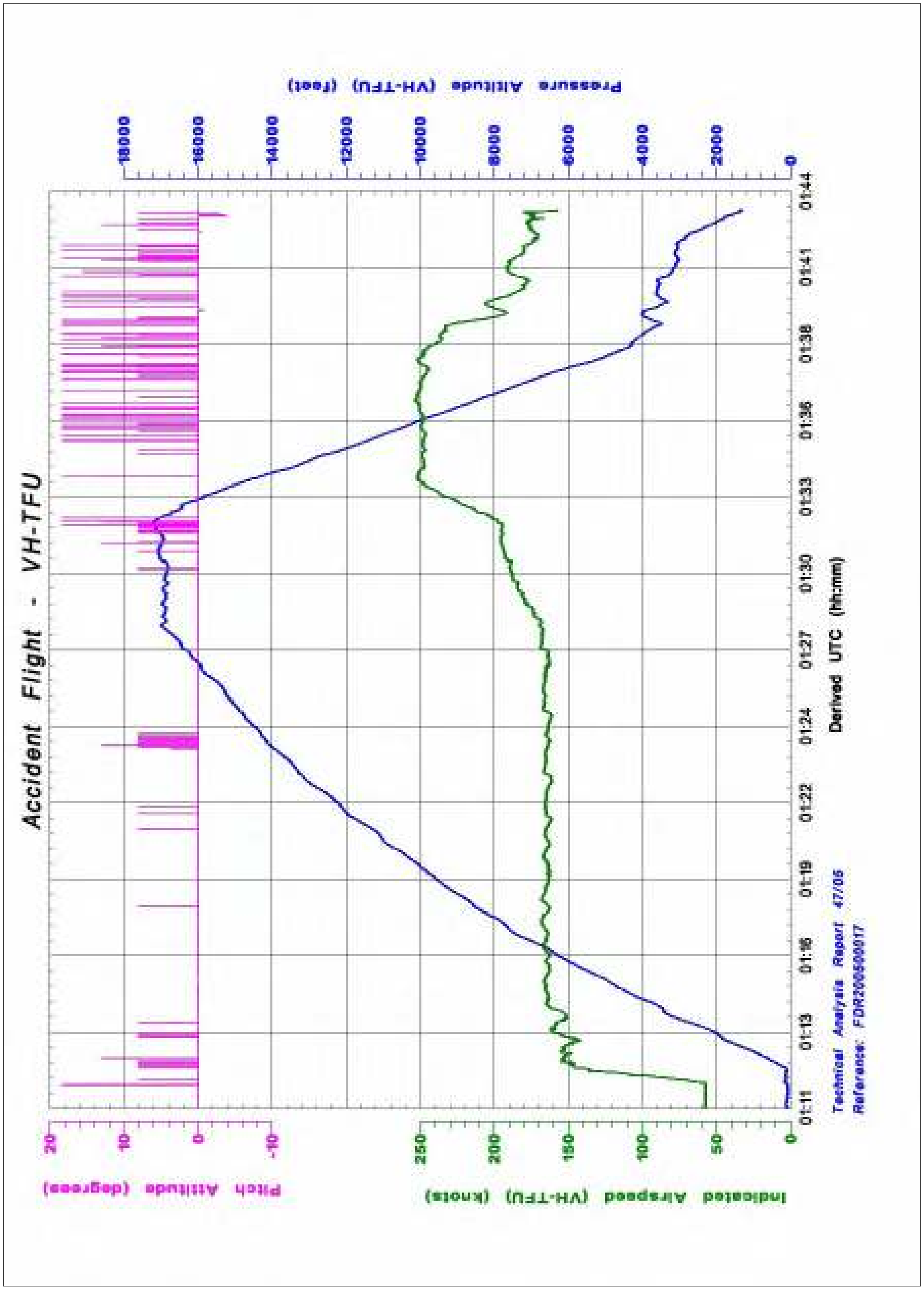
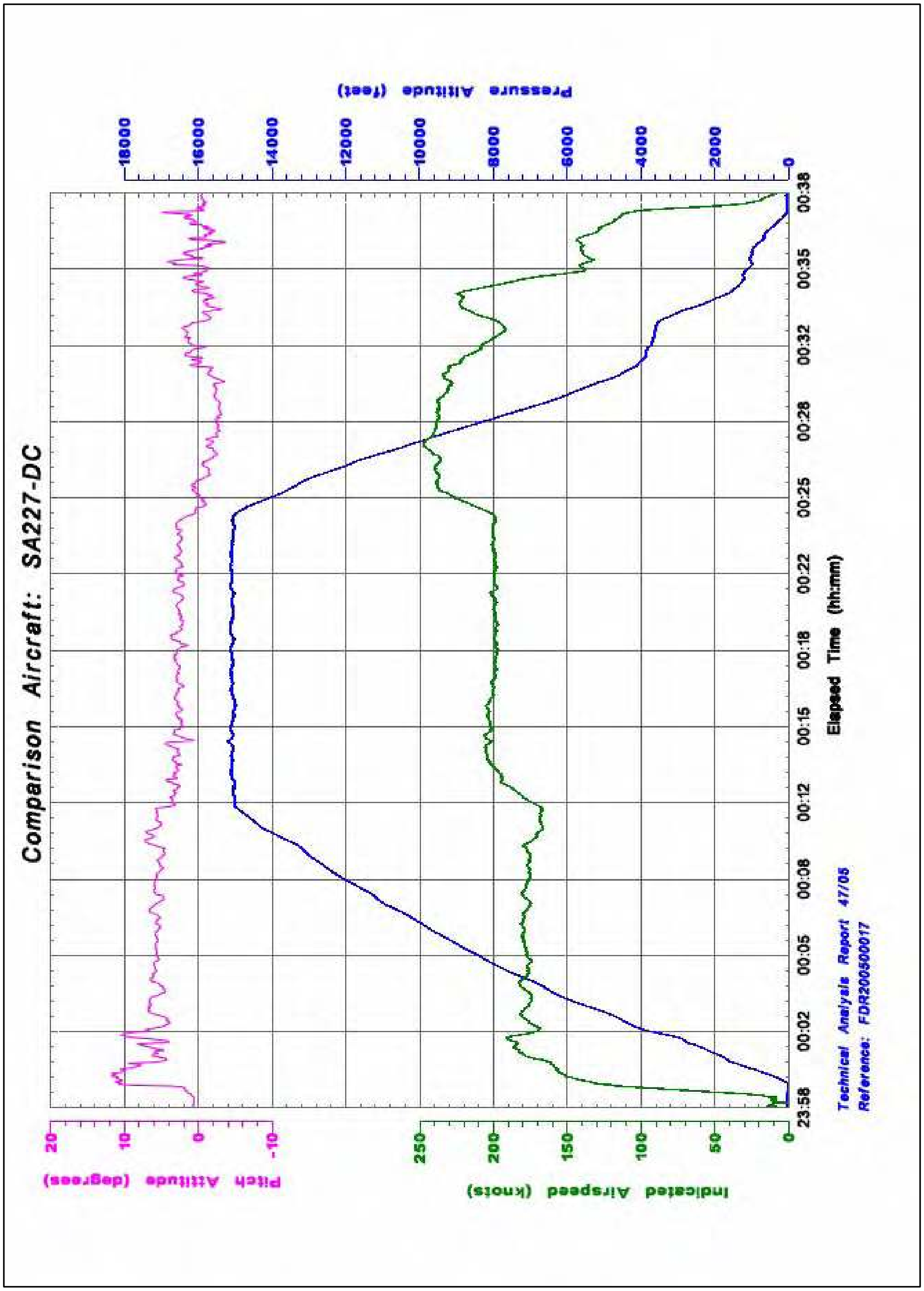


Figure A-39: Comparison pitch attitude data



Determination of the aircraft ground track

A ground track is the path an aircraft makes on the Earth's surface vertically below the aircraft. An aircraft ground track can be determined directly from FDR parameters when they are available, e.g. latitude and longitude. When an aircraft is under radar coverage, its ground track can also be determined from radar data recorded on the ground.

In the absence of this information, as was the case with VH-TFU, the ground track must be determined indirectly and requires the following information:

- groundspeed[20]
- aircraft track angle[21]
- a ground fix somewhere along the track.

Groundspeed

Groundspeed was not recorded by the FDR on VH-TFU. Groundspeed was estimated using recorded IAS[22] and converting it to true airspeed (TAS[23]) by allowing for atmospheric pressure and outside air temperature, refer to table A-2. TAS was converted to groundspeed by allowing for wind speed, wind direction and aircraft magnetic heading, refer to table A-3. A correction of -1° was made to magnetic heading as a result of a comparison between recorded heading when the aircraft was on the runway, and actual runway heading.

20 The aircraft's speed over the ground.

21 The angle between north and the aircraft's actual path over the Earth's surface.

22 Indicated airspeed.

23 TAS is the speed of an aircraft relative to the air mass in which it flies.

Table A-2: Determination of TAS from IAS

Inputs:				Result:
Parameter:	Source:	Values:	Correction:	
IAS	FDR	IAS parameter	- 8 knots	TAS
Atmospheric pressure	FDR	Pressure altitude parameter	Nil	
Outside air temperature	BOM[24]	Linear variation with altitude (16°C at 6,000 ft and 25°C at sea level)	Nil	

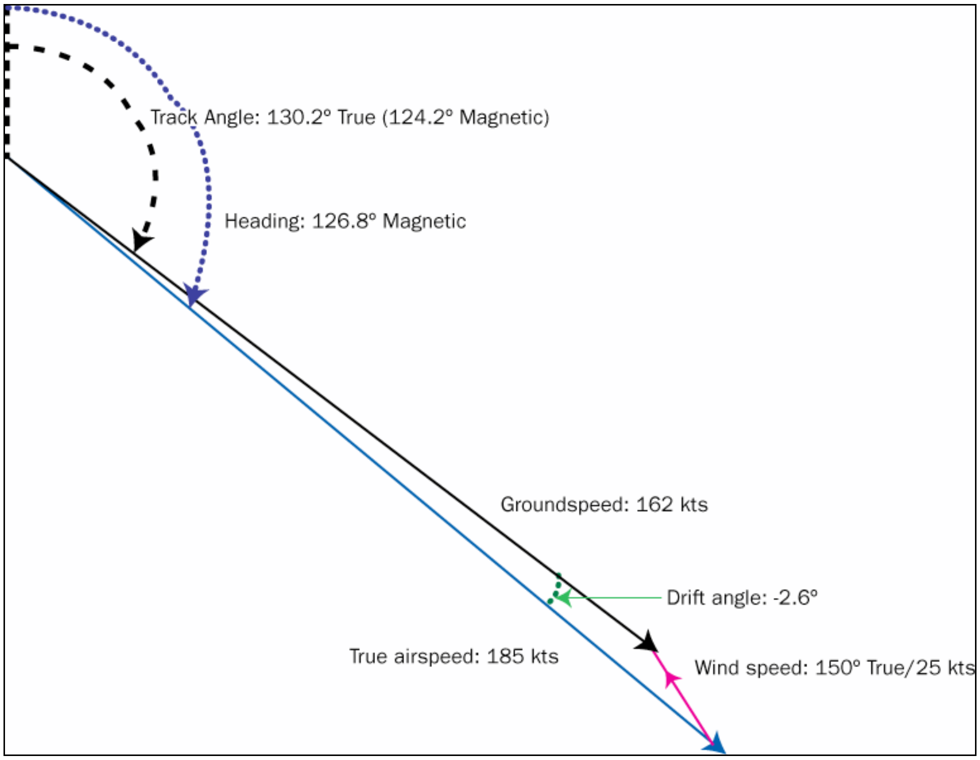
Table A-3: Determination of groundspeed from TAS

Inputs:				Result:
Parameter:	Source:	Values:	Correction:	
TAS	Derived	TAS	Nil	Groundspeed
Magnetic heading	FDR	Magnetic heading parameter	-1°	
Wind speed	BOM	30 knots (altitude > 3,600 ft i.e. until 0141:06 UTC) 25 knots (altitude ≤ 3,600 ft i.e. after 0141:06 UTC)	Nil	
Wind direction	BOM	110°T (altitude > 3,600 ft ft i.e. until 0141:06 UTC) 150°T (altitude ≤ 3,600 ft i.e. after 0141:06 UTC)	Nil	

24 Bureau of Meteorology (BOM)

An example of the relationship between IAS, TAS and groundspeed is shown in the following speed vector diagram.

Figure A-40: Speed vector diagram



Aircraft track angle

When an aircraft is in flight, it is moving relative to the body of air it is flying in, therefore the pilot must adjust the aircraft's heading to compensate for the wind, in order to follow a desired ground track.

Aircraft track angle was not recorded by the FDR on VH-TFU. Track angle was estimated by using recorded magnetic heading and converting it to true heading by allowing for the published magnetic deviation (+6°) at LHR, refer to table A-4. A correction of -1° was made to magnetic heading as a result of a comparison between recorded heading, when the aircraft was on the runway, and actual runway heading. True heading was converted to track angle by allowing for wind speed and direction.

Table A-4: Determination of track angle from magnetic heading

Inputs:				**Result:**
Parameter:	**Source:**	**Values:**	**Correction:**	
TAS	Derived	TAS	Nil	Track angle
Magnetic heading	FDR	Magnetic heading parameter	-1°	
Wind speed	BOM	30 knots (altitude > 3,600 ft) 25 knots (altitude ≤ 3,600 ft)	Nil	
Wind direction	BOM	110°T (altitude > 3,600 ft) 150°T (altitude ≤ 3,600 ft)	Nil	

Ground fix

The accident site (South Pap) was the location used for the ground fix.

Ground track error

The ground track was calculated for the last six minutes of flight. Error in the derived ground track increased with distance from the ground fix i.e. the accident site.

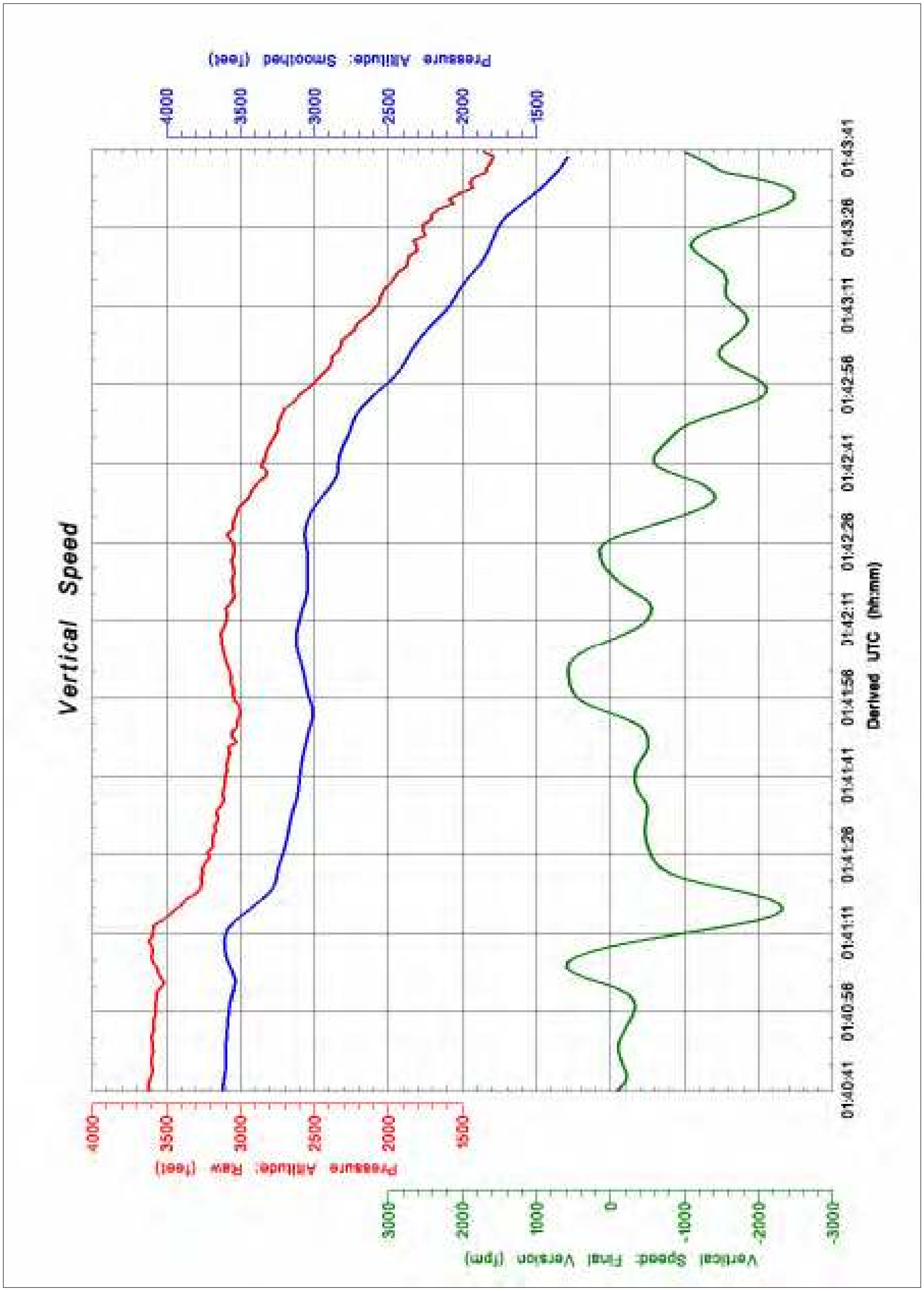
Determination of vertical speed

The aircraft vertical speed was not directly recorded and was therefore derived from recorded pressure altitude data. The steps used were:

1. First order differentiation of pressure altitude (raw) data to obtain vertical speed in feet per minute
2. Multiply by 60 to obtain vertical speed in feet per second
3. Smooth using a cubic spline function
4. Manually curve fit the last 14 values as automatic smoothing requires values before and after the point being smoothed.

The results of these steps are plotted in figure A-41.

Figure A-41:



Vertical Speed
Pressure Altitude: Smoothed (feet)
4000
3500
3000
2500
2000
1500
Pressure Altitude: Raw (feet)
4000
3500
3000
2500
2000
1500
Vertical Speed: Final Version (fpm)
3000
2000
1000
0
-1000
-2000
-3000
01:40:41
01:40:56
01:41:11
01:41:26
01:41:41
01:41:56
01:42:11
01:42:26
01:42:41
01:42:56
01:43:11
01:43:26
01:43:41
Derived UTC (hh:mm)

Comparison of the altitude profile with the nominal RNAV profile

The data recorded by the FDR was referenced to (elapsed) time. Comparing the altitude profile flown by VH-TFU with the nominal RNAV profile required altitude to be determined referenced to distance from the missed approach point (LHRWM), refer to figure A-42.

Distance from the accident site was calculated using the technique described in the section ‘Determination of the aircraft ground track’.

Altitude values were produced from recorded pressure altitude data as described in the parameter description section ‘Pressure altitude’.

The ground track was calculated for the last six minutes of flight. Error in the derived ground track increased with distance from the ground fix i.e. the accident site.

Figure A-42:

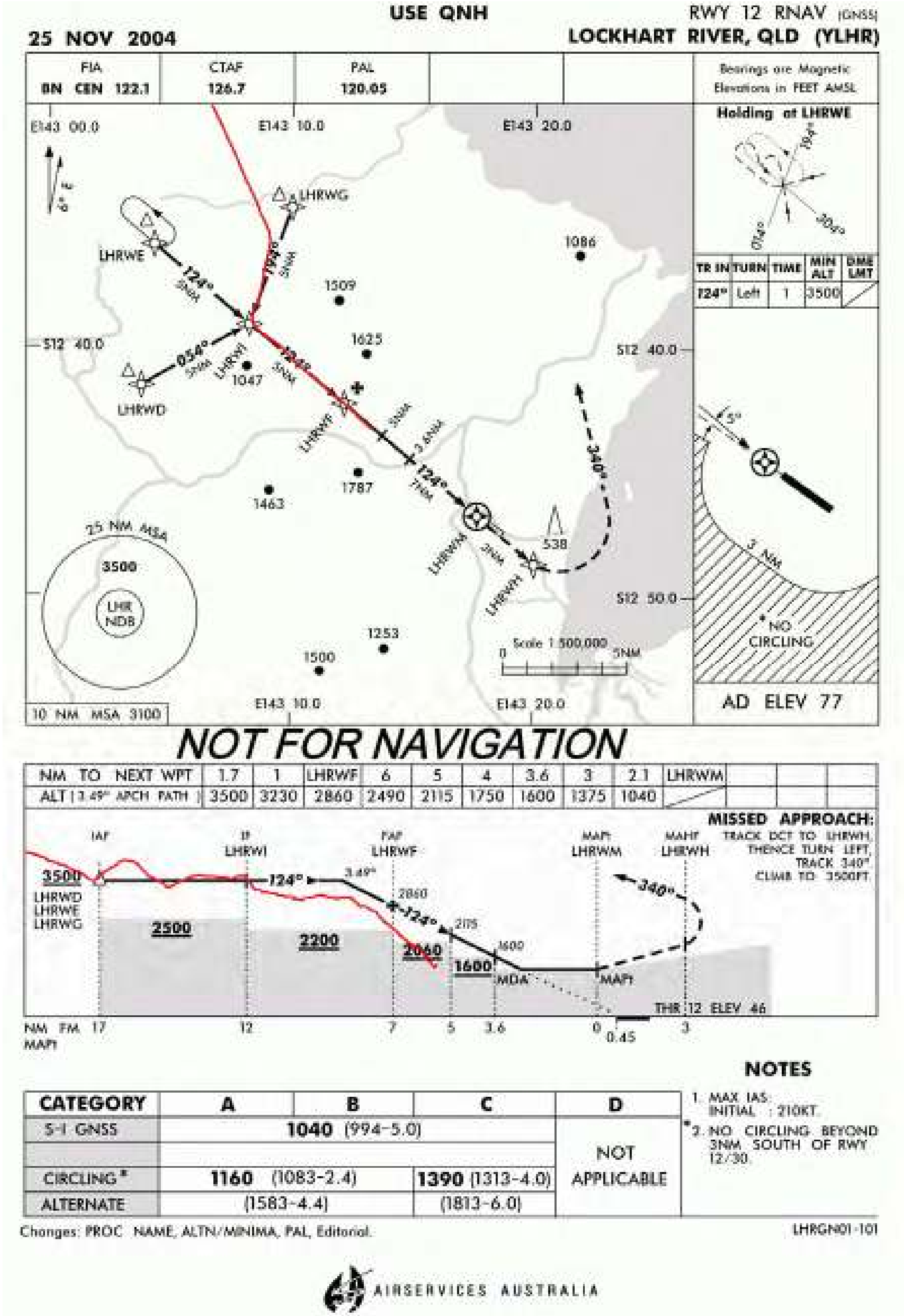
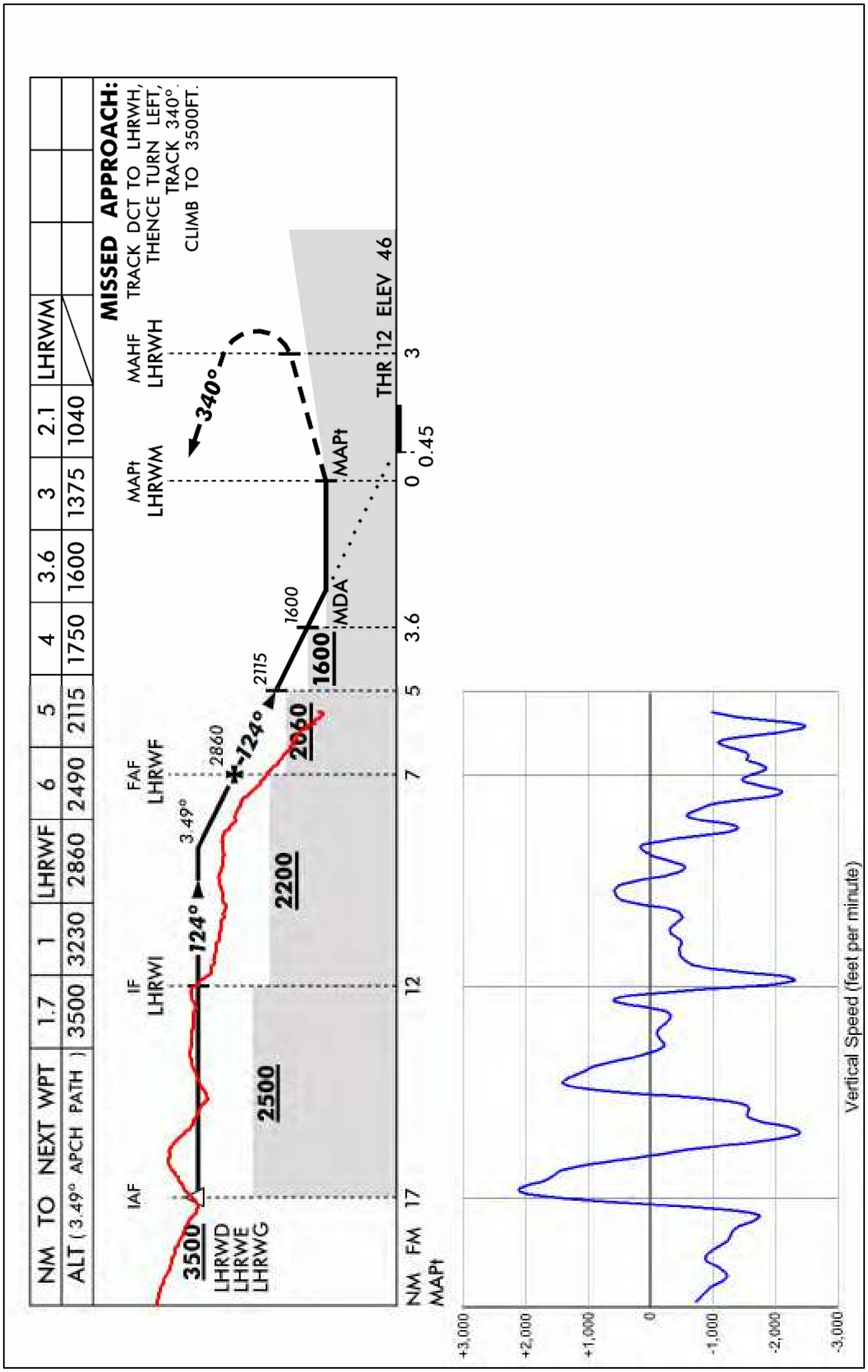

USE QNH
RWY 12 RNAV (GNSS)
25 NOV 2004
LOCKHART RIVER, QLD (YLHR)
FIA BN CEN 122.1
CTAF 126.7
PAL 120.05
Bearings are Magnetic
Elevations in FEET AMSL
Holding at LHRWE
TR IN TURN TIME MIN ALT DME LMT
124° Left 1 3500
LHRWG
LHRWE
LHRWI
LHRWD
LHRWF
LHRWM
LHRWH
25 NM MSA
3500
LHR NDB
10 NM MSA 3100
Scale 1:500,000
NO CIRCLING
AD ELEV 77
NOT FOR NAVIGATION
NM TO NEXT WPT 1.7 1 LHRWF 6 5 4 3.6 3 2.1 LHRWM
ALT (3.49° APCH PATH) 3500 3230 2860 2490 2115 1750 1600 1375 1040
MISSED APPROACH: TRACK DCT TO LHRWH, THENCE TURN LEFT, TRACK 340°, CLIMB TO 3500FT.
THR 12 ELEV 46
NOTES
1. MAX IAS: INITIAL : 210KT.
*2. NO CIRCLING BEYOND 3NM SOUTH OF RWY 12/30.
CATEGORY A B C D
S-I GNSS 1040 (994-5.0)
CIRCLING* 1160 (1083-2.4) 1390 (1313-4.0)
ALTERNATE (1583-4.4) (1813-6.0)
D: NOT APPLICABLE
Changes: PROC NAME, ALTN/MINIMA, PAL, Editorial.
LHRGN01-101
AIRSERVICES AUSTRALIA

Figure A-43:



NM TO NEXT WPT
ALT (3.49° APCH PATH)
1.7
3500
1
3230
LHRWF
2860
6
2490
5
2115
4
1750
3.6
1600
3
1375
2.1
1040
LHRWM
MISSED APPROACH:
TRACK DCT TO LHRWH, THENCE TURN LEFT, TRACK 340°. CLIMB TO 3500FT.
IAF
IF
LHRWI
FAF
LHRWF
MAPt
LHRWM
MAHF
LHRWH
3500
LHRWD
LHRWE
LHRWG
124°
3.49°
2860
2115
1600
2500
2200
2060
1600
MDA
MAPt
340°
THR 12 ELEV 46
NM FM MAPt
17
12
7
5
3.6
0
0.45
3
Vertical Speed (feet per minute)
+3,000
+2,000
+1,000
0
-1,000
-2,000
-3,000

Computer graphics animation of the accident approach

A computer graphics animation of the FDR data was produced to assist in the analysis of the accident approach. The animation covered a six minute period during descent from 6,700 ft until the end of recording.

The software used to produce the animation was Insight Animation (Version 1.5.0.84) developed by Flightscape Inc.

The animation consisted of two windows and a panel of instruments:

Upper Window: Plan View

A 1:250,000 scale topographic map was obtained from Geoscience Australia (2005 release) and used in the animation. An extract of the LHR RWY 12 RNAV chart, obtained from Airservices Australia and dated 25 November 2004, was overlayed on the topographic map.

The aircraft ground track was determined using the technique described in the section 'Determination of the aircraft ground track'.

Two significant limitations of the animation were:

1. The aircraft was shown in clear weather conditions and not the actual lighting, visibility and weather conditions that existed at the time of the accident.
2. Due to an FDR recording system unserviceability, the aircraft pitch attitude was always shown as zero i.e. nose level. In reality, the aircraft pitch attitude would have varied and not been constant at zero degrees.

Lower Window: Elevation View

An extract of the Airservices Australia LHR RWY 12 RNAV chart was used. Overlayed on this chart was a terrain profile (coloured brown) and the altitude profile flown by VH-TFU (coloured red). The terrain profile was obtained from shuttle radar topography mission (SRTM) digital elevation data. The resolution of the SRTM elevation data for Australia was 3 arc second (approximately 90 metres).

Instrument Panel

An instrument panel was overlayed on top of the upper and lower windows. The airspeed indicator, attitude director indicator, altimeter, directional gyro, flap position indicator, vertical speed indicator and torque instruments used in the animation were portrayed in a similar way to the actual instruments used by the crew. As a consequence of limitations in the recorded FDR data (such as accuracy, resolution and sampling rate) the instrument readings shown in the animation may not necessarily be the same as those that were displayed to the crew on the aircraft instruments.

The vertical acceleration display shown in the animation was used to give a qualitative indication of turbulence and was not a parameter that was available to the crew.

The microphone keying lights (COM 1 and COM 2), Local Time counter and distance to WF and WM counters shown in the animation were not displayed to the crew in that format.

The sources of data, used to drive the instruments and the aircraft model depicted in the computer graphics animation, are shown in table A-5.

Table A-5:

Altimeter	**FDR pressure altitude parameter**
Airspeed Indicator	FDR indicated airspeed parameter
Directional Gyro (Magnetic Compass)	FDR magnetic heading parameter
Attitude Director Indicator (ADI)	FDR roll attitude parameter (Pitch attitude displayed constantly at zero)
Vertical Speed Indicator (VSI)	Derived vertical speed parameter
Flap Position	FDR flap position parameter
Landing Gear Position	Landing gear position was not recorded by the FDR. The time of landing gear extension was estimated to have coincided with the IAS decreasing below V_{LO} (175 kts).
Vertical acceleration	FDR vertical acceleration parameter
Torque: left engine	FDR left engine torque parameter
Torque: right engine	FDR right engine torque parameter
Local Time i.e. Eastern Standard Time.	Derived by correlating UTC from ATC radio transcript with FDR microphone keying discrete parameters. Local Time = UTC + 10 hours.
Distance to WF	Derived
Distance to WM	Derived

Figure A-44: Animation plan view

Figure A-45: Animation elevation view

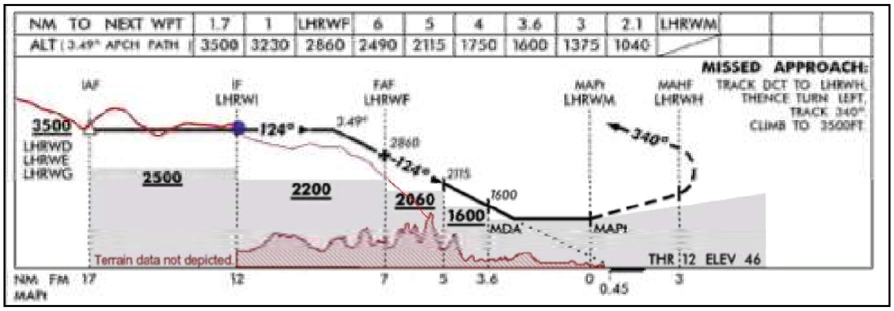
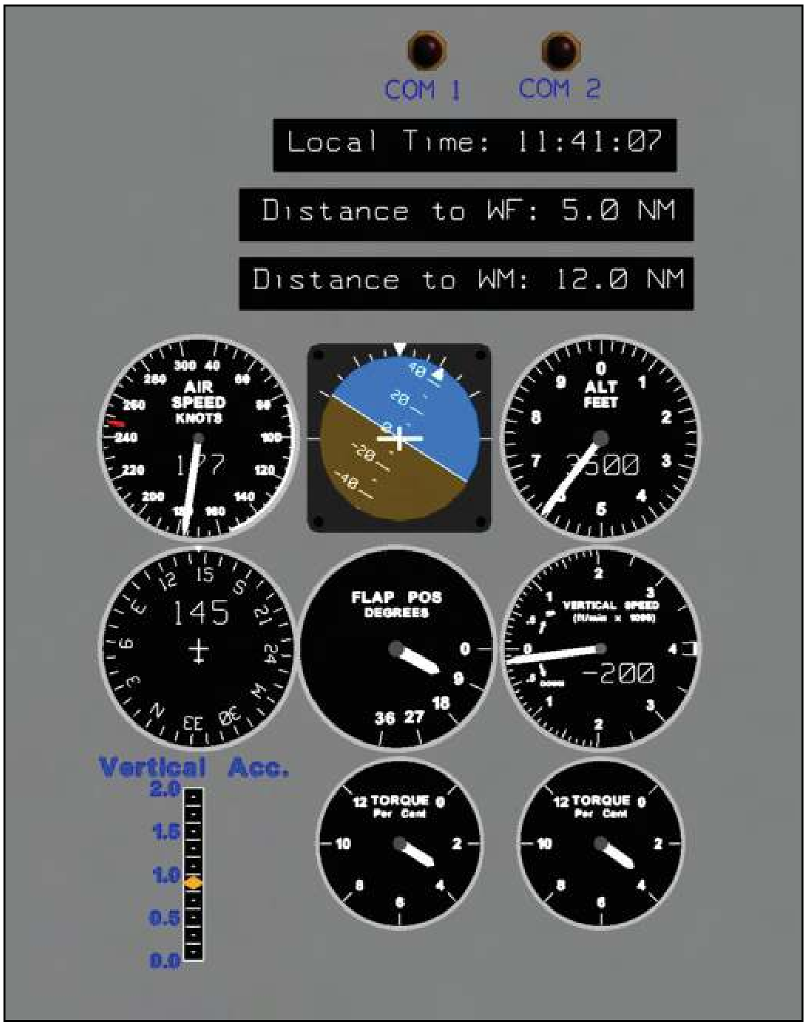


Figure A-46: Animation instrument panel



The animation is released as part of this report. A file containing the animation in Insight View™ format (.isv) is available for download from the ATSB website.[25]

25 This file requires the installation of an Insight Viewer that can be downloaded from <www.flightscape.com/products/view.php> at no charge.

Comparison of the accident approach with other approaches to Lockhart River

Data from the nine previous landings at Lockhart River were still retained by the FDR. Details are provided in table A-6.

Table A-6:

Flight sequence (before accident flight)	Sector	Date	Runway
2	Cairns – Lockhart River	7 May 2005	12
9	Cairns – Lockhart River	4 May 2005	12
17	Bamaga – Lockhart River	30 April 2005	12
19	Cairns – Lockhart River	30 April 2005	12
28	Bamaga – Lockhart River	27 April 2005	12
30	Cairns – Lockhart River	27 April 2005	12
34	Cairns – Lockhart River	25 April 2005	12
36	Bamaga – Lockhart River	23 April 2005	12
50	Cairns – Lockhart River	20 April 2005	12

The three Bamaga – Lockhart River flights were examined and on one flight, on the 27 April 2005, the runway 12 RNAV (GNSS) approach was observed to have been conducted.

Bamaga to Lockhart River flight on 27 April 2005

The FDR data for this flight showed that the aircraft descended continuously from Flight Level 170 until reaching 5,700 ft where it levelled for a few seconds. The average rate of descent was 1,490 feet per minute while the maximum rate of descent was 1,930 feet per minute descending through 15,200 ft. During the descent, the aircraft was flown near V_{MO} (246 KIAS) between 15,590 ft and 7,890 ft, a period of 5 minutes and 18 seconds.

An estimated ground track was derived assuming nil wind. Using this estimate, the aircraft intercepted the runway 12 RNAV (GNSS) approach track between waypoint LHRWE and LHRWI. The aircraft then tracked directly for LHRWM.

Table A-7:

Position	Time before touchdown (mm:ss)	Altitude (ft AAL[26])	IAS (kts)	Flap	Torque (%)
1/4 flap selection	07:16	5,670	222	Up	19
Joining RNAV approach (between LHRWE & LHRWI)	05:22	3,390	193	1/4	12
LHRWI	04:23	2,490	186	1/4	25
LHRWF	02:48	1,900	177	1/4	30
1/2 flap selection	02:16	1,880	175	1/4	29
Full flap selection	01:06	760	164	1/2	23
LHRWM	00:19	130	150	Full	21
Touchdown	00:00	0	139	Full	6

26 Above aerodrome level (AAL).

Cairns to Lockhart River flight on 7 May 2005

The FDR data for this flight showed that the aircraft descended continuously from Flight Level 180 until reaching 1,000 ft (refer to Figure A-47). The average rate of descent was 1,640 feet per minute while the maximum rate of descent was 2,540 feet per minute between 6,600 ft and 5,200 ft. During the descent, the aircraft was flown at or near V_{MO} (246 KIAS) between 14,900 ft and 5,000 ft, a period of 5 minutes and 40 seconds.

An estimated ground track was derived. Using this estimate, the aircraft intercepted the runway 30 RNAV (GNSS) approach track at waypoint LHREI (the IF) and left the approach track at waypoint LHREF (the FAF). The aircraft then tracked for a left downwind circuit leg for runway 12.

Table A-8:

Position	Time before touchdown (mm:ss)	Altitude (ft AAL)	IAS (kts)	Flap	Torque (%)
LHREI	05:01	3,840	237	Up	21
LHREF	03:51	2,350	205	1/4	8
500 ft AAL	00:48	500	150	1/2	41
Full flap selection	00:44	435	149	1/2	42
On runway heading	00:34	350	146	Full	25
Touchdown	00:00	0	130	Full	18

Lockhart River to Bamaga flight on 7 May 2005

The FDR data for this flight showed that the aircraft descended continuously from Flight Level 180 until reaching 1,000 ft AAL. The average rate of descent was 1,730 feet per minute while the maximum rate of descent was 2,270 feet per minute at an altitude of 7,300 ft AAL. During the descent, the aircraft was flown at or near V_{MO} (246 KIAS) between 15,800 ft and 1,500 ft, a period of 8 minutes and 4 seconds.

The recorded data indicated that, from a northerly heading, the aircraft turned left continuously until it was on runway heading. The track and altitude profile were not consistent with the published runway 13 RNAV (GNSS) approach.

Table A-9:

Position	Time before touchdown (mm:ss)	Altitude (ft AAL)	IAS (kts)	Flap	Torque (%)
Left turn onto final commenced	02:24	950	176	1/4	21
1/2 flap selection	02:16	930	174	1/2	24
On runway heading	01:17	630	157	1/2	37
Full flap selection	01:12	590	160	1/2	34
500 ft AAL	01:00	500	145	Full	16
Touchdown	00:00	0	118	Full	18

Figure A-47: Animation elevation view (BAM-LHR 27 April 2005)

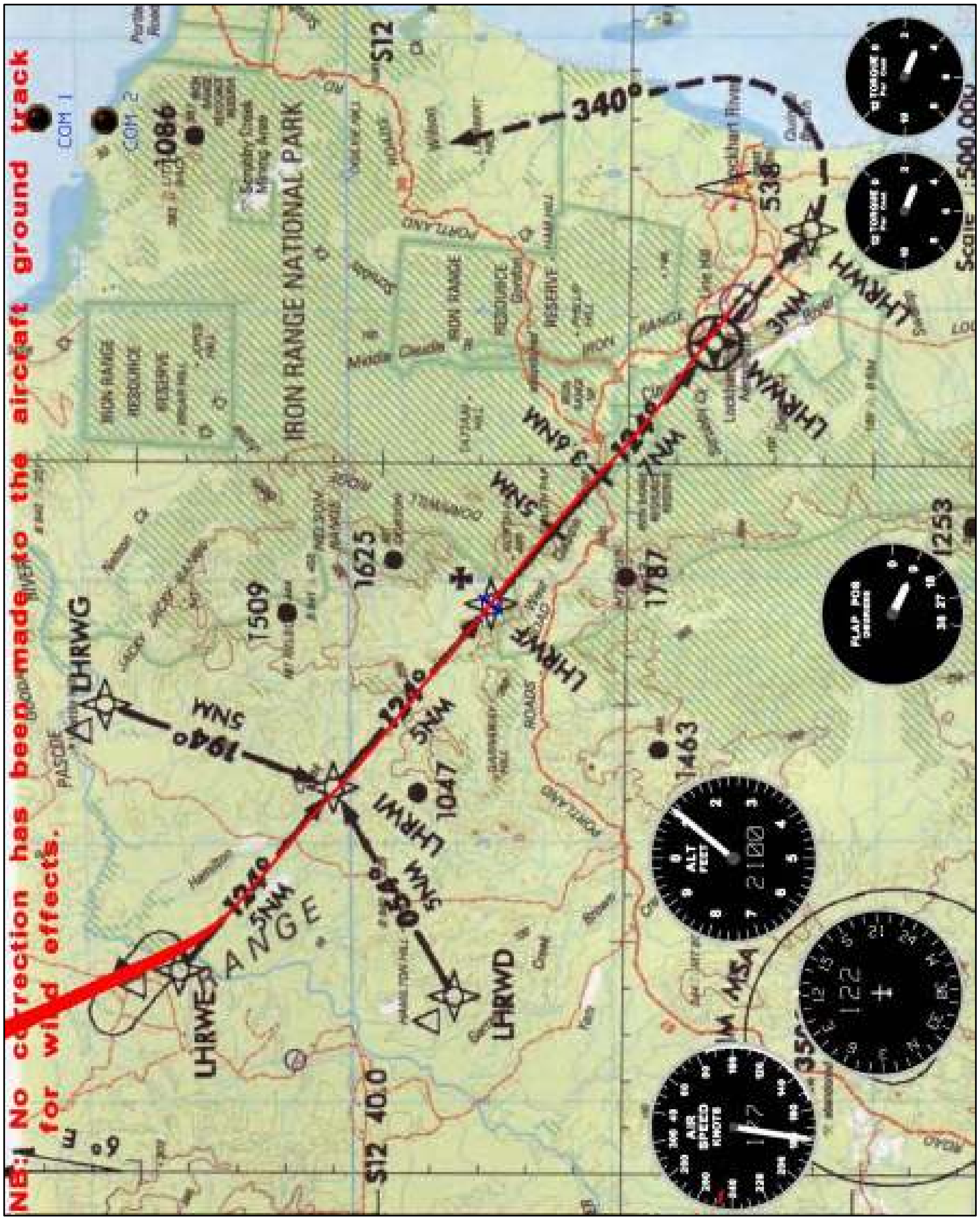


Figure A-48:

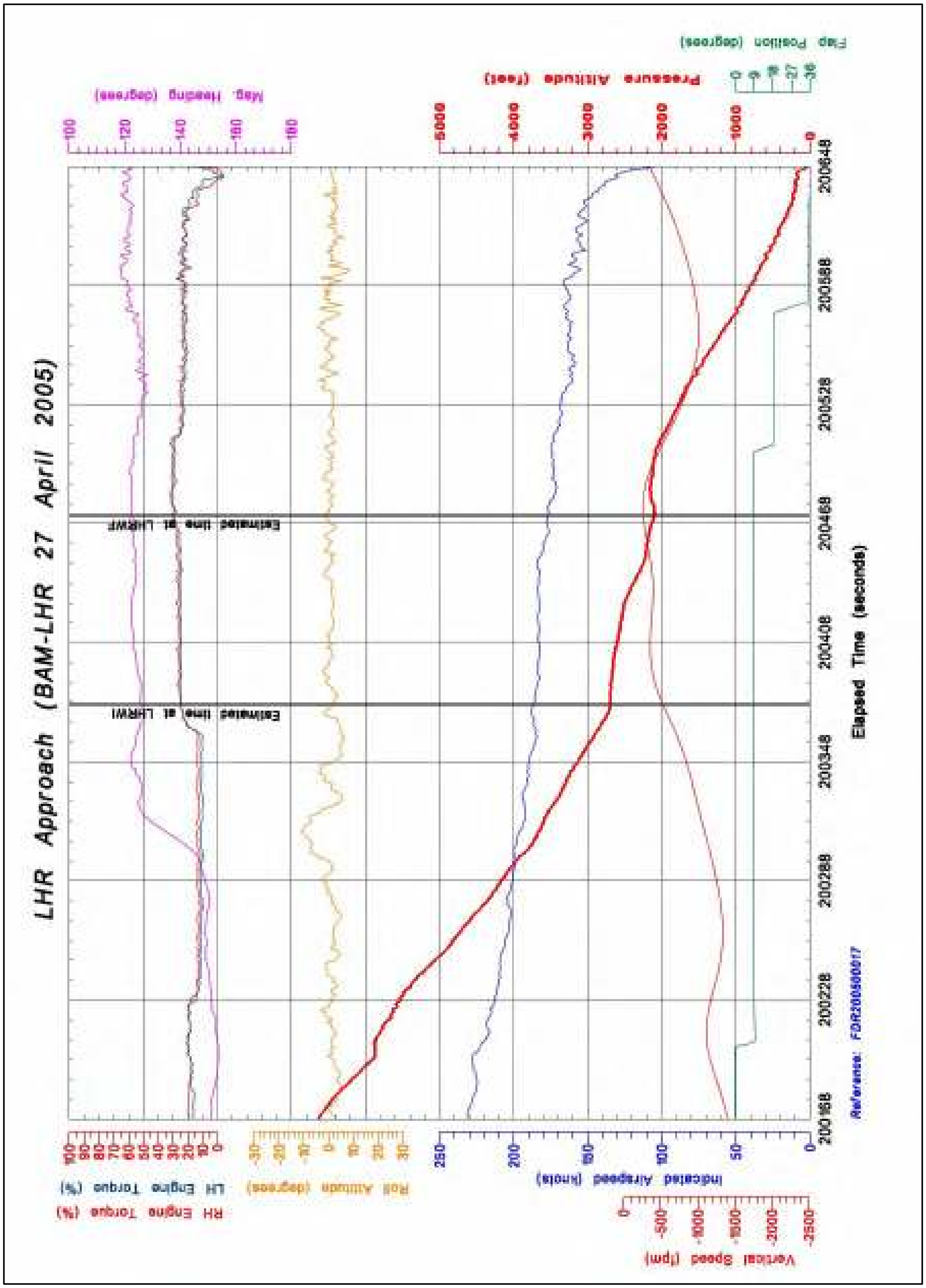

LHR Approach (BAM-LHR 27 April 2005)
Elapsed Time (seconds)
Estimated time at LHRWI
Estimated time at LHRWF
Mag. Heading (degrees)
Pressure Altitude (feet)
Flap Position (degrees)
RH Engine Torque (%)
LH Engine Torque (%)
Roll Attitude (degrees)
Indicated Airspeed (knots)
Vertical Speed (fpm)
Reference: FDR200500017

Figure A-49: Animation elevation view (CNS-LHR 7 May 2005)

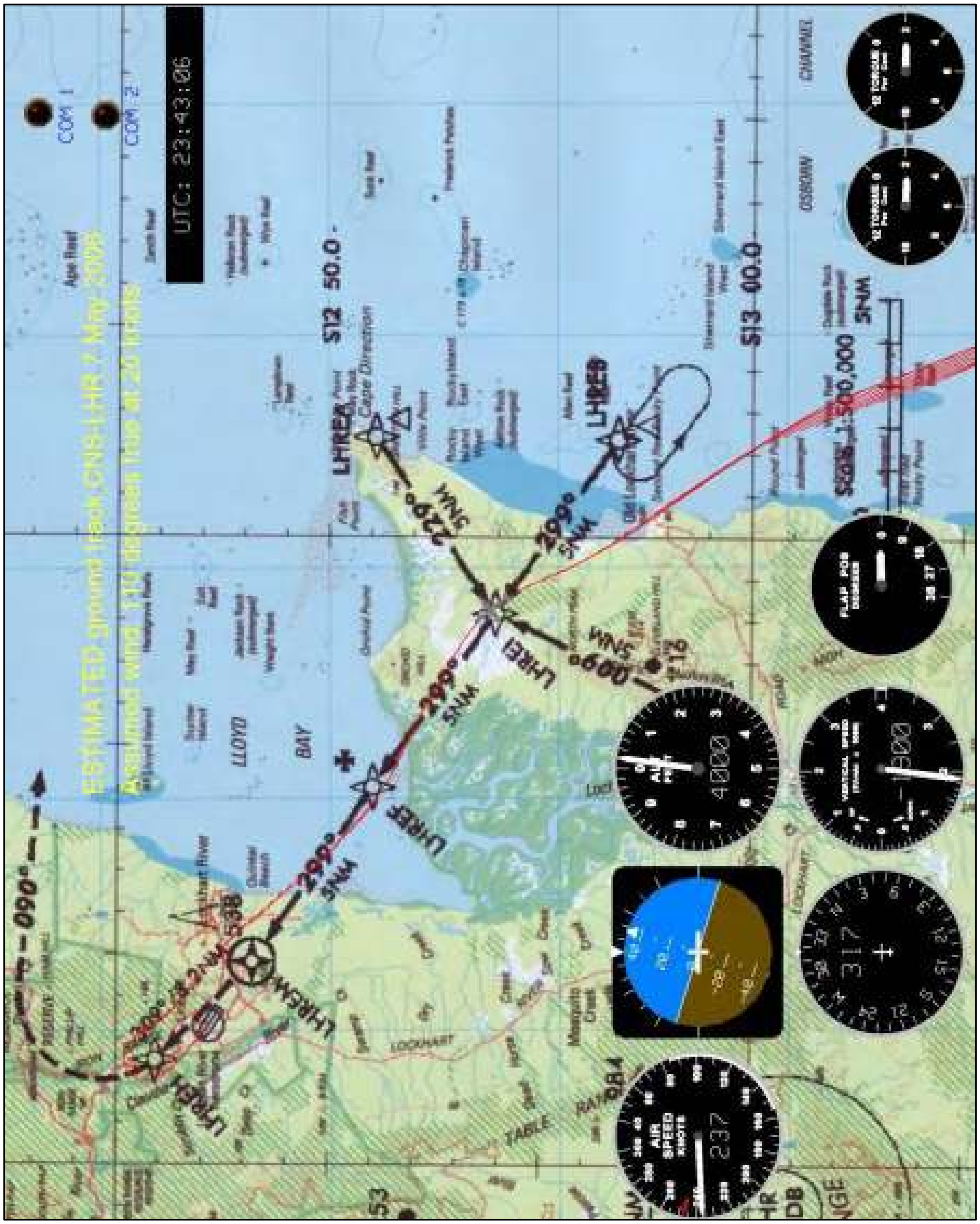
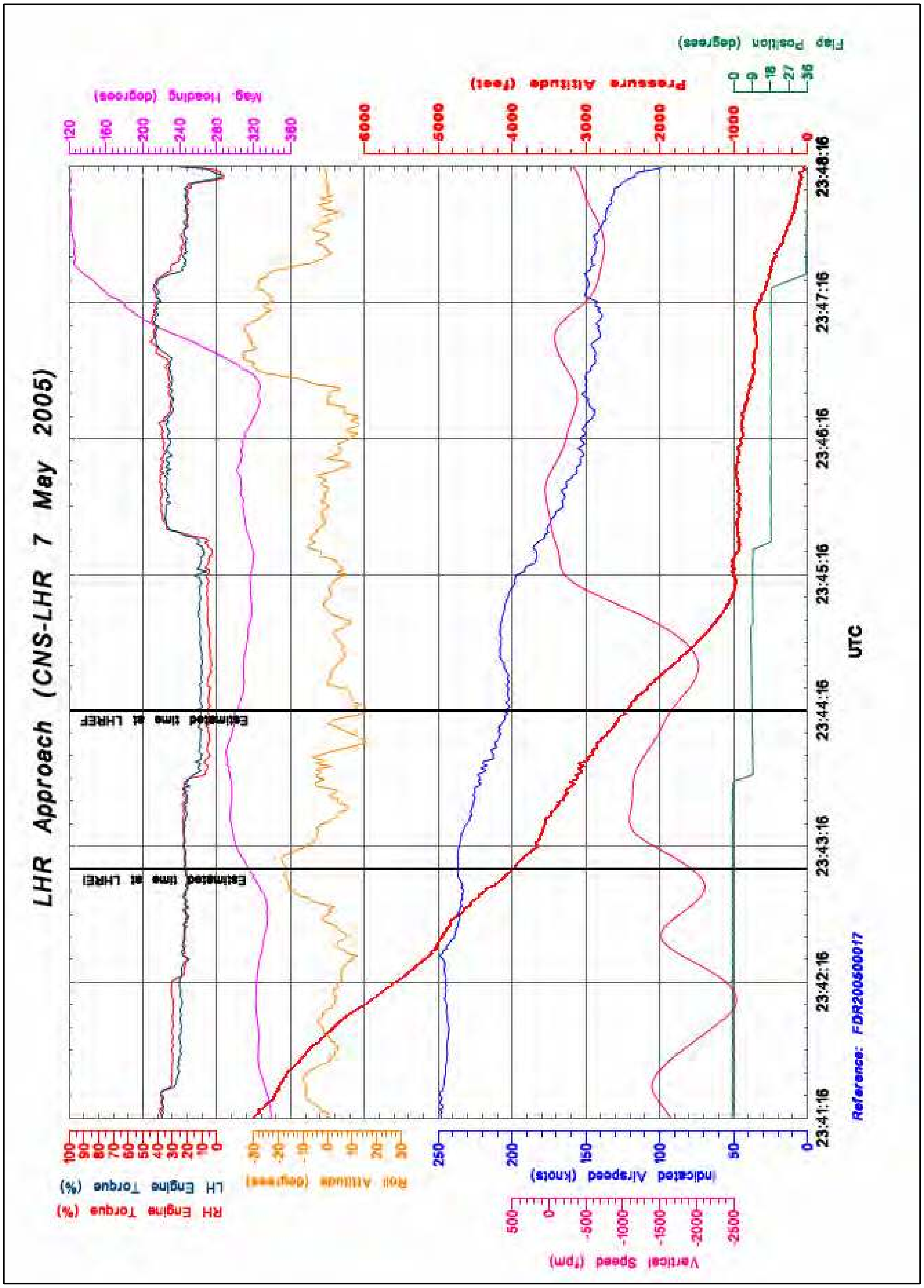
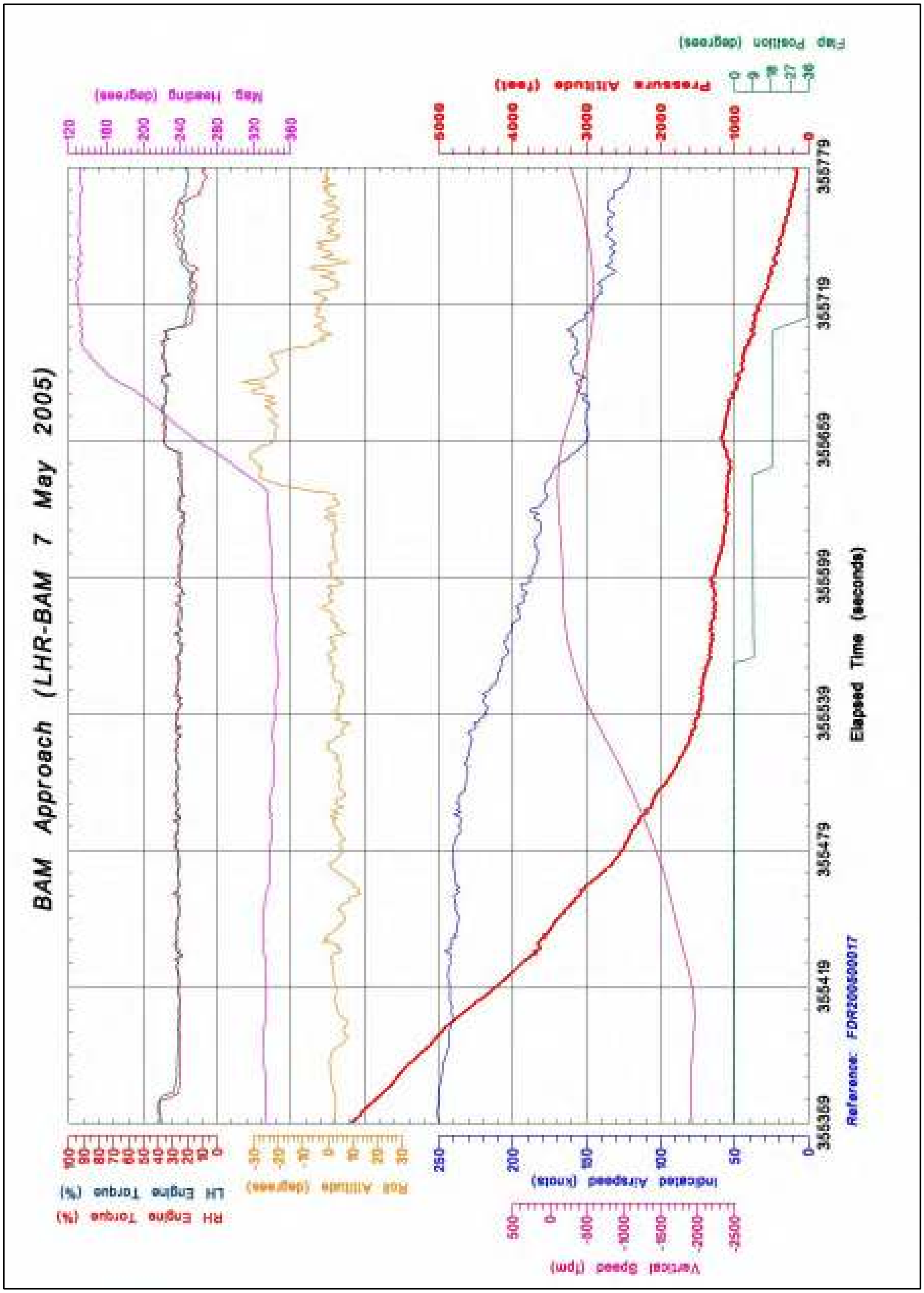


Figure A-50:



LHR Approach (CNS-LHR 7 May 2005)
Estimated time at LHREI
Estimated time at LHREF
Mag. Heading (degrees)
Pressure Altitude (feet)
Flap Position (degrees)
RH Engine Torque (%)
LH Engine Torque (%)
Roll Attitude (degrees)
Indicated Airspeed (knots)
Vertical Speed (fpm)
UTC
Reference: FDR200500017

Figure A-51:


BAM Approach (LHR-BAM 7 May 2005)
Elapsed Time (seconds)
Reference: FDR200500017
RH Engine Torque (%)
LH Engine Torque (%)
Roll Attitude (degrees)
Indicated Airspeed (knots)
Vertical Speed (fpm)
Mag Heading (degrees)
Pressure Altitude (feet)
Flap Position (degrees)

Flight controls

An aircraft is controlled in three axes:

- Pitch control around the lateral axis using elevators and the horizontal stabiliser
- Roll control around the longitudinal axis using ailerons
- Yaw control around the vertical axis using rudder

Figure A-52:

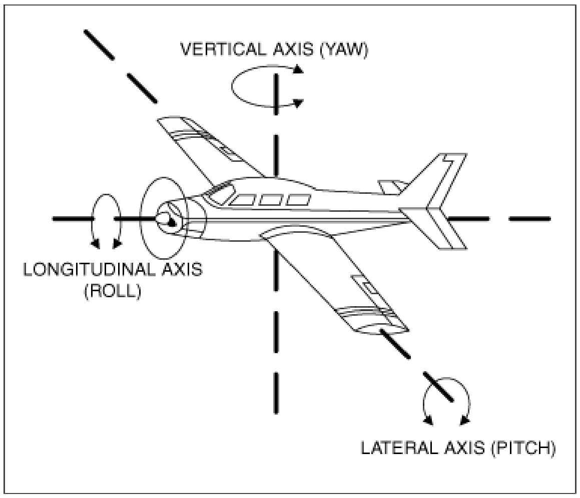
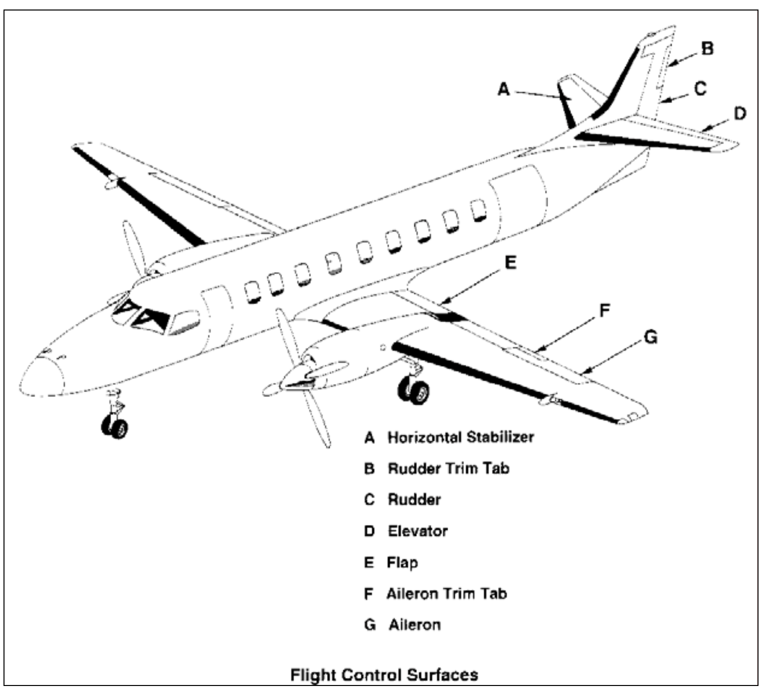


Figure A-53: Flight control surfaces of a Metro 23 aircraft



Pitch control – horizontal stabiliser

Horizontal stabiliser position was plotted in figures A-54 to A-56. An increase in horizontal stabiliser angle corresponded to an increase in aircraft nose-up input. Stabiliser position was electrically controlled through trim switches on the pilots' control wheels. Two electric motors were available to drive a dual jackscrew mechanism to position the stabiliser.

Stabiliser position during the accident flight was compared with the position recorded during the previous sectors flown on 7 May 2005 (i.e. CNS – LHR and LHR – BAM). The magnitude and direction of stabiliser movement during the accident flight was consistent with the changes observed during the previous sectors. During the accident flight, significant changes in stabiliser position occurred during initial climb, top of climb, top of descent and during configuration changes (e.g. flap extension) on the approach. These changes in stabiliser position were consistent with the changes observed during the same phases of flight for the previous sectors.

The rate of change in stabiliser position during all the sectors on 7 May 2005 was consistent with the normal rate (approximately 0.5 degrees/second).

On the ground, at LHR and BAM, stabiliser movement was consistent with resetting the stabiliser after landing in accordance with the After Landing Checklist.

No anomalies were observed in recorded horizontal stabiliser position during the accident flight or the two previous flights recorded on 7 May 2005.

Pitch control – elevators

Left elevator position was plotted in figures A-54 to A-56 (right elevator position was not recorded nor was it required to be recorded). An increase in elevator position corresponded to an increase in aircraft nose-up input. Elevator position was an angle measured relative to the horizontal stabiliser. If the elevator remained stationary and the horizontal stabiliser was moved then the measured elevator position appeared to change. This characteristic can be seen in figure A-55 where nose-down stabiliser movements were reflected in apparent nose-up elevator movements. Conversely nose-up stabiliser movements were reflected in apparent nose-down elevator movements. There was a direct mechanical connection between the pilot control column and the elevators.

Elevator position during the accident flight was compared with the position recorded during the previous sectors flown on 7 May 2005. The magnitude and direction of elevator movement during the accident flight was consistent with the changes observed during the previous sectors. During the accident flight, significant changes in elevator position occurred during takeoff (rotation) and top of descent and during configuration changes (e.g. flap extension) on the approach. These changes in elevator position were consistent with the changes observed during the same phases of flight during the previous sectors.

The elevators were attached to the trailing edge of the horizontal stabiliser. To minimize drag, it was desirable that the elevators and horizontal stabiliser were co-linear. Rather than maintaining a constant elevator input, it was normal practice for the horizontal stabiliser to be manually re-trimmed to remove any elevator force.

On the ground, the elevators normally rested in a trailing edge down position (-15 degrees). This behaviour was observed when the aircraft was on the ground at CNS, LHR and BAM.

The Pre-Start Checklist required that full and free movement of the control surfaces was available. This check is seen in figure A-55 as a ‘spike’ in elevator position while the aircraft was on the ground.

During smooth atmospheric conditions, and at higher airspeeds, only small and infrequent elevator inputs were required such as during cruise. During turbulent atmospheric conditions, and at lower airspeeds, larger and more frequent elevator inputs were required such as during the approach at LHR.

No anomalies were observed in recorded elevator position during the accident flight or the two previous flights recorded on 7 May 2005.

Roll control – ailerons

Left aileron position was plotted in figures A-57 and A-58 (right aileron position was not recorded nor was it required to be recorded). Positive aileron position corresponds to a left roll (i.e. left wing low) input. Negative aileron position corresponds to a right roll (i.e. right wing low) input. There was a direct mechanical connection between the pilot control wheel and the ailerons.

Aileron position during the accident flight was compared with the position recorded during the previous sectors flown on 7 May 2005. The magnitude and direction of aileron movement during the accident flight was consistent with the changes observed during the previous sectors. During the accident flight there was a consistent correlation between changes in aileron position and changes in roll attitude (bank angle) and magnetic heading.

The Pre-Start Checklist requires that full and free movement of the control surfaces is available. This check is seen in figure A-57 as a ‘spike’ in aileron position while the aircraft was on the ground.

Once the aircraft reached top of climb, an offset in aileron position first became apparent. This offset remained until the top of descent (refer to figure A-57) and was characteristic of the application of aileron trim.

During smooth atmospheric conditions, and at higher airspeeds, only small and infrequent aileron inputs were required e.g. during cruise. During turbulent atmospheric conditions, and at lower airspeeds, larger and more frequent aileron inputs were required such as during the approach at LHR.

Although the magnitude of aileron inputs was increasing during the final 10 seconds of recorded data, no anomalies were observed in recorded aileron position during the accident flight.

Yaw control – rudder

Rudder position was plotted in figures A-59 and A-60. An increase in rudder position angle corresponded to an increase in aircraft nose-right input.

The pre-flight rudder control check for full and free movement was not observed to have occurred at the same time as the elevator and aileron checks. This was the case for the accident flight and all other flights examined. It is likely that this check occurred during taxi when large rudder movements were observed in the recorded data.

Rudder position during the accident flight was compared with the position recorded during the previous sectors flown on 7 May 2005. The magnitude and direction of rudder movement during the accident flight was consistent with the changes observed during the previous sectors. During the accident flight, there was a consistent correlation between changes in rudder position and changes in magnetic heading.

During the accident flight, significant changes in rudder position occurred during taxiing and takeoff. These changes in rudder position were consistent with the changes observed during the same phases of flight during the previous sectors.

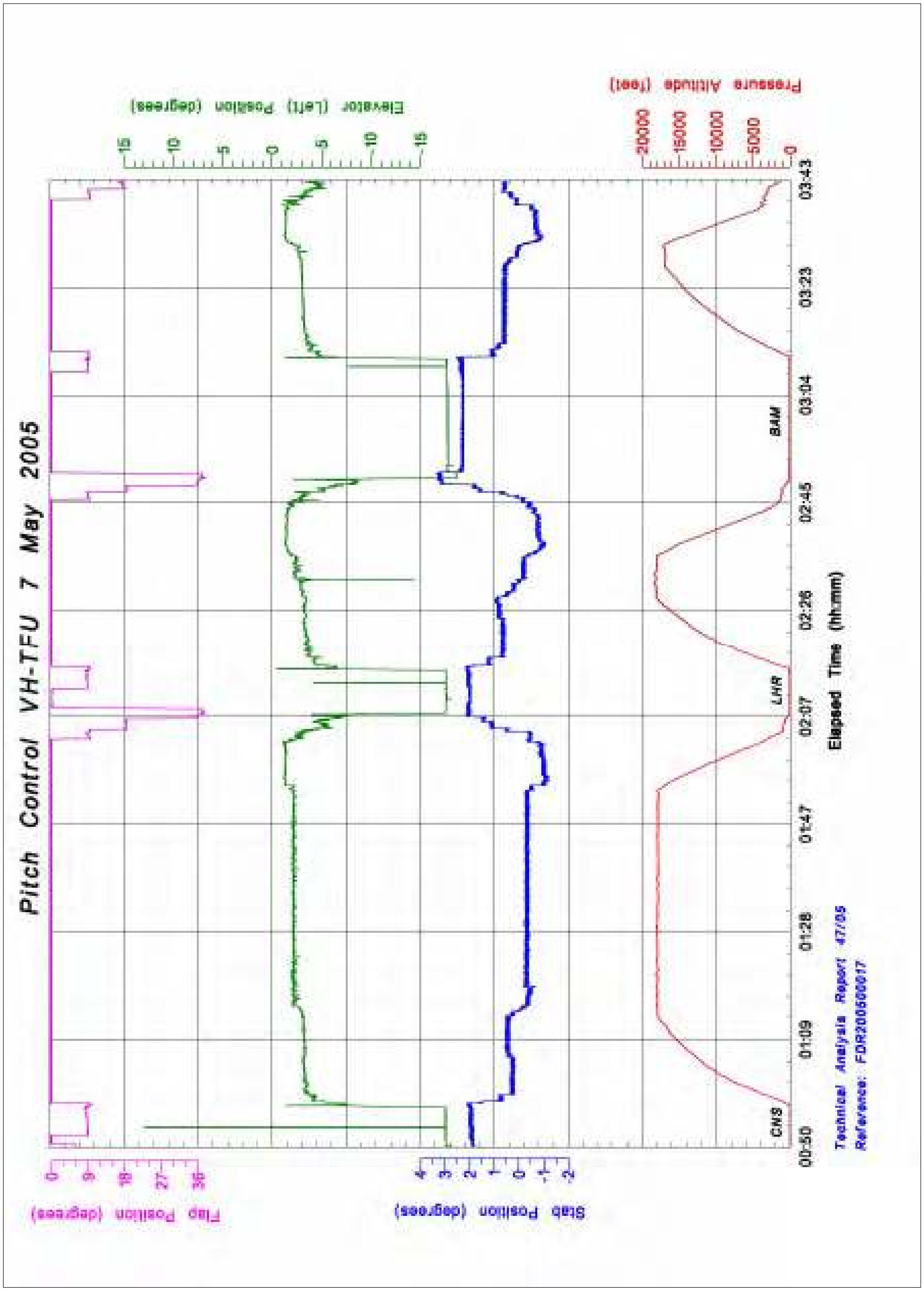
No anomalies were observed in recorded rudder position during the accident flight or the two previous flights recorded on 7 May 2005.

Pilot inputs – final 10 seconds of recorded data

The final 10 seconds of recorded data showed that the aircraft was experiencing turbulence as evidenced by fluctuations in the vertical acceleration parameter. Small pitch and yaw control inputs were evident as small elevator and rudder position changes. Larger roll control inputs were evident as aileron position changes. The roll inputs were applied in the opposite sense to the aircraft bank angle showing that the aircraft attitude was being actively controlled by the handling pilot.

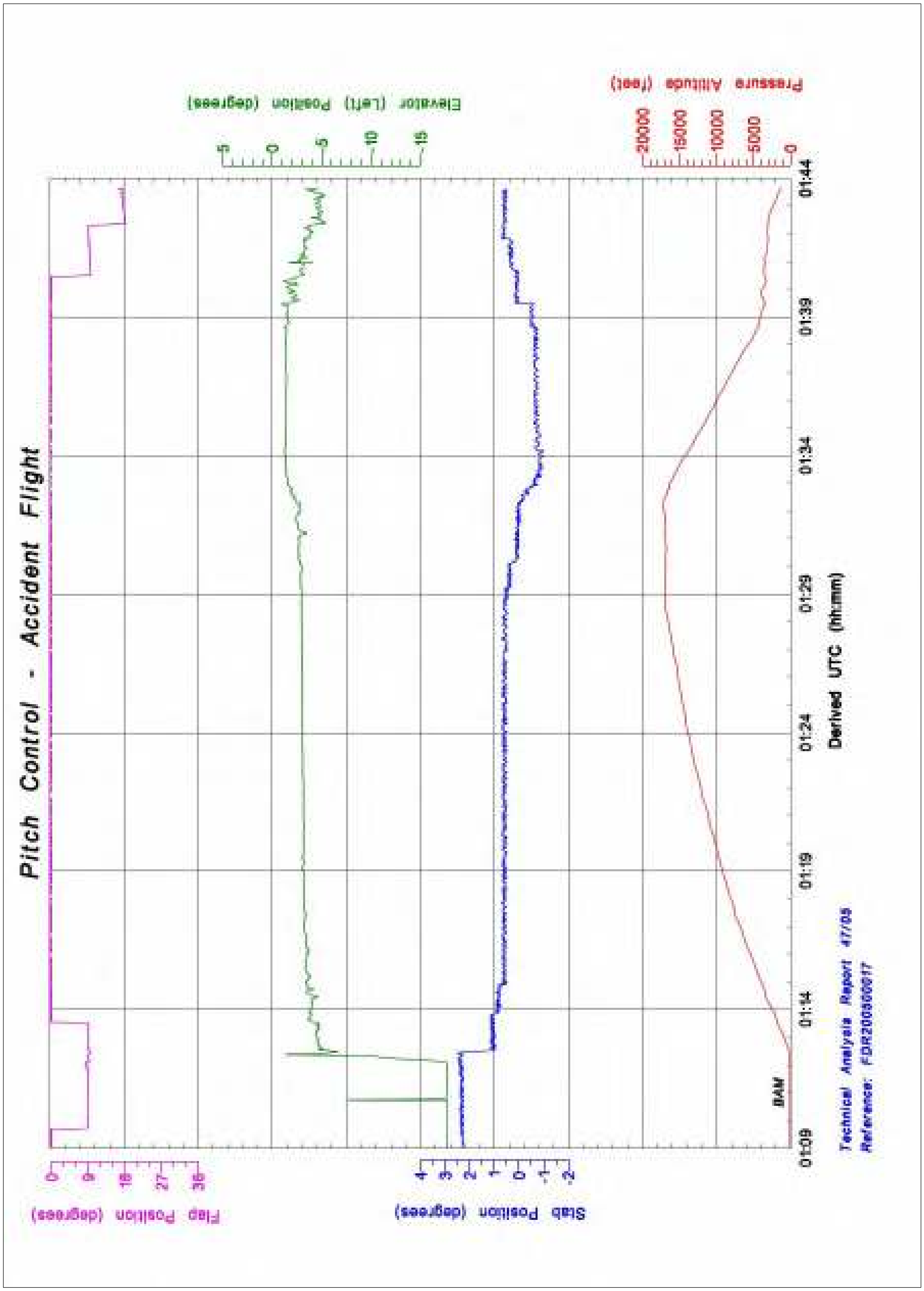
A GPWS escape manoeuvre requires that the pilot make a large nose-up pitch control input and apply maximum power. Recorded elevator position and engine torque parameters showed no evidence of such commands.

Figure A-54:



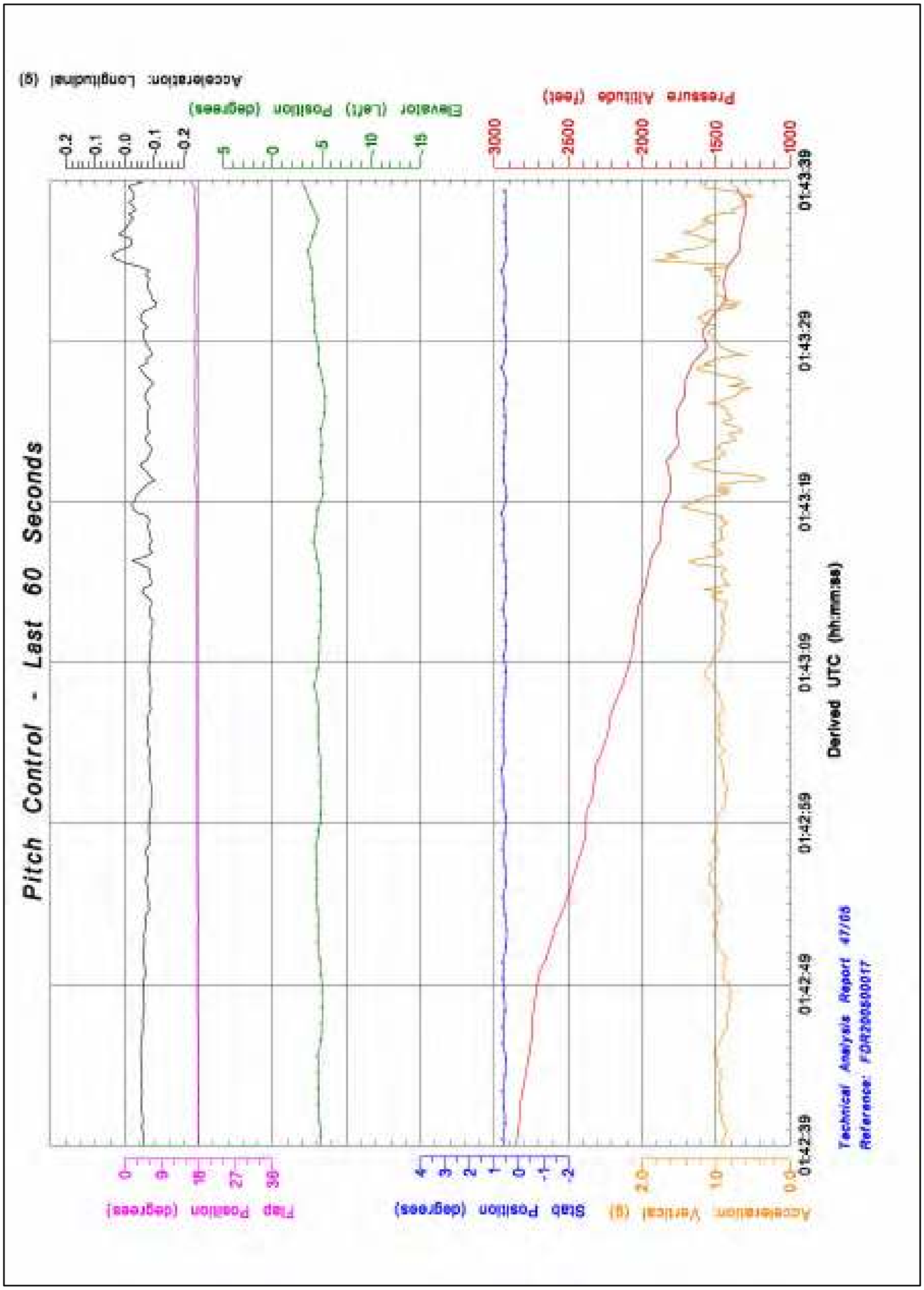
Pitch Control VH-TFU 7 May 2005
Flap Position (degrees)
Stab Position (degrees)
Elevator (Left) Position (degrees)
Pressure Altitude (feet)
Elapsed Time (hh:mm)
CNS
LHR
BAM
00:50
01:09
01:28
01:47
02:07
02:26
02:45
03:04
03:23
03:43
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-55:



Pitch Control - Accident Flight
Elevator (Left) Position (degrees)
Pressure Altitude (feet)
Flap Position (degrees)
Stab Position (degrees)
Derived UTC (hh:mm)
01:09
01:14
01:19
01:24
01:29
01:34
01:39
01:44
BAM
Technical Analysis Report 47/05

Figure A-56:



Pitch Control - Last 60 Seconds
Acceleration: Longitudinal (g)
Elevator (Left) Position (degrees)
Pressure Altitude (feet)
Flap Position (degrees)
Stab Position (degrees)
Acceleration: Vertical (g)
Derived UTC (hh:mm:ss)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-57:

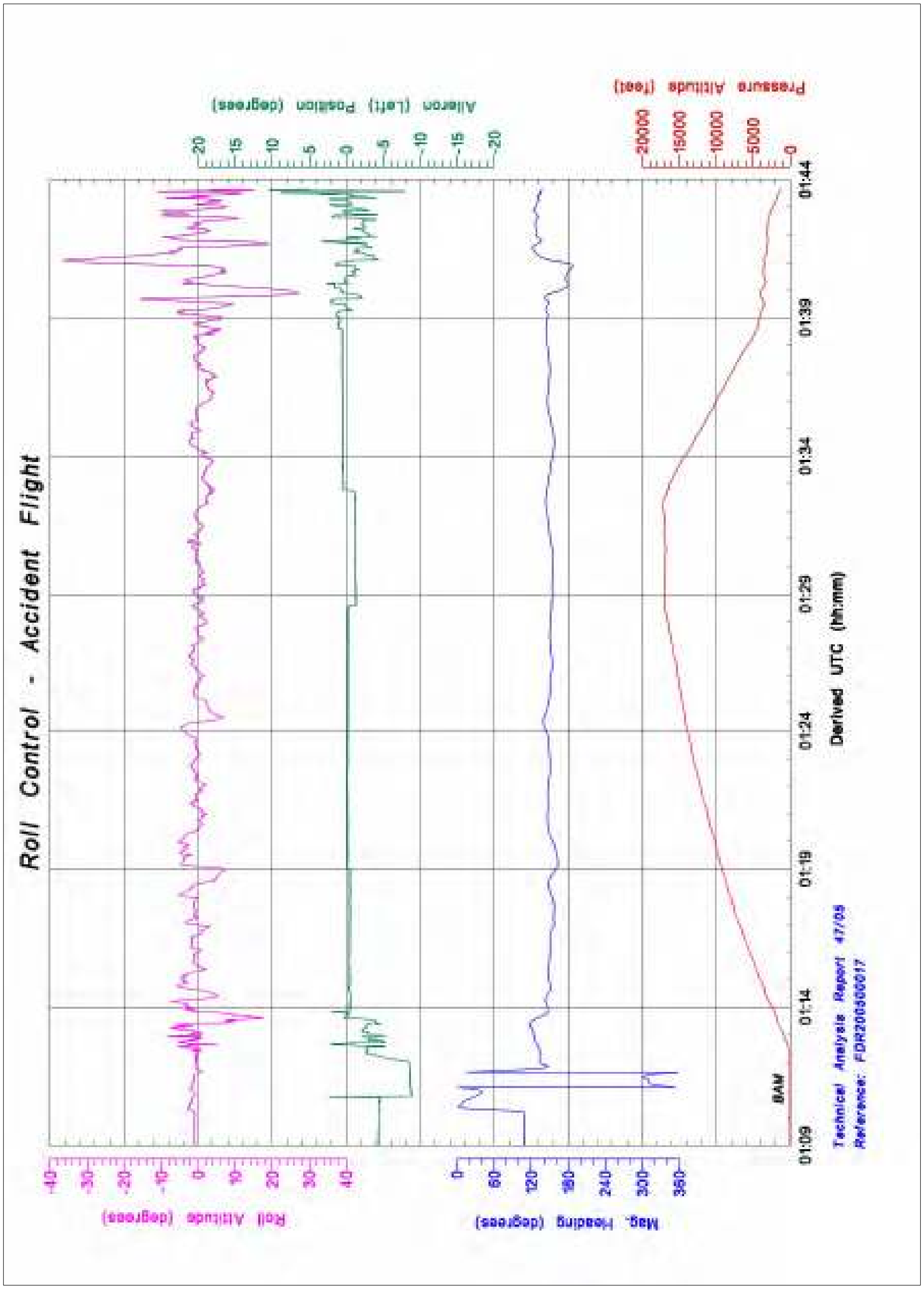

Roll Control - Accident Flight
Roll Attitude (degrees)
Mag. Heading (degrees)
Aileron (Left) Position (degrees)
Pressure Altitude (feet)
Derived UTC (hh:mm)
01:09
01:14
01:19
01:24
01:29
01:34
01:39
01:44

Figure A-58:

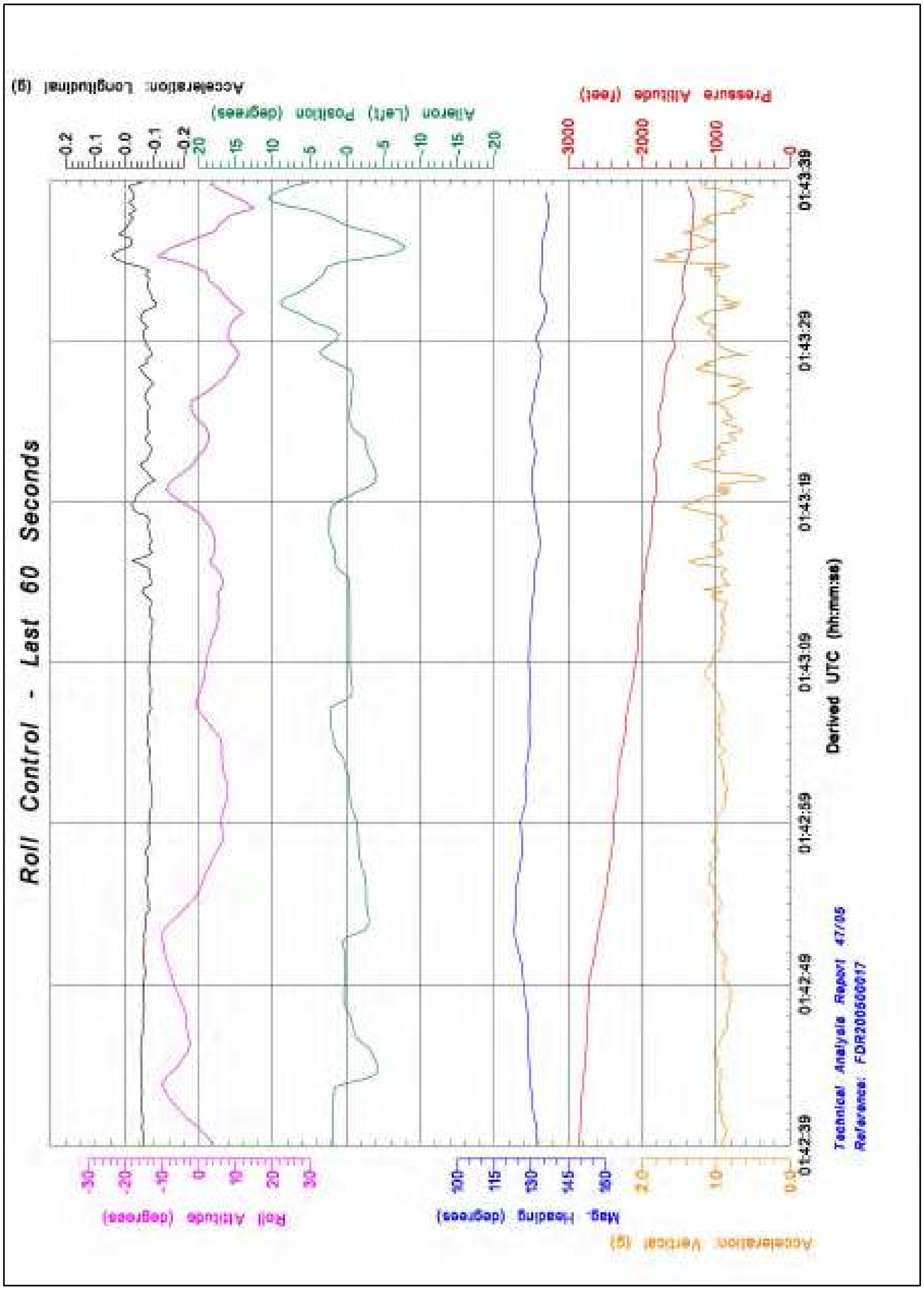
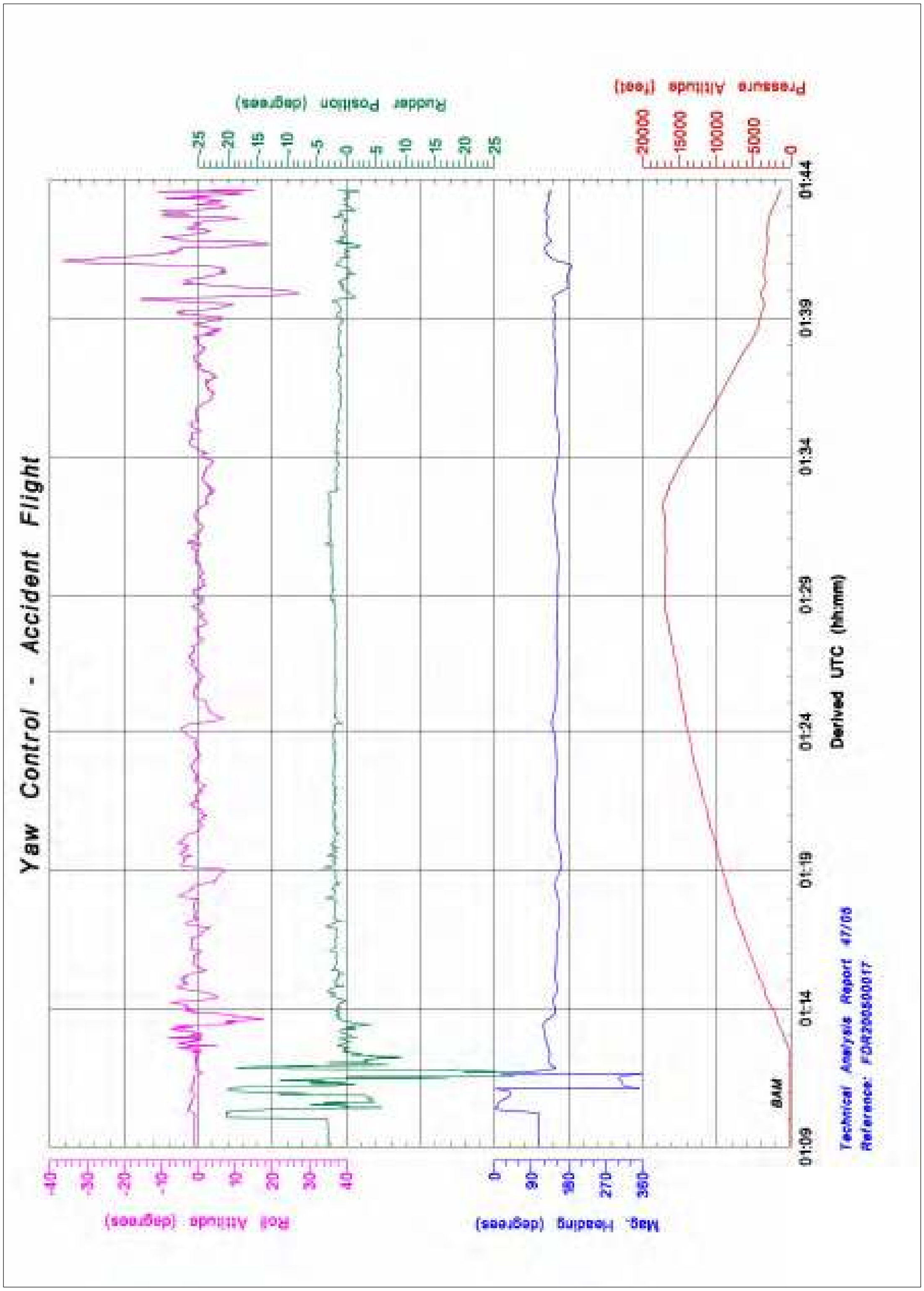
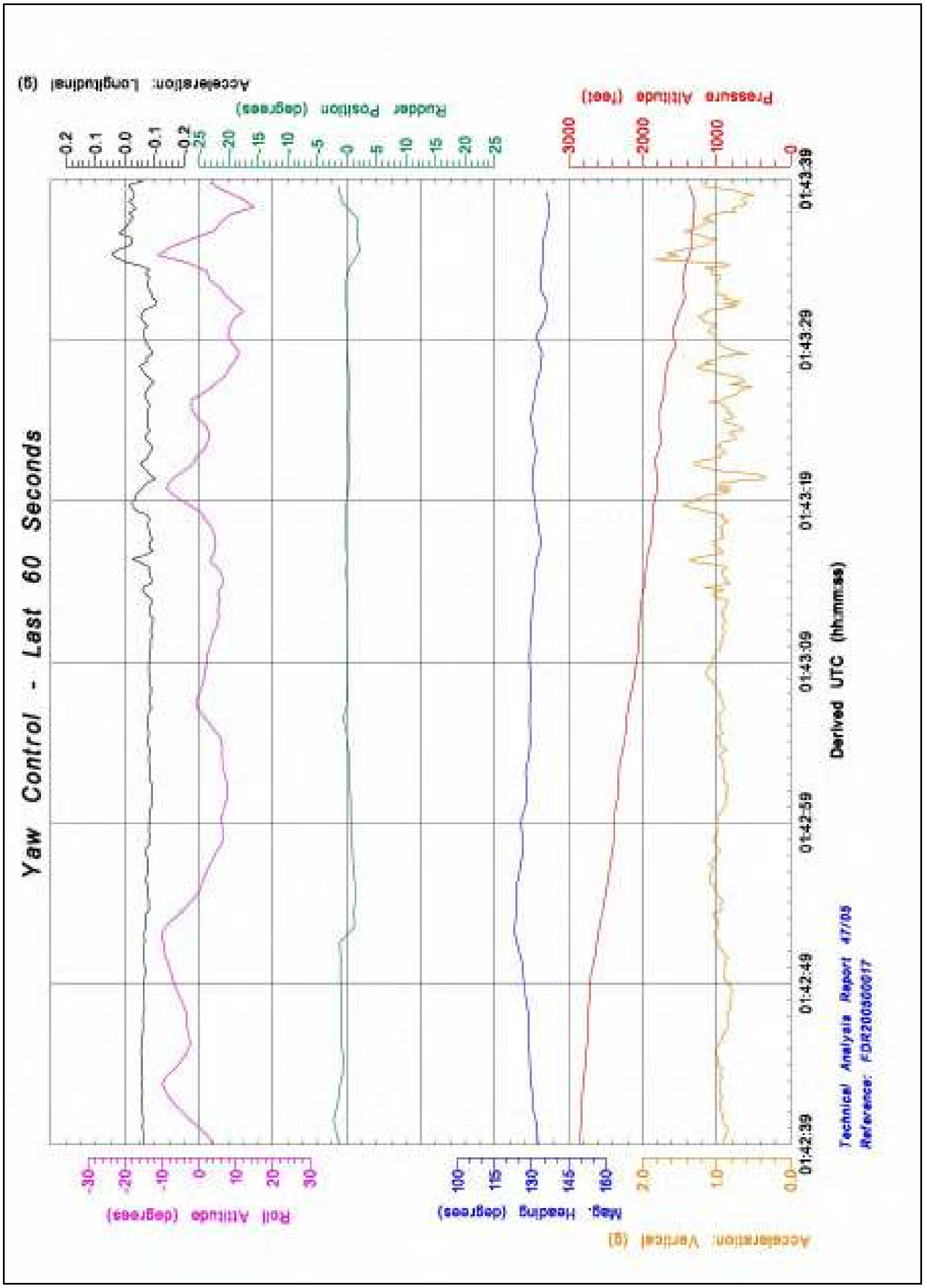

Roll Control - Last 60 Seconds
Derived UTC (hh:mm:ss)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Acceleration: Longitudinal (g)
Aileron (Left) Position (degrees)
Pressure Altitude (feet)
Roll Attitude (degrees)
Mag. Heading (degrees)
Acceleration: Vertical (g)
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-59:



Yaw Control - Accident Flight
Roll Attitude (degrees)
Mag. Heading (degrees)
Rudder Position (degrees)
Pressure Altitude (feet)
Derived UTC (hh:mm)
01:09
01:14
01:19
01:24
01:29
01:34
01:39
01:44
BAM
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-60:



Yaw Control - Last 60 Seconds
Acceleration: Longitudinal (g)
Rudder Position (degrees)
Pressure Altitude (feet)
Roll Attitude (degrees)
Mag. Heading (degrees)
Acceleration: Vertical (g)
Derived UTC (hh:mm:ss)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Technical Analysis Report 47/05
Reference: FDR200500017

Aircraft systems serviceability

The FDR system included external sensors located throughout the aircraft. Most of those sensors were also part of other aircraft systems. Evidence regarding the serviceability of those other systems could be obtained by examination of the recorded FDR data.

Electrical system – DC

The FDR (powered by 28 VDC) operated when power was available from either the Right Essential Bus or the Left Essential Bus provided that the G switch had not activated. The FDR did not require the avionics master switch to be ON to obtain power.

The FDR started recording elapsed time (commencing at zero) from the time of power-up and the elapsed time incremented once per second. A power interruption of greater than 0.5 of a second would cause the FDR counter to reset to zero and begin incrementing again.

The FDR began operating on the ground at Bamaga before either engine was started. Examination of the recorded elapsed time counter showed that the FDR operated continuously until impact as the subframe counter incremented each second and did not reset to zero at any stage during the flight. This is evidence that at least one Essential Bus was available to provide power throughout the flight at least until the FDR stopped recording. The FDR stopped recording due to the activation of the G switch during the impact sequence.

Torque and propeller RPM parameters for each engine were recorded by the FDR. Torque and propeller sensors for the right engine were powered from the Right Essential Bus while torque and propeller sensors for the left engine were powered from the Left Essential Bus. Valid torque and propeller RPM data for both engines were continuously recorded throughout the flight. This provides evidence that the Right Essential Bus and the Left Essential Bus were both available to provide power throughout the flight at least until the time that the FDR stopped recording.

Electrical power from the Non Essential Bus to a flap selector valve directed hydraulic pressure to the flap actuators. The actuators extended or retracted the flaps.

The aircraft took off with flap ¼ set and after takeoff, the flaps retracted normally. During the approach, flaps were moved twice: from the zero degrees (up selection) extending to approximately 9 degrees (¼ selection) and later from 9 degrees extending to approximately 18 degrees (½ selection).

This provides evidence that the Non Essential Bus was available to provide power before takeoff and during approach at least until 78 seconds before the FDR stopped recording.

Electrical system – AC

Magnetic heading excitation was provided by the Right 26 VAC Bus and required the Avionics Master switch to be ON to obtain power. Recorded magnetic heading data during the flight correlated well with runway direction, roll attitude and expected aircraft track. This provides evidence that the Right 26 VAC 400 Hz Bus was providing power throughout the flight at least until the FDR stopped recording. The Right 26 VAC 400 Hz Bus was powered from the Right AC Bus.

Roll attitude information was sourced from the pilot's attitude gyro indicator. This indicator was powered by 115 VAC from the Left AC Bus. Reasonable roll attitude data was recorded throughout the flight until the FDR stopped recording. This provides evidence that the Left 115 VAC Bus was providing power throughout the flight at least until the FDR stopped recording.

Hydraulic system

Flaps and landing gear were hydraulically actuated. Flap position was recorded by the FDR but not landing gear position. The aircraft took off with flap ¼ set and after takeoff, the flaps retracted normally. During the approach flaps were moved twice: from the zero degrees (up selection) extending to approximately 9 degrees (¼ selection) and later from 9 degrees extending to approximately 18 degrees (½ selection).

Both extensions were continuous and stopped at the expected values. The extension from ¼ to ½ took 4 seconds and occurred 78 seconds before the FDR stopped recording. Three previous flights were examined and, on each, the flaps took approximately 4 seconds to extend from the ¼ position to the ½ position. This provides evidence that the hydraulic system was operating normally throughout the flight at least until 78 seconds before the FDR stopped recording.

Pitot/static system

The pitot/static system consisted of pitot masts and static ports, manifolds and plumbing to provide pitot/static pressures to the airspeed indicators while the altimeters and vertical speed indicators were connected to static lines only.

The pitot masts accumulated 'ram air' i.e. air forced against the opening of the tube by the passage of the aircraft. The static ports were located on the exterior of the aircraft, at locations chosen to detect the prevailing atmospheric pressure as accurately as possible without any disturbance from the passage of the aircraft.

On VH-TFU, as was standard on Metro 23 aircraft, two pitot masts faced forward in the direction of flight and were located on the upper section of the aircraft nose. Four static ports were located at the rear of the aircraft (two ports on either side of the aft fuselage).

Two separate pitot systems and two separate static systems were used. The pilot's instruments were connected to one pitot/static system (i.e. the pilot's system) and the copilot's instruments to the other pitot/static system (i.e. the copilot's system). The FDR was connected to the copilot's pitot/static system.

Allowing for FDR system tolerances, the following observations were made:

- The pressure altitude recorded by the FDR, while the aircraft was on the ground at BAM, was consistent with the aerodrome elevation.
- The recorded pressure altitude increased continuously after takeoff at BAM, reaching a maximum of 17,000 ft (FL170). This was consistent with the cruising level reported by the crew to ATC.
- On approach to LHR, the aircraft leveled at 3,500 ft approaching waypoint LHRWI. This was consistent with the RWY 12 RNAV approach altitude at that point.
- The minimum pressure altitude recorded by the FDR (1,292 ft) was consistent with the elevation of the accident site.

These observations provide evidence that the pilot's and copilot's static systems were providing accurate static pressures to the aircraft instruments until the FDR stopped recording.

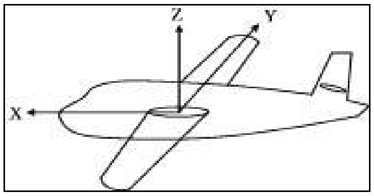
Engines and propellers

Recorded torque data for each engine was symmetrical and appropriate for the phase of flight. Propeller RPM parameters were also symmetrical and appropriate for the phase of flight. During the accident flight, the recorded data did not provide any evidence of a problem with either engine or propeller.

Turbulence

A dual axis DC accelerometer was fitted to VH-TFU. It provided acceleration information in the aircraft vertical (Z) and longitudinal (X) axes.

Figure A-61:



With the aircraft on the ground the nominal value recorded for vertical acceleration is 1g. In flight, vertical acceleration data represents the combined effects of flight manoeuvring loads and turbulence. Examination of the data can provide an indication of the turbulence that was experienced in flight.

Vertical acceleration data recorded during the accident flight and the six previous flights were examined. The examination showed that the flight phases where turbulence was more prevalent were initial climb and approach. Turbulence is less likely at higher altitudes such as during cruise.

A qualitative assessment of the vertical acceleration trace for the accident flight shows that, apart from the last five seconds of the flight, the turbulence was within the range experienced on other flights. During the last five seconds the turbulence was greater than that experienced during the six comparison flights.

The area forecast, issued by the BOM at 1134 local time on 7 May 2005, gave the wind at 2,000 ft as from the SE (130°T) at 20 knots. As VH-TFU approached from the NW, it would have been in the lee of the South Pap ridge line. An airflow of the forecast magnitude, over the ridge line, would have created mechanical turbulence.

The last 25 seconds of recorded data showed that the turbulence experienced by the aircraft, as indicated by increasing activity in the vertical acceleration trace, increased. During this period, it is likely that the aircraft would have been under the increasing influence of mechanical turbulence from the South Pap ridge line.

Consistent with increasing turbulence, roll control inputs of increasing magnitude were made during the final 10 seconds of recorded data. Elevator position data showed that no significant pitch control inputs were made during the corresponding period.

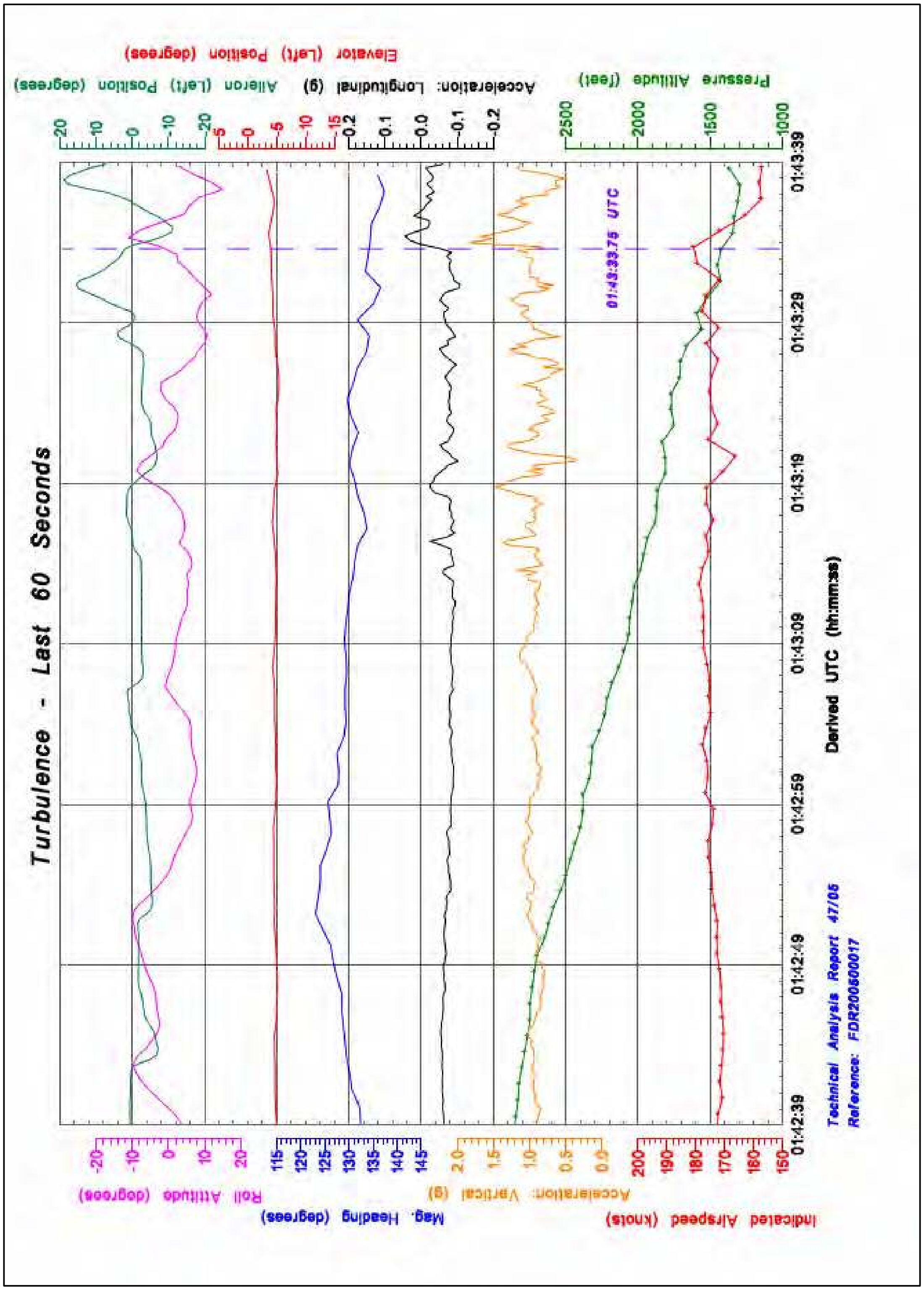
A spike in the vertical acceleration trace was evident at 01:43:33.75 UTC, approximately five seconds before the end of recorded data, refer to figure A-62. The rapid increase in vertical acceleration and the lack of nose-up elevator movements make it likely that the spike was due to turbulence and not flight manoeuvring loads.

The maximum and minimum values of vertical acceleration recorded during the flights are detailed in table A-10.

Table A-10:

Flight:	Maximum vertical acceleration (g's):	Minimum vertical acceleration (g's):
Accident flight 7 May	+ 1.84	+ 0.35
LHR-BAM 7 May	+ 1.56	+ 0.28
CNS-LHR 7 May	+ 1.47	+ 0.56
BAM-CNS 6 May	+ 1.32	+ 0.67
CNS-BAM 6 May	+ 1.53	+ 0.37
BAM-CNS 5 May	+ 1.34	+ 0.55
CNS-BAM 5 May	+ 1.55	+ 0.46

Figure A-62:


Turbulence - Last 60 Seconds
Elevator (Left) Position (degrees)
Aileron (Left) Position (degrees)
Acceleration: Longitudinal (g)
Pressure Altitude (feet)
Roll Attitude (degrees)
Mag. Heading (degrees)
Acceleration: Vertical (g)
Indicated Airspeed (knots)
01:43:33.75 UTC
Derived UTC (hh:mm:ss)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Technical Analysis Report 47/05
Reference: FDR200500017

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APPENDIX A FINDINGS

Examination of the recovered data showed that the accident flight and 59 previous flights had been recorded by the FDR. The total duration of recorded data was 100 hours, 2 minutes and 16 seconds.

Parameter serviceability

Examination of the data showed that the following parameters were serviceable during the accident flight:

Pressure Altitude[27]

Indicated Airspeed

Magnetic Heading

Roll Attitude

Horizontal Stabiliser Position

Flap Position

Elevator Position

Rudder Position

Aileron Position

Right Engine Propeller RPM

Left Engine Propeller RPM

Right Engine Torque

Left Engine Torque

Vertical Acceleration

Longitudinal Acceleration

Microphone Keying – Pilot

Microphone Keying – Copilot

The pitch attitude parameter was unserviceable during the accident flight and all the previous flights recorded by the FDR.

27 When processed using the manufacturer's standard conversion equations, it was observed that pressure altitude and indicated airspeed values were unreasonable. Calibration equations were developed which corrected for this FDR system problem.

Aircraft systems

Analysis of the FDR data provided direct and indirect evidence concerning the serviceability of the following aircraft systems:

- electrical power
- hydraulic power
- flight controls and
- pitot/static system.

This analysis did not provide any evidence of problems with these systems.

Engines and propellers

Recorded torque data for each engine was symmetrical and appropriate for the phase of flight. Propeller RPM parameters were also symmetrical and appropriate for the phase of flight. During the accident flight, the recorded data did not provide any evidence of a problem with either engine or propeller.

Turbulence

As indicated by increasing activity in the vertical acceleration trace, examination of the last 25 seconds of recorded data showed that the turbulence experienced by the aircraft increased. During this period the aircraft would have been under the increasing influence of mechanical turbulence from the South Pap ridge line.

Flight control inputs

The final 10 seconds of recorded data showed that small pitch and yaw control inputs were evident as small elevator and rudder position changes. Larger roll control inputs were evident as aileron position changes. The roll inputs were applied in the opposite sense to the aircraft bank angle showing that the aircraft attitude was being actively controlled by the handling pilot.

Elevator position data showed that no significant pitch control inputs were made during the corresponding period. A GPWS escape manoeuvre requires that the pilot make a large nose-up pitch control input and apply maximum power. Recorded elevator position and engine torque parameters showed no evidence of such commands.

APPENDIX A ABBREVIATIONS

Acronyms may be used in upper case or lower case.

AC	Alternating Current
AD	Aerodrome
ADI	Attitude Director Indicator
ALT	Altitude
ATC	Air Traffic Control
BAM	Bamaga
BoM	Bureau of Meteorology
C	Celsius
CNS	Cairns
CVR	Cockpit Voice Recorder
DC	Direct Current
ELEV	Elevation
FAF	Final Approach Fix (e.g. LHRWF)
FDR	Flight Data Recorder
FFD	Frame Format Descriptor
FS	Fuselage Station
G	Gravitational Constant
g	Acceleration due to Gravity
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
hPa	Hectopascals
Hz	Hertz (cycles per second)
IAF	Initial Approach Fix
IAS	Indicated Airspeed
IF	Intermediate Fix (e.g. LHRWI)
ILS	Instrument Landing System
LHR	Lockhart River
LSW	Least Significant Word
MHz	Mega Hertz (frequency)

MSL	Mean Sea Level
MSW	Most Significant Word
NDB	Non-Directional Beacon
NM	Nautical Mile
NPA	Non-Precision Approach
PCB	Printed Circuit Board
P/N	Part Number
QNH	Mean Sea Level Atmospheric Pressure
RMS	Root Mean Square
RNAV	Area Navigation
RPM	Revolutions Per Minute
RWY	Runway
S/N	Serial Number
ºT	Degrees True
TAS	True Airspeed
UTC	Coordinated Universal Time
VAC	Volts AC
VDC	Volts DC
VSI	Vertical Speed Indicator
WPT	Waypoint

APPENDIX B: COCKPIT VOICE RECORDER TECHNICAL ANALYSIS REPORT

Cockpit Voice Recorder Replay and Analysis
SA227-DC VH-TFU
7 May 2005

ATSB TECHNICAL ANALYSIS REPORT 25/06

Kenneth Kell
Senior Transport Safety Investigator – Technical Analysis

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

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APPENDIX B CONTENTS

APPENDIX B FACTUAL INFORMATION

Introduction

A Fairchild Industries SA227-D.C. Metro 23, VH-TFU, was carrying out a regular public transport flight between Bamaga and Lockhart River, Qld on the 7 May 2005. While performing an Area Navigation Global Navigation Satellite System (RNAV(GNSS)) approach to runway 12, the aircraft impacted terrain approximately 11 km NW of Lockhart River and was destroyed.

VH-TFU was required by Civil Aviation Order 20.18 to carry both a flight data and a cockpit voice recorder (CVR). Both recorders were recovered from the aircraft wreckage and transported to the Australian Transport Safety Bureau (ATSB) facilities at Canberra, ACT for examination.

The CVR was examined and the recording tape extracted and replayed. The initial replay of audio signals recorded on the recovered tape did not reveal conversation that could be positively related to the operation of the aircraft during the accident flight. Repetitive short duration pulsed signals not found in a normal recording were also present in the recovered audio.

The unusual signals contained in the recovered audio indicated a fault had manifested itself in the CVR at some time prior to the accident. This report documents the examination of the CVR unit, recording tape and signals recorded on the tape, and the possible failure mode of the CVR.

CVR System

CVR systems are fitted to aircraft to provide, particularly if there is a fatal accident, a record of conversations of the operating crew, both between themselves and with external parties. Conversations can indicate how the controls of the aircraft were being manipulated, how the crew were interacting while flying the aircraft and how the crew were managing the progress of flight by responding to instructions and requesting information from ground sources. CVR recordings may also capture other relevant sounds.

The CVR system installed on an aircraft comprises the CVR unit, a control unit and an area microphone and microphones at each flight crew position. These components are connected to the aircraft wiring that provides a path for electrical power, monitoring and audio signals. The CVR unit is capable of simultaneously recording four channels of information. The CVR system fitted to aircraft operated as two crew configuration, such as the Metro 23, has a separate channel dedicated to each flight crew position audio system and signals detected by the area microphone. The fourth channel can be utilised for signals from the public address system.

The CVR unit usually referred to as the CVR and sometimes ‘black box’, is the unit which records and stores the audio signals. The unit is usually mounted in the rear fuselage or tail of an aircraft to provide enhanced protection from impact damage and fire in the event of an accident. The audio signals are processed by the electronic interface within the unit and the signals are stored on recording media, usually tape or more modern solid state integrated circuits. The duration of the recording may vary, with most units fitted with tape containing at least 30 minutes of information. Units fitted with solid-state recording medium may contain up to two hours of information. The recording medium is packaged inside a crash-protected module that is armoured to provide impact and crush resistance and is thermally insulated to resist damage from fire or heat.

The CVR control unit, located in the cockpit, provides remote control of the CVR unit through the TEST and ERASE switches. A meter and headset jack allows cockpit indication of CVR unit monitor signals. The control unit also houses the area microphone preamplifier and/or its microphone. The microphone may be remotely mounted on the instrument panel glare shield or windscreen pillar. The function of the cockpit area microphone (CAM) is to capture the audio environment in the cockpit.

Signals required to provide information sources and control the CVR system are carried between the separate units through electrical wires. The interwiring between the CVR unit, the control unit, area microphone and aircraft audio select and control panels, is located throughout the aircraft and stretches from the cockpit to the rear fuselage where the CVR unit is located.

The CVR unit can record up to four individual tracks of information. These tracks are allocated to a signal source. For example, one track may contain signals originating from the Captain's audio system, another may contain signals originating from the First Officer's audio system and a third may contain sound detected by the CAM. Where a CVR is installed in an aircraft where there are more than two flight deck crew positions, a fourth track may contain signals originating from an additional crew position such as a Flight Engineer position. Alternatively, signals relating to public address announcements may be recorded.

A track associated with a flight crew position would be expected to contain signals relating to crew conversation regarding the operation and management of the flight, communication with Air Traffic Control and any activation of aural alerts relating to aircraft systems operation (for example, undercarriage unsafe or fire warning). The CAM track would be expected to provide a record of the cockpit audio environment, such as sounds relating to engine/propeller operation, operation of switches and levers, activation of undercarriage and weather such as rain or hail.

Recovery of recording tape from CVR

The CVR was recovered from the aircraft wreckage by on-site investigators. The CVR was transported by 'safe hand' to the ATSB laboratories at Canberra.

The CVR had been significantly exposed to fire with the paint on the outer casing burnt off. The pattern left from where reflective tape had been affixed, was visible. Several spots of molten metal had become fixed to the outer case. The underwater locator beacon (ULB) mount had molten metal attached. The ULB mount had been distorted during recovery at the accident site as the damaged ULB was removed from the CVR unit before transport. A photograph of the CVR as received, see Figure B-1.

Figure B-1: L-3 Communications Aviation Recorders Fairchild model A100A CVR recovered from VH-TFU

The CVR appeared structurally intact. The casing and front panel had not been subjected to high impact forces. The cockpit voice recorder was identified from the manufacturer's data plate shown in Figure B-2. The CVR was a Fairchild Model A100A, part number 93-A100-83, serial number 60652, manufactured in May 1992. The CVR was manufactured by Loral Data Systems, Fairchild Aviation Recorders, Sarasota Florida, USA. Fairchild Aviation Recorders is now known as L-3 Communications Aviation Recorders.

Figure B-2: CVR identification plate

The dust cover was removed in a normal manner by removing the retaining screws and sliding off. This revealed that the electronic assemblies contained in the CVR were significantly heat affected, see Figure B-3.

Figure B-3: CVR with casing removed

The crash-protected module containing the recording tape was removed in the conventional manner by removing the ULB mount and internal fixing screws. The electrical connections to the crash-protected module were significantly heat affected with molten insulation and damaged connectors. To remove the crash-protected module, the electrical wires were cut a short distance from the connector.

Fire and heat protection for the recording tape is provided by water[28] which is held in the insulation assembly that surrounds the drive unit assembly. Although the capsule had suffered heat distress, it was noted that some moisture was still present. This indicated that the capsule had been providing some fire and heat protection to the recording tape as shown in Figure B-4.

Figure B-4: Crash protected module with armouring removed. Heat damage to the fire protection can be seen.

The insulation assembly was removed and the reel cover assembly opened revealing an intact reel and tape assembly. The recording tape was in the normal location following the installed tape path. Figure B-5 shows the recording tape in situ after being cut for removal. The slight distortion, probably from heat, can be seen where the tape is fed from the centre of the take-up spool. Apart from the minor heat damage, the recording tape was in good condition with very little mechanical wear present. The drive unit assembly was quite clean and showed little evidence of build up of debris that can shed from the tape around the head bridge assembly and can indicate mechanical wear of the tape.

28 The use of water ensures that the internal temperature of the module does not rise above 100°C, while the water is present.

Figure B-5: Recording tape in tape transport; note slight damage to tape at centre of spool.

The tape was cut between the guide rollers to allow removal from the drive unit assembly. The tape was joined by the manufacturer to make an endless loop 308 ft long. The 308 ft (93.9 m) tape length is calculated to provide about 32 minutes 51 seconds of recording at the nominal tape speed of 1⅞ in/s (47.6 mm/s). The recovered tape was wound onto a 5 inch (12.7 cm) spool so the tape could be replayed in a linear manner on a conventional tape transport.

Initial replay of recording tape from CVR

Following recovery, an initial replay of the CVR tape was made on 9 May 2005. The five inch spool containing the recording tape was placed onto the Bureau's CVR replay tape deck[29].

The nominal tape speed specified for the model A100A CVR is 1⅞ in/s, however the actual tape speed is dependent upon the frequency of the alternating current power supply to the tape transport drive motor. The CVR was fitted with a d.c. to a.c. inverter whose frequency is specified as 400 Hz ± 5%.

The Nagra replay speed was set to 1⅞ in/s. The appropriate replay head selection to emulate the model A100A CVR was made. The output signals from the Nagra were routed to the Bureau's Apple G4 audio analysis workstation, allowing the four replay signals to be copied and digitised for further analysis. The output signals were also monitored to check recording amplitude for distortion.

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29 A Nagra T instrumentation tape transport that has been fitted with replay head assemblies to emulate the tape transport path found in a variety of cockpit voice recorders.

Interference signals that relate to the a.c. power supply that may be present are utilised to determine the correct replay speed. These signals are measured and correlated with the specified a.c. frequency, 400 Hz. A variation in frequency from 400 Hz may indicate the replay speed is not the same as when originally recorded. The replay speed of the Nagra may be adjusted manually to compensate for variation in speed of the original recording.

No interference signals relating to the a.c. power supply frequency could be detected. Therefore, replay was made at the specified A100A record speed, 1⅞ in/s, which resulted in the recorded speech sounding normal in pitch and duration.

As the CVR tape was replayed, the audio signals were copied by the Apple G4 using Protools software and Digidesign hardware interface. Four digital files: Audio1_01.wav; Audio2_01.wav; Audio3_01.wav; and Audio4_01.wav were created in folder ‘Initial Replay 9 May 2005’.

A second partial replay of the CVR tape was made on 9 May 2005 on the Bureau’s Nagra TI instrumentation tape deck. Four digital files: Audio1_01.wav; Audio2_01.wav; Audio3_01.wav; and Audio4_01.wav were created in folder ‘9 May 2005 Std Nagra (Part)’. About the last 12.5 minutes of the CVR recording was replayed. This replay was made due to the unusual recording recovered from the initial replay. It was therefore considered valuable to use an independent replay unit to confirm the signals recovered from the tape. The Nagra TI was fitted with a pair of two-track replay heads spaced by about 39 mm which resulted in a fixed time shift between the recovered audio from the odd and even tracks. Replay speed of the tape transport was set to 1⅞ in/s.

A full replay of the CVR tape was made on 11 May 2005 on the Bureau’s Nagra TI instrumentation tape deck. Four digital files: Audio1_01.wav; Audio2_01.wav; Audio3_01.wav; and Audio4_01.wav were created in folder ‘9 May 2005 Std Nagra (Full)’.

The recovered audio was also monitored via the line output from the Digidesign interface. The recording consisted of fragments of recorded information that contained crew speech, aircraft operation both on the ground and in the air, communications with air traffic control and a ‘pulsed’ interference signal. The fragments of recorded information did not appear to be in a logical sequence.

Most CVR installations are configured to allow the CVR system to begin recording prior to the pre-start checklists being performed[30]. Therefore, a normal recording of aircraft operation containing a flight that exceeds the maximum CVR recording duration, would consist of the aircraft operating during the descent, landing and subsequent taxi to parking bay and shutdown.

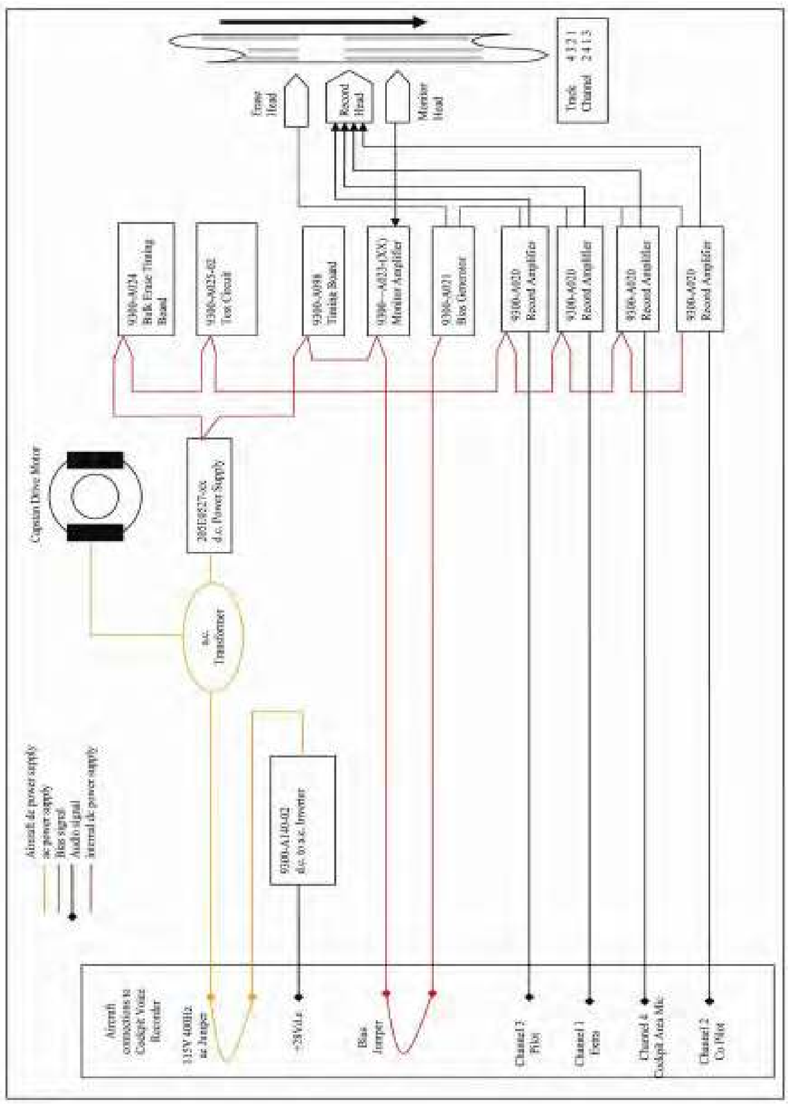
30 Civil Aviation Order 20.18 section 6 paragraph 6.4

M7[31] Aerospace model SA227-D.C. CVR installation

Description of CVR System

The CVR unit fitted to VH-TFU was a Fairchild Model A100A, part number 93-A100-83, serial number 60652. This CVR configuration was listed in Table B-1 of the L-3 Aviation Recorders component maintenance manual as a model A100A CVR fitted with an acoustic ULB with mount and a 27.5 V d.c. to 115 V 400 Hz a.c. inverter. The inverter allows the CVR unit to be powered from the d.c. electrical busses available on the aircraft. Figure B-6 shows a Model A100A CVR unit simplified block diagram.

Figure B-6: Simplified block diagram of the power supply and input signal electrical paths.



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31 M7 Aerospace was the holder of the type certificate for the Fairchild Metro series aircraft and source for parts and technical support.

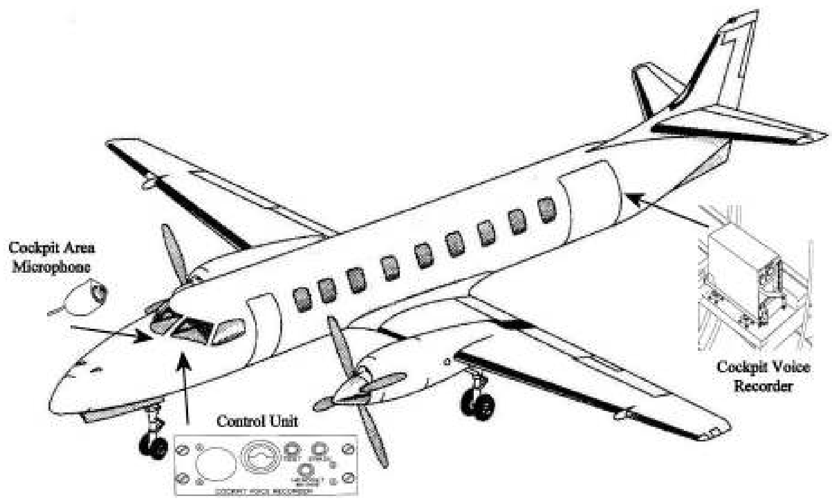
Physical Location of CVR and Control Unit

The CVR unit is located on the right side of the Metro 23, behind the rear luggage compartment, see figure B-7. The location is designated as between fuselage stations (F.S.) 548.81 and 565.96 and stringer 10 and 13[32].

The CVR control unit is usually mounted on the instrument panel. The control unit has a headset jack fitted to allow monitoring of recorded audio, an ERASE switch to erase the recording following flight, and a 'go / no-go' TEST button and meter to indicate the results of the test.[33]

VH-TFU had the CAM remotely mounted from the CVR control unit. Figure B-8 shows the microphone located on the glare shield in the centre of the instrument panel.

Figure B-7: Location of cockpit voice recorder system components



32 M7 Aerospace Illustrated Parts Catalogue (PN 27-10054-141) Revision 45, August 31 2004, chapter 23-70-10.

33 M7 Aerospace Maintenance Manual (PN 27-10054-133) Revision 43, February 01 2005, chapter 23-70-10.

Figure B-8: Photograph of VH-TFU instrument panel showing location of cockpit area microphone.

Aircraft interwiring

The aircraft interwiring connects the components of the CVR system. The wiring also connects to relevant audio sources and aircraft power supply, as well as enabling the record function.

The CVR obtains d.c. power supply from either the left or right essential bus via a 5 A circuit breaker[34].

The d.c. power supply is also controlled via a ‘g’ switch located under the centre aisle between F.S 272 and F.S. 254.52. The ‘g’ switch is installed to interrupt power and preserve the CVR recording in the event the aircraft being subjected to excessively high acceleration forces.

34 M7 Aerospace Maintenance Manual (PN 27-10054-133) Revision 43, February 01 2005, chapter 24-60-00 page 2.

Examination of signals recorded by the CVR

Examination using Magnasee

The magnetic tape recovered from the CVR was examined using Magnasee. Magnasee is a fluid containing magnetically sensitive particles. As the fluid evaporates the particles align with the magnetic domains on a tape which are then rendered visible.

Figure B-9 shows the signals recorded on a section of the tape recovered from the CVR fitted to VH-TFU that were made visible by Magnasee. The interference signal ‘spikes’ are indicated by the light grey transverse stripes visible on the tape. Sources of the spikes are characterised by the stripes visible across the width of the 0.25 in (6.4 mm) tape. Present are single full-width stripes and shorter stripes that are broken into four segments across the tape. Only the erase head is able to impress a signal across the full width of the tape. The four segments represent the four tracks produced by the four pole pieces of the recording head. The second track from the tape edge where the scale is located, see Figure B-9, has more signals visible than the other tracks. This track contains signals originating from the CAM. Replay of the CAM showed that signals relating to propeller noise associated with the operation of the aircraft were present on this portion of tape.

From about 62 mm to 77 mm, there are no stripes visible. This corresponds with the physical area of tape that existed between the erase head and the record head (about 15.5 mm) at the time of stoppage. The absence of stripes indicates the erase head was functioning. The magnified image of the section of tape following the erased portion, see Figure B-10, and preceding the erased portion, Figure B-11, clearly shows the visible stripes.

Figure B-9: Recovered tape with Magnasee applied

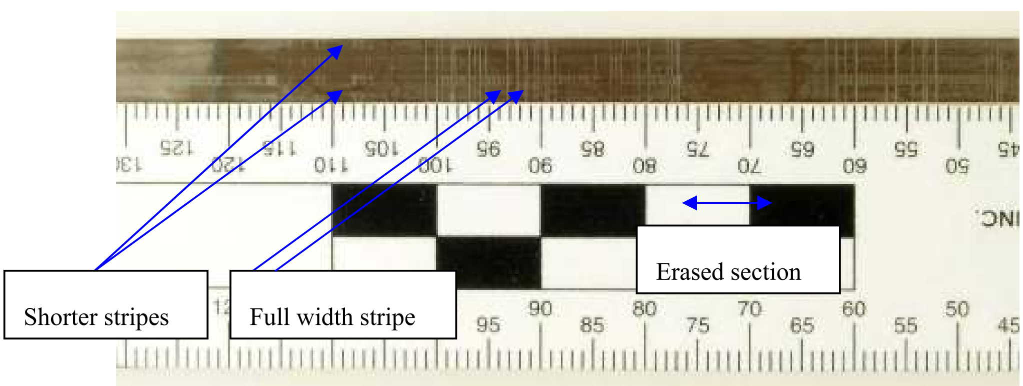


Figure B-10: The newest information recorded on the CVR tape, showing stripes indicating 'spikes' that are present for individual tracks and full width of the tape. Also illustrated is part of the erased section of tape.

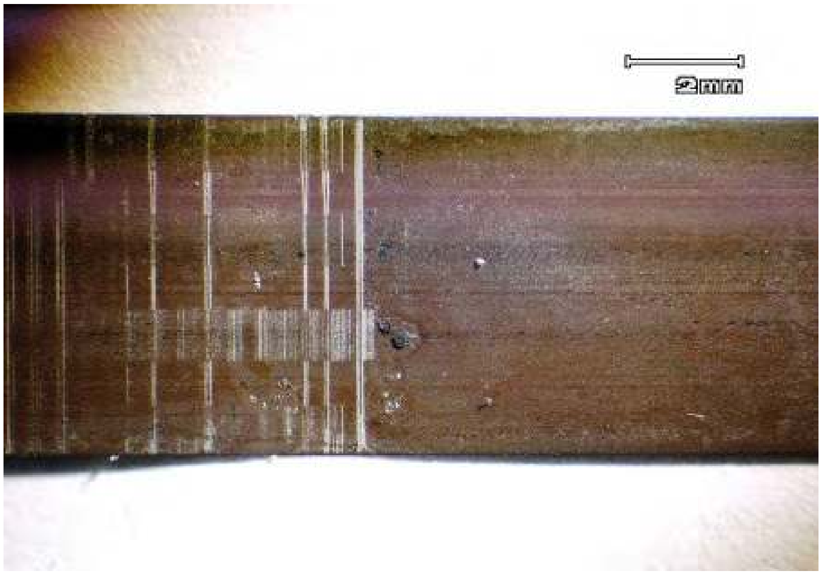


Figure B-11: Recovered tape with Magnasee applied, magnified to oldest information recorded.

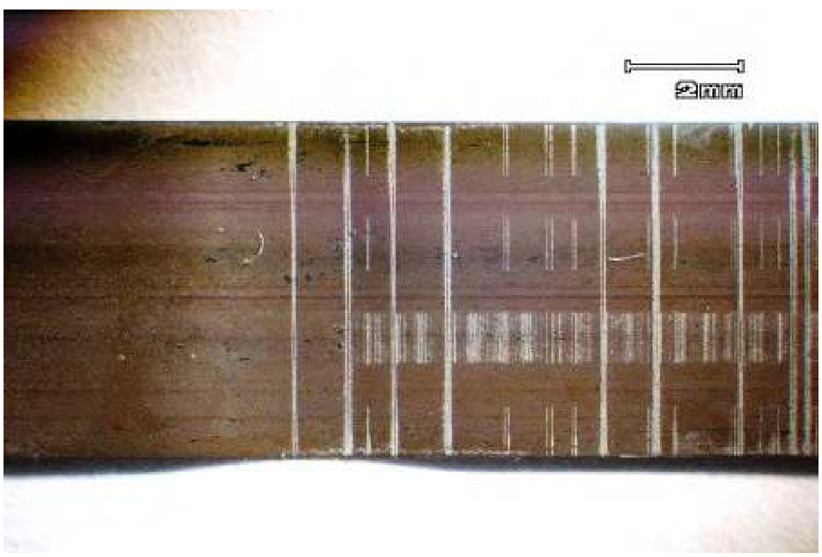
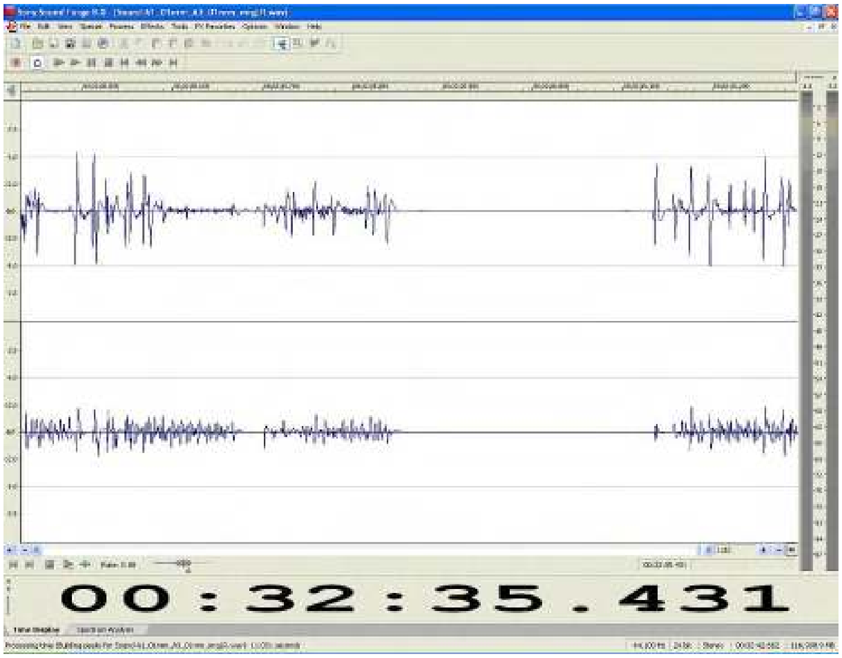


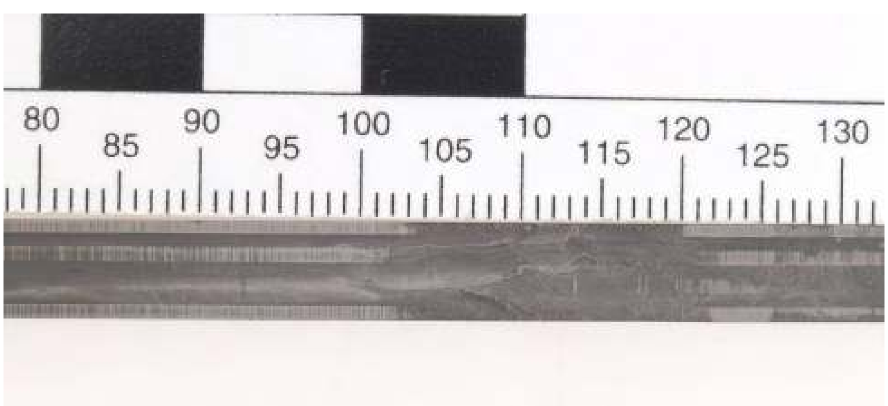
Figure B-12 is a time domain or oscillograph presentation of the spikes. The top trace relates to a recording made of a crew position and the bottom trace relates to audio recorded from the CAM. The spacing, duration and amplitude exhibited by the spikes contained in the CVR recording were examined. Although the spikes appeared to be present at certain intervals or groupings in certain areas, the timing and amplitude varied throughout the recording. No characteristic pattern or attributes of the spikes could be determined across the recording.

Figure B-12: Oscillograph plot of interference signal (note flat line area correlates with erase area in Magnasee view).



As an example, a tape from another L-3AR model A100A, which contained an accident flight recording where the audio signals were recovered successfully, was also examined with Magnasee. The three grey longitudinal lines, see Figure B-13, represent three of the four tracks provided by the four pole pieces of the recording head. This is consistent with the CVR installation of two-crew channels and area microphone channel being recorded on three tracks. In this case, the fourth channel was not allocated to a signal source. The characteristics of these longitudinal lines show a more even distribution of Magnasee, which indicates a recording of consistently varying signals such as voice and aircraft operating sounds, rather than the distinctive stripes or spikes that extend across the full width of the tape recovered from VH-TFU. From about 104 mm to 120 mm there are no longitudinal lines visible. This indicates the erased portion of tape that corresponds with the physical area of tape that existed between the erase head and the record head.

Figure B-13: Tape from another Fairchild A100A with Magnasee applied



Assay of signals contained on the recovered tape

Table B-1: L-3 Communications Aviations Recorder model A100A signal source

Nagra TI channel and Protools digital file	CVR Track (from CMM)	Model A100A CVR Channel Allocation (from CMM)
Audio1_01.wav	Track 1	Channel 3 – Pilot
Audio2_01.wav	Track 2	Channel 1 – 3rd Crew Member/PA
Audio3_01.wav	Track 3	Channel 4 – Area Microphone
Audio4_01.wav	Track 4	Channel 2 - Co-Pilot

The Protools digital files made during the initial replay on the 9 May 2005 were transferred to the Bureau's Dell audio analysis workstation. Table B-1 shows the correlation between the Protools digital file and the Model A100A CVR channel allocation. The files were imported for analysis using Soundforge V8.0. The audio files were normalized. Normalizing allows the amplitude of the recording to be increased to a user-defined level without clipping or introducing distortion. The original filenames were appended with _norm to indicate that the audio had been normalized. All four files are of the same duration with CVR information beginning at an elapsed time of about 2.5 seconds and ending at about 32 minutes 37.5 seconds.

All tracks contained an 'impulse' interference signal. The rapid rise and fall of the amplitude of the impulse gave a characteristic that could be more accurately described as a spike. The positive transition appeared to be consistently shorter in duration than the negative transition.

There were more spikes present when the aircraft was moving.

Audio1_01.wav recording contains information that indicates that the audio source was related to a flight crew position. This recording contains crew conversation, communication with ATC and other aircraft via VHF and HF radio equipment. The majority of speech recorded was similar in content and correlated with Audio4_01.wav, with some passages of conversation being easier to discern than others due to the relative amplitude. The conversations detected were fragmented, having several conversations interleaved or present at the same time. Also recorded was audio relating to the operation of pitch trim and activation of ground proximity warning system (GPWS) alerts.

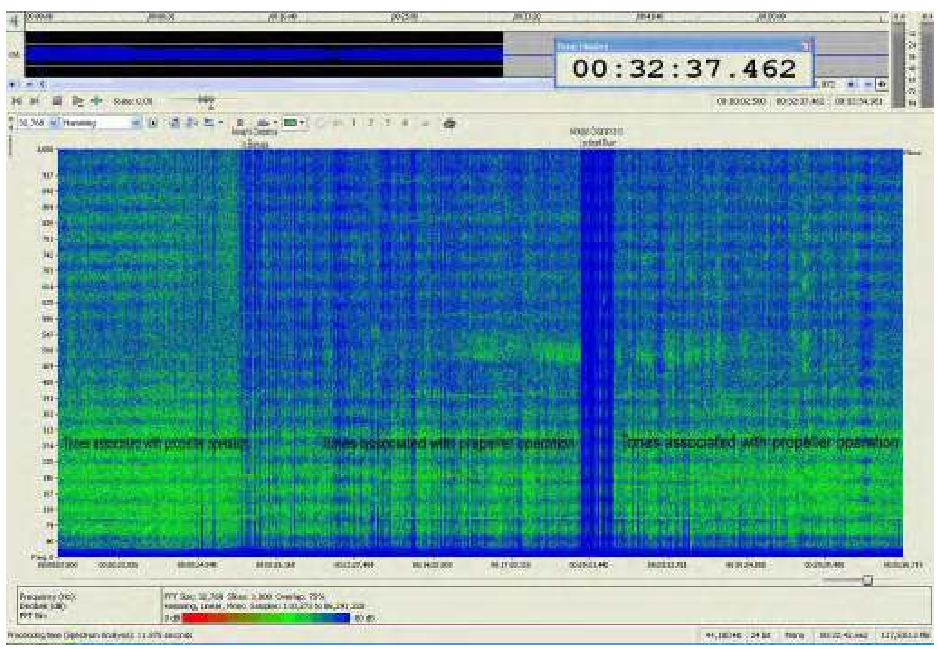
Audio2_01.wav recording contains several fragments of conversation. These fragments correlate with what appears to be public address announcements from the operating crew to the passengers that were also recorded in file Audio1_01.wav.

Audio3_01.wav recording contains information that indicates that the audio source was related to the CAM. This recording contains signals relating to propeller rotation. Crew conversation is also present; the conversations detected were recorded while the aircraft was on the ground with engines stopped. Engine operation generated sound levels that masked conversations. Figure B-14, is a spectrograph of the CAM recording. The frequencies associated with propeller operation are shown as bright lines running from left to right, the lowest frequency can be seen about half way between 79 and 118 on the frequency scale. The breaks in the lines indicate recording predominantly consisting of aircraft operation on the ground.

Audio4_01.wav recording contains information that indicates that the audio source was related to a flight crew position. This recording contains crew conversation, communication with air traffic control (ATC) and other aircraft. The speech recorded was similar in content with Audio1_01.wav, with some passages of conversation being easier to discern than others due to the relative amplitude. The conversations detected were fragmented, having several conversations interleaved or present at the same time. Also recorded was audio relating to the operation of pitch trim and activation of ground proximity warning system (GPWS) alerts.

The conversations recorded did not follow a logical sequence of operation of the aircraft. For example, the CVR twice recorded instances of the crew of VH-TFU requesting an airways clearance from Cairns ATC. The destination relating to one clearance was Lockhart River and the other Bamaga. Apart from the destination, the airways clearances issued were distinguished by the secondary surveillance radar (SSR) code allocated; 4351 for Lockhart River, and 4075 for Bamaga. The trip records for VH-TFU indicate that it would take about 1 hour 40 minutes to travel from Cairns to Bamaga or about 1 hour 30 minutes to travel to Lockhart River. The 30 minutes CVR duration would mean that the clearance conversation should have been overwritten.

Figure B-14: Spectrograph of Audio3_01.wav showing frequencies associated with propeller operation



The spectrograph gives a pictorial presentation of the fragmented recording with time presented on the x axis and frequency presented on the y axis. The colour provides a presentation of amplitude with red representing the highest amplitude (loudest) signals, while blue the lowest amplitude.

Identification of recording period

Records obtained from Airservices Australia indicated that on the 27 April 2005, VH-TFU operated from Cairns to Lockhart River and the SSR code of 4351 was allocated. On 3 May 2005, VH-TFU operated from Cairns to Bamaga and the SSR code of 4075 was allocated.

GPWS aural alerts detected from the CVR recording

The usual Metro 23 GPWS installation routes the aural alerts to the crew headsets and the cockpit speaker. The GPWS alerts detected in the recording from VH-TFU were contained in the crew channels indicating the aural alert was presented to the crew headsets. The audio may have been routed to the cockpit speaker, but may not have been detected in the CVR recording due to the propeller and aircraft operating sound levels generated while the aircraft was in flight.

GPWS alerts recorded were MINIMUMS (mode 6 GPWS alert), SINKRATE (mode 1 GPWS alert), DON'T SINK (mode 3 GPWS Alert), TOO LOW GEAR (Mode 4A GPWS alert), TOO LOW TERRAIN (Mode 4C GPWS alert), TOO LOW (mode 4 GPWS alert) and GLIDESLOPE (mode 5 GPWS Alert). The recording was also examined to determine the mode of flight when the GPWS annunciation occurred. Although the GPWS GLIDESLOPE alert recorded at 31:18 appeared to be recorded while the aircraft was on the ground, the actual mode of flight, when the GPWS alerts were recorded, could not be positively determined due to the interference and fragmented recording, see Table B-2.

Table B-2: GPWS alerts.

Elapsed time from beginning of file Audio4_01.wav **MM:SS**	**GPWS alert** **Note: annunciations in brackets were indistinct.**
01:53	MINIMUMS
02:56	SINK RATE
05:03	GLIDESLOPE
07:59	(TOO LOW)
08:09	TOO LOW (TERRAIN)
14:20	SINK RATE
14:23	SINK RATE
14:26	SINK RATE
15:54	TOO LOW GEAR
28:47	TOO LOW
28:59	TOO LOW (TERRAIN)
30:00	DON'T SINK
31:18	GLIDESLOPE (possible GPWS test recorded while aircraft was on ground)

GPWS Alert criteria

MINIMUMS – is an advisory callout annunciated when the aircraft has descended below the decision height selected on the radio altimeter by the flight crew.

SINKRATE – is an advisory callout annunciated when the aircraft exceeds a nominated rate of descent with reference to height above terrain.

DON'T SINK – is an advisory callout annunciated for significant altitude loss after takeoff , or, after a go around that has been executed below 200 ft above ground level (AGL) with gear or flaps in other than a landing configuration.

TOO LOW GEAR – is an advisory callout annunciated when the aircraft descends below 500 ft above terrain and slows below 190 kts airspeed, with the gear retracted.

TOO LOW – is annunciated for GPWS mode 4 alerts. The advisory is usually suffixed with 'gear', 'flaps' or 'terrain' to indicate the operating flight situation that warrants alert. While one complete annunciation was able to be heard, others were of low amplitude and indistinct. Also, it is considered that some of these annunciations may have been truncated either by the CVR fault condition becoming active or by being overwritten.

GLIDESLOPE – is an advisory alert annunciated for inadvertent descent below the glideslope beam during an instrument landing system (ILS) approach, with the gear down. The GLIDESLOPE alert may be activated if the aircraft is being flown on a visual approach, or in response to ATC vectors, which position the aircraft below the ILS glideslope beam.

Assessment of GPWS alert with respect to accident flight profile

To ascertain if the GPWS alerts that were detected, were related to the accident flight, the time of alert recording was compared with the recorded flight profile. As both the CVR and FDR power is controlled via 'g' switches, it is considered that the CVR would have ceased recording almost coincident with the FDR.

The duration of the CVR recording was about 32 minutes 35 seconds. The CVR elapsed time, with reference to the end of recording, was directly correlated with the FDR elapsed time with the end of CVR recording made coincident with the last recorded FDR data. The recorded FDR flight profile present when the GPWS audio alert was recorded on the CVR were compared with the Honeywell published GPWS activation parameters. The results of the comparison are seen in Table B-3.

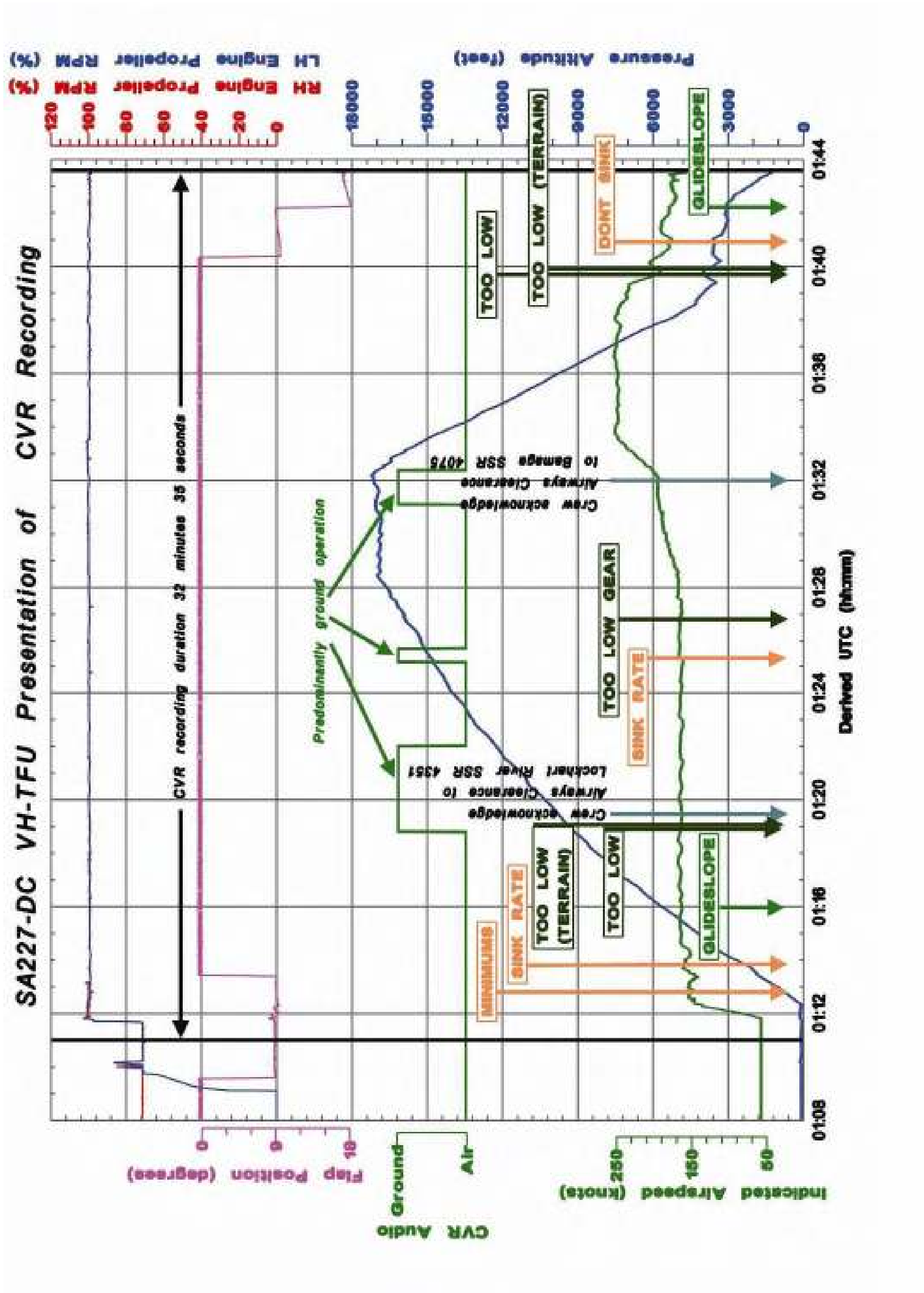
Table B-3: GPWS alerts recorded on the CVR correlated with the FDR data (the timebase was synchronised by aligning the data when the CVR and FDR ceased recording)

Annunciation	VH-TFU status from the FDR	Relevant to the Accident flight	Justification, based on Honeywell Mk-VI GPWS
MINIMUMS	Aircraft was climbing with positive rate of climb.	No.	VH-TFU was not descending and did not meet the Mode 6 GPWS criteria required to activate a mode 6 MINIMUMS annunciation.
SINKRATE	Aircraft was passing about 2,365 ft and was achieving a positive rate of climb of about 1,500 ft/min.	No.	VH-TFU was climbing and therefore did not meet the GPWS criteria required to activate a mode 1 SINKRATE annunciation.
GLIDESLOPE	Aircraft was passing about 5,613 ft , airspeed was recorded as 163 knots and maintaining a rate of climb of about 1,400 ft/min.	No	The flight profile of VH-TFU did not meet the GPWS criteria required to activate mode 5 GLIDESLOPE annunciation. The height AGL was greater than 925 ft, which is the upper radio altitude alert threshold.
TOO LOW	Aircraft was passing about 9,272 ft , airspeed was recorded as 165 knots and maintaining a rate of climb of about 1,100 ft/min.	No	The flight profile of VH-TFU did not meet the GPWS criteria required to activate mode 4 TOO LOW annunciation. The height AGL was greater than 750 ft, which is the upper radio altitude alert threshold.
TOO LOW (TERRAIN)	Aircraft was passing about 9,413 ft , airspeed was recorded as 164 knots and maintaining a rate of climb of about 1,100 ft/min.	No	The flight profile of VH-TFU did not meet the GPWS criteria required to activate mode 4 TOO LOW annunciation. The height AGL was greater than 750 ft, which is the upper radio altitude alert threshold.
SINKRATE, SINKRATE, SINKRATE (the three annunciations were spaced 3 seconds indicating there was one GPWS alert activation)	Aircraft was passing about 14,800 ft and was achieving a positive rate of climb.	No	VH-TFU was climbing and therefore did not meet the GPWS criteria required to activate a mode 1 SINKRATE annunciation.

Annunciation	VH-TFU status from the FDR	Relevant to the Accident flight	Justification, based on Honeywell Mk-VI GPWS
TOO LOW GEAR	Aircraft was climbing through 15,897 ft, airspeed was 166 kts and maintaining a rate of climb of about 700 ft/min.	No.	The flight profile of VH-TFU did not meet the GPWS criteria required to activate mode 4A TOO LOW GEAR annunciation. The height AGL was greater than 750 ft, which is the upper radio altitude alert threshold.
TOO LOW	Aircraft was climbing through about 3,992 ft. Indicated airspeed was recorded as 195 kts.	No.	The flight profile of VH-TFU did not meet the GPWS criteria required to activate mode 4 TOO LOW annunciation. The height AGL was greater than 750 ft, which is the upper radio altitude alert threshold.
TOO LOW (TERRAIN)	Aircraft was climbing through about 3,852 ft. Indicated airspeed was recorded as 197 kts	No	The flight profile of VH-TFU did not meet the Mode 4 GPWS criteria required to activate a mode 4 'TOO LOW' annunciation. Further evidence was provided by conversation flanking this, and the previous, TOO LOW annunciation that indicated the recording was made when the aircraft was operating in airspace controlled by ATC.
DON'T SINK	The aircraft was passing over terrain which would have provided clearance in excess of 1,000 feet AGL	No	The flight profile of VH-TFU did not meet the GPWS criteria required to activate mode 3 DON'T SINK annunciation. The height AGL was greater than 925 ft, which is the upper radio altitude alert threshold.
GLIDESLOPE	The approach to Lockhart River is not equipped with an ILS	No	Further evidence is provided by information recorded on the area microphone which indicated that it was possible that the aircraft was on the ground when the alert was recorded.

A synopsis of significant events detected on the CVR and overlaid with FDR data, is presented in pictorial form as Figure B-15. The presentation also indicates areas detected during the recording where the aircraft was predominantly on the ground.

Figure B-15: Synopsis of significant events recorded by CVR and FDR



Examination of the CVR by flight recorder specialists of the Air Accident Investigation Branch

On 21 September 2005, a digital CDROM copy of the CVR recording was delivered to the Air Accident Investigation Branch (AAIB) in the UK for examination by their flight recorder specialists.

An AAIB flight recorder specialist evaluated the audio supplied and offered an opinion that has been paraphrased below:

Three CDs of the audio recovered from the CVR were made available for further analysis at the Air Accidents Investigation Branch, UK. Two of the CDs contained digitised files of the raw recordings whilst the third was a copy with some audio enhancements applied.

From an initial assessment of all four channels of the CVR it was apparent that the recorded audio was of very poor quality. Present on each channel were very large numbers of noise spikes which rendered most speech unintelligible. Also, from previous analysis by ATSB and an assessment of the area microphone channel recording (with particular regard to powerplant and propeller frequencies), it was apparent that the audio appeared to contain two (or more), separate recordings which were interleaved. It is possible that a rapid switching between record and replay mode of operation may have exhibited similar characteristics. Due to this interleaving, it was deemed impractical to attempt any analysis of push-to-talk and radio transmissions.

From a further analysis of the noise spikes, it was observed that there was a greater concentration when the aircraft engines were operating, adding credence to the theory that the CVR fault was related to vibration level and hence may be attributable to a loose connection or bad solder joint.

Previous MagnaSee analysis by ATSB showed that, in some cases, the noise spike was recorded across the entire width of the tape and in others, it was limited to the track area covered by the pole pieces of either the record or monitor head. A full width noise spike could only have been induced by operation of the erase head. From a relatively quiet section of the recording it was determined that, although random in occurrence, there was a definite grouping (in groups of three) associated with the spikes. Present were an initial spike and then, 307 milliseconds later, a second spike. The third occurred 23 milliseconds after the second. An analysis of physical separation of the erase, recording and monitoring heads on an identical tape transport showed no correlation with these timings. This lack of correlation assumed that the tape had been recorded at 1⅞ in/s, the standard operating tape speed. No evidence was found that the tape had been recorded at an incorrect speed.

It is recommended that ATSB conduct further analysis of this spike grouping with regard to full width or track width only in order to further understand the failure mechanism[35]. It is likely that the fault lay within the power supply circuitry which encompasses the switching of the erase and record heads.

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35 The spike grouping was examined at several points during the recording and no characteristic pattern or attributes of the spikes could be determined. See section 1.6.1

Examination by Flight Recorder specialists of the National Transportation Safety Board

On 23 September 2005 a digital CDROM copy of the CVR recording was carried to the National Transportation Safety Board (NTSB), Office of Research and Engineering in the United States of America for examination by their Vehicle Recorder National Resource Specialist.

An NTSB vehicle recorder specialist evaluated the audio supplied and offered an opinion that the ATSB recorder specialists had correctly identified the possible failure modes. The analysis of possible CVR failure modes are contained in section 2.2.

Examination of the CVR by L-3 Communications Aviation Recorders specialists

On 16 June 2006, a digital CDROM copy of the CVR recording was freighted to the NTSB in the USA, for on-forwarding to L-3 Communications Aviation Recorders. L-3 Communications are the manufacturers of the model A100A recorder and their opinion regarding the possible failure modes was sought.

L-3 Communications Aviation Recorders engineers evaluated the audio data supplied and offered an opinion that has been paraphrased below:

There was a failure of the CVR Bias Generator circuit card which resulted in the unintelligible audio recording on all four channels. The Bias Generator circuit provides the record bias signal to each of the four Record Amplifier circuit cards as well as the erase head. It is also possible that an intermittent power input to the Bias Generator circuit card could have resulted in the same anomaly.

Unfortunately, due to the fire damage, it is not possible to test the circuit to determine the actual cause of the problem.

However, since the Bias Generator circuit provides the record bias signal to each of the four Record Amplifier circuit cards as well as the erase head, it is the most likely cause of the anomaly that was observed.

In either case, the failure would have been easy to detect, even with a casual evaluation of the real time CVR monitor audio output or with the CVR 'push-to-test' activation. In the case of the 'push-to-test' activation, the test meter indication (needle deflection) would have been intermittent rather than continuous.

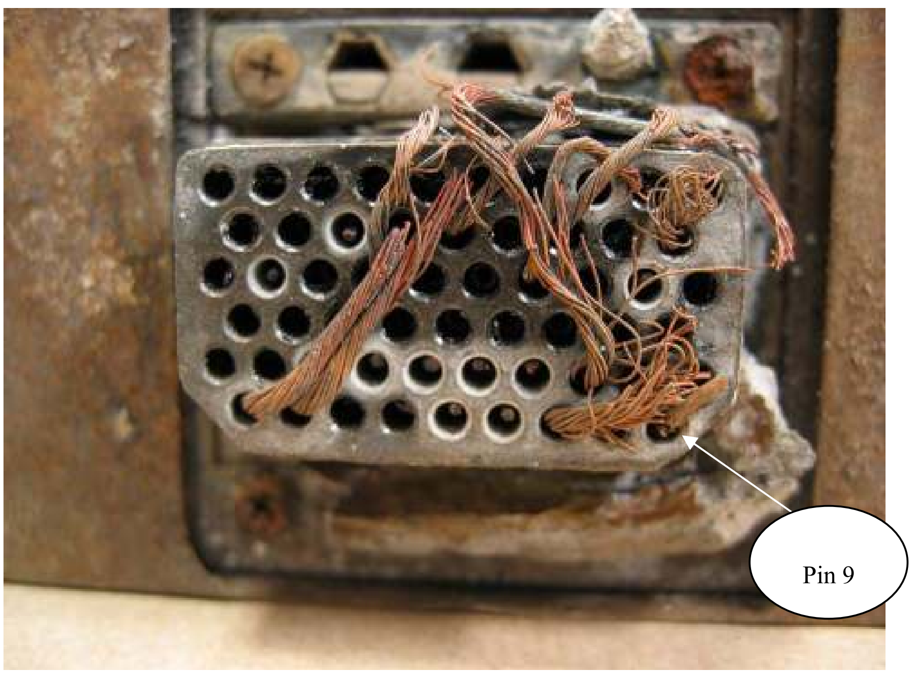
Physical examination of CVR

On the 8 May 2006, a physical examination of the CVR was begun to ascertain any physical evidence of electrical or mechanical malfunction.

Aircraft Interface connector

The aircraft interface connector fitted to the CVR unit was examined. A photograph of the rear of the connector is included as Figure B-16. The photograph shows the rear of the connector, part number DPXB-57-33S-0001, fitted to the rack that holds the CVR in the aircraft. This connector mates with plug (P1), p/n DPXB-57-34P-0101, at the rear of the CVR. The remnants of wiring and pins, still fitted to the connector, conform to the interwiring shown in L-3 Communications Aviation Recorders Component Maintenance Manual (CMM), p/n 165E101-00, page 125, interwiring diagram regarding CVR units model A100, A100A.

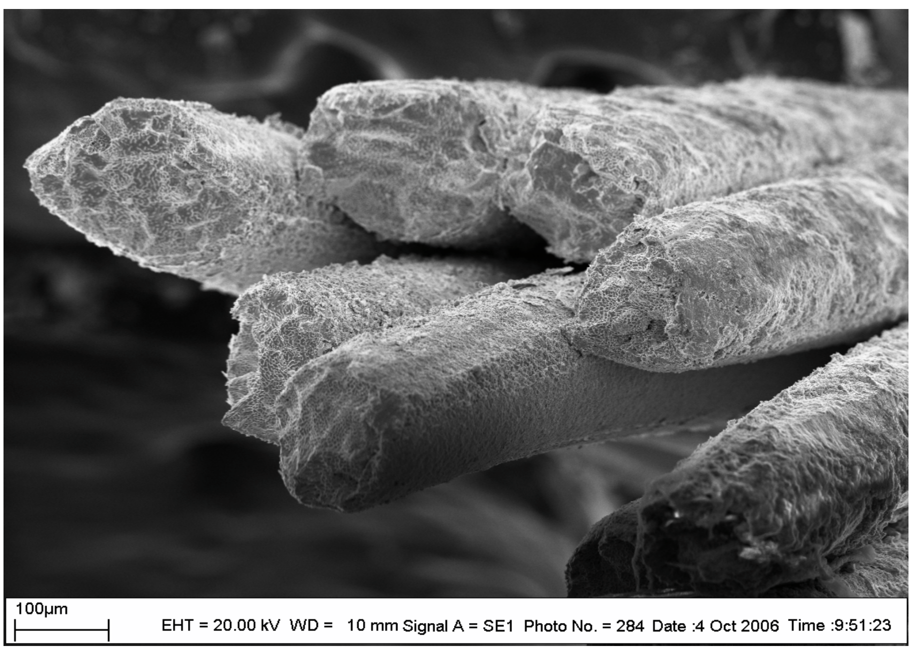
Figure B-16: Photograph of VH-TFU CVR unit aircraft interface connector



Examination of the wire strands showed they had failed in overload and exhibited ductile 'necking' and a crystalline fracture surface, as shown in Figure B-17. A similar characteristic was exhibited by the broken strands of the wire connecting to pin 9, the connection to the aircraft 27.5 V d.c. power supply. A close up photograph is shown in figure 18.

Figure B-17: Photograph of aircraft interface connector wire strand ductile unpowered fracture

Figure B-18: Highly magnified electron microscope image of wire strands connected to pin 9 of the aircraft interface connector



If electrical power had been present at the time the wire strands parted, the strands would exhibit a smooth surface formed by the copper melting due to heating from electrical arcing as the wire strands separate. The absence of electrical arcing indicates that d.c. power had not been present to the CVR unit when the wire strands parted, probably due to operation of the ‘g’ switch.

CVR unit printed circuit assemblies and wiring

The location and complement of assemblies present were documented. The connection of wiring to assemblies was also examined.

The CVR had been subjected to intense heat. This resulted in the solder, found at wiring connections and printed circuit assemblies, having been melted, running from the connection, and in some instances having the appearance of having been boiled and oxidised.

The printed circuit assemblies had parts of the interconnecting copper foil missing. Heat had affected the base substrate, in this case fibreglass. In places, the epoxy resin in the board had evaporated, exposing the layers of glass fibre mat.

Figures 19 through 27 show the extent the CVR unit was affected by heat and fire. The integrity of the printed circuit assemblies and the CVR unit interwiring could not be determined due to the damage.

Location and type of boards

Fairchild A100A CVR serial number 60652 was fitted with a full complement of assemblies including a d.c. to a.c. inverter. The identification and part numbers of the boards fitted to the CVR unit is included in Table B-4.

Table B-4: CVR printed circuit card assembly fitment

<table>
<tr><th>Description of Assembly</th><th>Part Number</th><th>Fitted to CVR from VH-TFU</th></tr>
<tr><td>(as prescribed by L-3 Aviation Recorders CMM)</td><td>(as prescribed by L-3 Aviation Recorders CMM)</td><td></td></tr>
<tr><td>Record Amplifier</td><td>9300A020</td><td rowspan="10">No part number or serial number was found due to heat damage. Assembly identified by shape and position of components</td></tr>
<tr><td>Record Amplifier</td><td>9300A020</td></tr>
<tr><td>Record Amplifier</td><td>9300A020</td></tr>
<tr><td>Record Amplifier</td><td>9300A020</td></tr>
<tr><td>Bias Generator</td><td>9300A021</td></tr>
<tr><td>Power Supply</td><td>205E0527-xx</td></tr>
<tr><td>Bulk Erase Timing</td><td>9300A024</td></tr>
<tr><td>Monitor Amplifier</td><td>9300A023</td></tr>
<tr><td>Test Circuit</td><td>9300A025-02</td></tr>
<tr><td>Timer</td><td>9300A098</td></tr>
<tr><td>Inverter</td><td>9300A140-02</td><td>9300A140-02 serial number 05044 (punched into plate fixed to inverter)</td></tr>
</table>

Figure B-19: VH-TFU CVR printed circuit card assemblies

Figure B-20: Serviceable Fairchild A100A, s/n 55233, CVR printed circuit card assemblies

Figure B-21: VH-TFU CVR printed circuit card assembly wiring

Figure B-22: Serviceable Fairchild A100A, s/n 55233, CVR printed circuit card assembly wiring

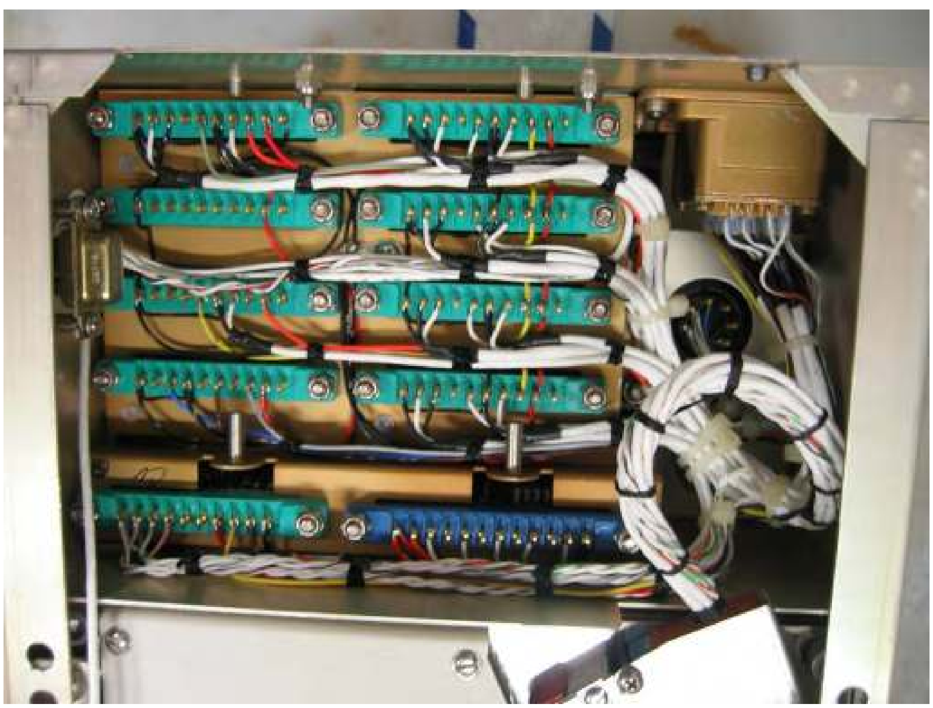


Figure B-23: VH-TFU power supply assembly

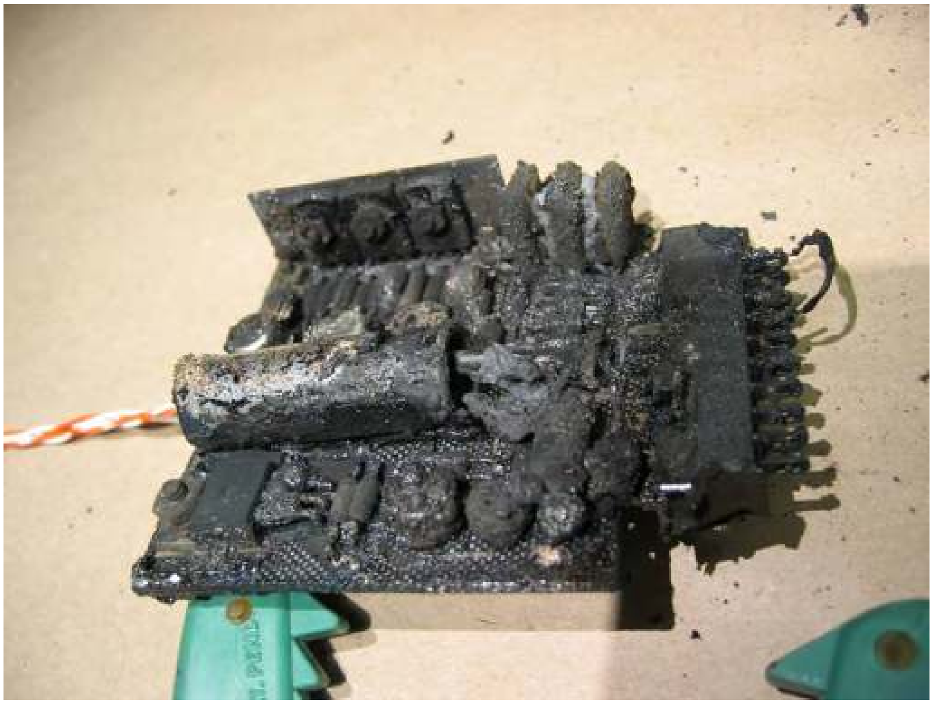


Figure B-24: Serviceable power supply card

Figure B-25: VH-TFU bias oscillator assembly

Figure B-26: Serviceable bias oscillator assembly

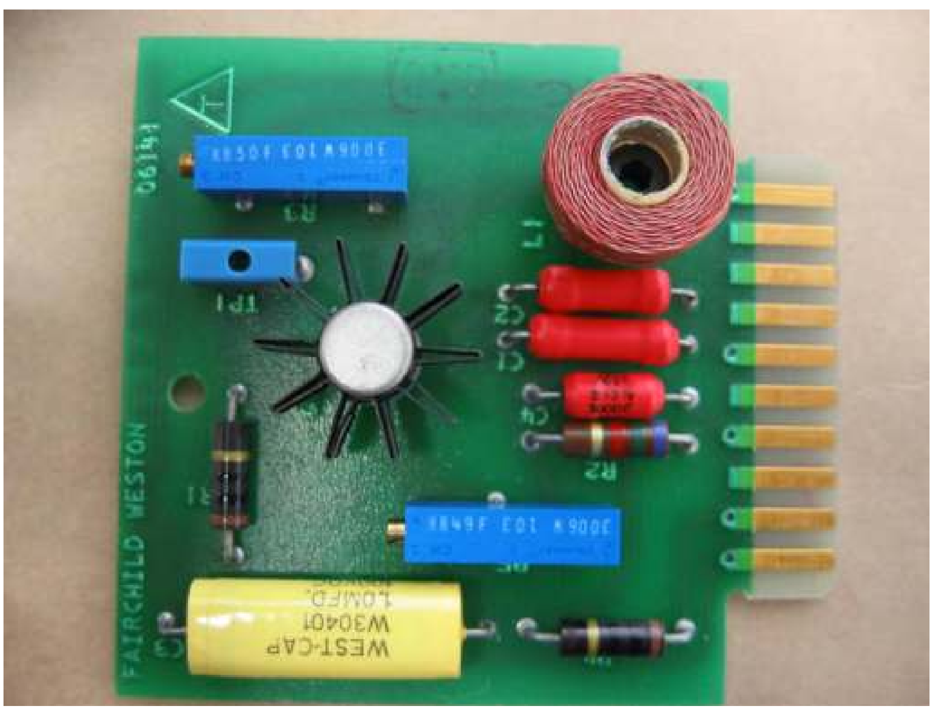


Figure B-27: VH-TFU CVR inverter assembly

CVR system integrity checks

A summary of maintenance checks for the CVR system as recommended by manufacturers, regulators and international aviation bodies, is included as Table B-5. The details of the summary can be found in the following paragraphs 1.8.1 to 1.8.5.

Table B-5: CVR system integrity checks

Organisation	Pre-Flight Check	Post Installation	System verification
Australian Civil Aviation Safety Authority (CASA)	None specifically prescribed	Advisory CAAP42L-7 This CAAP provides guidance for the maintenance of CVR systems and maintenance personnel who may be required to carry out a functional check on the CVR.	AD/REC/1 - accomplished 12mthly Advisory CAAP42L-7 is more comprehensive
M-7 Aerospace	Airplane Flight Manual checklist item – accomplished prior to each flight	Aircraft Maintenance Manual – accomplished on fitment of system component	Aircraft Maintenance Manual for alternative model CVR – accomplished in accordance with component manufacturer recommendation
L-3 Communications Aviation Recorders	Installation/ Operation Manual and component Maintenance Manual - accomplished prior to each flight	Installation/ Operation Manual and component Maintenance Manual – accomplished following work on associated system or fitment of component	Installation/ Operation Manual and component Maintenance Manual – accomplished during annual inspection of aircraft
Aircraft Operator	Not included in Operator's aircraft checklist items	Procedure not ascertained	AD/REC/1 – accomplished annually (last done 16 June 2004) M-7 Aerospace airplane flight manual Section 2 CVR check – performed at 170 hr intervals (last done 17 April 2005)
ICAO	Annex 6 Pt 1 Att D section3 Aural or visual means to check system to be utilised - accomplished prior to each flight	None specifically published however Section 6.3 contains a reference to EUROCAE standards for CVR system which requires post installation check	Annex 6 Pt 1 Att D section3 – accomplished annually

Civil Aviation Safety Authority mandated and advisory procedures

Pre-flight Check

None prescribed

CVR system

Airworthiness Directive - AD/REC/1 published September 1988

Civil Aviation Safety Authority (CASA) airworthiness directive AD/REC/1, Maintenance of CVR Systems, dated 09/88, requires a check and functional test of all CVR systems installed in compliance with Civil Aviation Order (CAO) part 20, section 20.18.

The check is required to confirm the proper recording of all required CAO 103.20 audio inputs for each voice channel, the proper functioning of the bulk erase inhibit logic, operation of crash sensor switches and maintain the underwater locating device, if fitted.

The check is required to be performed at intervals not exceeding twelve months or 2,000 hours time in service, whichever occurs first.

Civil Aviation Advisory Publication (CAAP) 42L-7 (0) CVR Maintenance published October 2002.

> This CAAP provides guidance for:
>
> Maintenance of Cockpit Voice Recorder Systems (CVR).
>
> Maintenance personnel who may be required to carry out a functional check on the CVR where the instructions for continued airworthiness (ICA) are not provided in the aircraft maintenance manual or a Supplemental Type Certificate (STC), or approved modification.
>
> Maintenance personnel who may be required to carry out a functional check on the CVR where the instructions contained in the maintenance manual are inadequate or deficient. (*Note: it is not the intent of this advisory material to supersede aircraft manufacturer's maintenance instructions but to complement them)*
>
> This CAAP does not provide advice or standards for the installation of a CVR, however the contents of this CAAP should be considered when preparing the ICA for a new installation.

Civil Aviation Advisory Publications (CAAPs) provide guidance and information in a designated subject area, or show a method acceptable to an authorised person or CASA for complying with a related Civil Aviation Regulation. CASA advise that CAAPs should always be read in conjunction with the referenced regulations.

M7 Aerospace recommended procedures

Pre-flight Check

The M-7 Aerospace 'Fairchild Pilots Flight Checklist SA227-D.C.'Airplane Flight Manual (AFM) document number 6D.C.-CL Revision: May 11/99 'Normal Procedures' page N-3 contains checklist actions to test the CVR system.

> 'Before Taxi' checklist item 4 specifies FDR/CVR (if installed)…..check

The procedure for the CVR system check is contained in Section 2 'System Check and Operation' of the SA227-D.C., AFM, document number 6D.C. revision Dec 02/97 page 2-24.

FDR/CVR

> 'If these items are installed, the following checks should be accomplished prior to engine start:'
>
> Item 4 specifies; CVR Test Button……Press and Hold 5 seconds minimum
>
> Item 5 specifies; CVR Meter…………..Check Pointer in Green Band

An additional Note is included:

> Additional assurance of proper CVR operation may be obtained by inserting a headphone plug into the jack on the CVR control panel and listening to the test tone and four cycle clicks. Whenever a headset is plugged into the CVR control panel, a composite playback of all four channels will be heard in the headset (with a ¼ second delay).

CVR system

The M-7 Aerospace maintenance manual, P/N 27-10054-133 Revision: 43, Feb 01 2005, recommends maintenance of CVR systems fitted to the aircraft.

Time limits for maintenance to be performed are contained in chapter 5, section 10 (ATA 05-10-00) page 202 'Time Limits – Maint Practices'. The manual lists two models of CVR that may be installed, model A100 is manufactured by L-3 Communications Aviation Recorders (L-3AR) and model 89090 is manufactured by B&D Instruments and Avionics.

Figure B-28 contains an extract from the maintenance manual. Of note is the difference in action required for each model CVR. An audio system check is specified when a B&D Instruments CVR is fitted, however not when an L-3AR CVR is fitted.

Figure B-28: extract from M-7 Aerospace Maintenance Manual ATA 05-10-00 page 202

SA227 SERIES
COMMUTER CATEGORY

MAINTENANCE MANUAL

TIME LIMITS – MAINTENANCE PRACTICES

PART NUMBER	PART NAME	ACTION	INTERVAL
	(CHAPTER 23 – COMMUNICATIONS – CONTINUED)		
A100	Cockpit Voice Recorder	Overhaul	Refer to Manufactures Recommendations.
89090	Cockpit Voice Recorder (B & D)	Audio System Check Replace Tape Overhaul	Refer to Manufactures Recommendations

Chapter 23, section 70, contains maintenance instructions regarding audio and video monitoring systems. This includes the CVR system.

ATA23-70-10 contains instructions regarding maintenance of the CVR system. Page 201, paragraph 2, specifies actions and equipment to carry out maintenance for 'adjustment/test – audio and video monitoring'.

Subparagraph A lists equipment required for test of the B&D Instruments model 89090 CVR but no equivalent instructions for the L-3 Communications A100/A100A CVR.

Subparagraph B contains instructions for a post installation check-out procedure that may be applied to either model CVR system.

Subparagraph C contains instructions for audio system verification. These instructions appear to be only able to be carried out for a B&D Instruments model 89090 CVR as the installation of a replay card, as specified in subparagraph A is required. However, no equivalent instructions are provided regarding the L-3 Communications Aviation Recorders model A100A CVR.

It should be noted that the L-3 Communications Component Maintenance Manual (CMM), page 905, contains instructions on how to perform;

> 'Playback of information recorded on individual channel using the record head monitor board (205-E0319-00)',

This is functionally the same audio system verification check as detailed for the B&D Instruments model 89090 CVR in the previous paragraph.

L-3 Communications Aviation Recorders recommended maintenance

Pre-flight Check

A procedure is contained in L-3 Communications Aviation Recorders Installation and Operation Instruction Manual for the model A100/A100A cockpit voice recorder unit.

Section 4 - Operation Tests

Subparagraph 4.1 Pre-Flight Functional Check.

> The Pre-flight Functional Check assures the operator that the equipment is serviceable. Therefore, it is to be performed before every flight or whenever maintenance has been performed on the aircraft or rotorcraft which may have affected the performance of the CVR or its associated Audio System interface, accessories, or components.

CVR system

The current L-3 Communications Aviation Recorders CMM for the model A100/A100A CVR unit, control unit and microphone module, is part number: 165E0101-00 Rev3, dated Mar 04.

The overhaul period for the CVR unit is specified as 4,000 operating hours (non-flight hours), (page 301 of the CMM). The non-flight hours proviso is to take into account the difference in practice between logging airframe operating hours, while the aircraft is airborne, and component operating hours. The CVR unit usually begins to operate prior to pre-start check lists and may continue to operate even when the aircraft is parked.

Page 905 and 906 of the CMM contains instructions on how to perform 'Playback of information recorded on an individual channel using the record head monitor board (205-E0319-00)'.

Instruction regarding the installation and operation of the model A100/A100A CVR is contained in a document titled Installation & Operation Instruction Manual, p/n: 165E2807-00 Revision 02, dated July 01/02.

Section 4 Operation Tests, specifies the time and procedures for checks that verify the correct function of the CVR system. The following are extracts from the manual.

Subparagraph 4.1 Pre-Flight Functional Check.

> The Pre-flight Functional Check assures the operator that the equipment is serviceable. Therefore, it is to be performed before every flight or whenever maintenance has been performed on the aircraft or rotorcraft which may have affected the performance of the Cockpit Voice Recorder or it's associated Audio System interface, accessories, or components.

Subparagraph 4.2 Complete Audio System Test

> A complete Audio System Interface test must be completed during each annual inspection or specified maintenance period on the aircraft or rotorcraft and whenever unscheduled maintenance is performed on the aircraft or rotorcraft which may have affected the performance of the Cockpit Voice Recorder system. To accomplish this test, the Pilot's, Co-pilot's, Cockpit Area Microphone, and Third Crew member or Public Address System inputs must be individually checked for their operational integrity with the Cockpit Voice Recorder. Upon satisfactory achievement of this test, an entry shall be made in the maintenance records of the aircraft or rotorcraft.

Aircraft Operator operational and maintenance procedures

Pre-Flight Check

Aircraft Operator SA227 Quick Reference Handbook Version 1.0-01/03/01 page 1 and 2, contained Pre-start, After-start, Pre-takeoff and Line-up checklist items. A check of the CVR system was not included.

Unserviceable CVRs discovered following the accident.

Following a test by the operator, after the accident, of the CVR system by activating the TEST button on the CVR control unit, two CVR units were found to be unserviceable. A further aircraft was tested by activating the TEST button and passed. It was reported that the unserviceable units had been detected using the M-7 Aerospace Airplane Flight Manual (AFM) method.

The operator subsequently issued a NOTAC[36] No: C17, dated 28/07/05: Test Procedure for CVR and FDR. The NOTAC mentioned that crews had not been testing the CVR and FDR prior to flight and directed aircrews to test the units prior to each flight, and to use the AFM for guidance. The NOTAC indicated that the pre-flight checklist would be amended to include a functional test of the CVR and FDR. The operator reported that revision two of the pre-flight checklist was issued on 20 September 2006 which included a test of the CVR and FDR system.

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36 Notice to aircrew.

The ATSB found that CASA airworthiness directive AD/REC/1 was carried out by Hawker Pacific Pty Ltd Cairns on the 16 June 2004 and no system defects were recorded. Also the CVR system check detailed in M-7 Aerospace airplane flight manual had been carried out at 170 hour intervals. The last check was made during the phase inspection on 17 April 2005, at that time the CVR system was certified as being serviceable. However the ground check may not have revealed the underlying problem that was more prevalent during flight.

International Civil Aviation Organisation (ICAO) recommended procedures

ICAO International Standards and Recommended Practices Annex 6 Operation of Aircraft Part 1 International Commercial Air Transport – Aeroplanes, Attachment D. Flight Recorders, eighth edition July 2001

Section 2 CVR, Section 2.1 General Requirements, subparagraph 2.1.4. The CVR is to be installed so that:

> c) there is an aural or visual means for pre-flight checking of the CVR for proper operation

Section 3 Inspections of FDR and CVR systems

> 3.1 Prior to the first flight of the day, the built-in test features on the flight deck for the CVR, FDR and Flight Data Acquisition Unit (FDAU), when installed should be monitored.
>
> 3.2 Annual inspections should be carried out as follows:
>
> a) the readout of the recorded data from the FDR and CVR should ensure the recorder operates correctly for the nominal duration of the recording;
>
> e) an annual examination of the recorded signal on the CVR should be carried out by re-play of the CVR recording. While installed in the aircraft, the CVR should record test signals from each aircraft source and from relevant external sources to ensure that all required signals meet intelligibility standards; and
>
> f) where practicable, during the annual examination, a sample of in-flight recordings of the CVR should be examined for evidence that the intelligibility of the signal is acceptable.

APPENDIX B   ANALYSIS

Specialist examination of the CVR unit and recording, by the ATSB and international equivalent agencies, found that a fault, that had not been discovered or diagnosed by the flight crew, had been present in the CVR unit, at least since the 27 April, and had stopped the unit from functioning as intended. As a consequence, the recorded data contained fragments of audio, other noises and pulsed interference signals. Other than conversation relating to the airways clearance issued on the 27 April and the 4 May 2005, the date of the recordings, or relevance to the accident, could not be determined.

Audio recovered from CVR

The audio recorded by the CVR unit was fragmented with conversations having been overwritten and interleaved with multiple conversations present at the same time. In addition, the recording did not follow a logical sequence of sounds consistent with the last 30 minutes of the recorded flight. High amplitude, short duration interference, pulses or 'spikes' were present throughout the recording.

The conversations did not follow a logical sequence of operation of the aircraft. The 30 minutes CVR duration would mean that the conversation relating to the issue of an airways clearance at Cairns should be overwritten; the presence of the recording of an airways clearance indicated a fault had developed in the CVR unit.

The four channels of recovered audio appear to correspond with L-3 channel allocation and physical track allocation on tape. Actual crew position recorded on a specific track could not be determined.

GPWS provided aural alert functions. The GPWS alerts detected in the recording from VH-TFU were contained in the crew channels indicating the aural alert was presented to the crew headsets. The GPWS aural alerts were compared with the accident flight profile recorded by the FDR and it was considered the alert activation and recording was not related to the accident flight. The activation of the pitch trim aural alert was also recorded.

The recording of the aural alerts indicated that the alerts were functioning when the recording was made. However, it could not be determined when that occurred.

In the recovered passages of conversation, there was a record of the crew performing checklist items, communicating with ATC by providing position reports on VHF and HF radio equipment, requesting airways clearances when on the ground, communicating with other aircraft, and making mandatory broadcast zone transmissions. The content of the recovered conversations did not indicate that the crews had any concerns with the aircraft equipment.

Records obtained from Airservices Australia indicated that on the 27 April 2005, the crew of VH-TFU obtained an airways clearance to operate from Cairns to Lockhart River, the SSR code of 4351 was allocated by ATC. The Airservices records also indicate on the 3 May 2005, the crew of VH-TFU obtained an airways clearance to operate from Cairns to Bamaga and the SSR code of 4075 was allocated by ATC. The airways clearance and SSR code correlates with both airways clearance conversations recovered from the CVR.

No audio recovered from the CVR recording could be confirmed as having been recorded during the accident flight.

Possible CVR failure mode

The CVR recording exhibited a number of non-standard characteristics. Listed below are those characteristics and a possible explanation. To assist with the understanding of the interconnection of the major components, a simplified block diagram of the model A100A CVR unit is shown in Figure B-29.

- The fragmented audio indicates record mode being turned on and off, possibly as a result of an interrupted power supply to the record amplifiers.
- There are passages where there is no recorded signal on crew channels, but there is signal present on the CAM channel. This indicates that power was available to at least the CAM record amplifier. There are four record amplifiers.
- The random spikes in amplitude and frequency had a consistently high transient response that was more predominant when the aircraft was moving. This indicates the possibility of an intermittent electrical connection.
- The spikes present across the full width of the tape (seen with Magnasee), indicates that the signal was impressed on the tape from the erase head pole piece. The presence of spikes on individual tracks, indicate that the signal was impressed on the tape from the record head pole pieces. Both signals are present at different times. This indicates a possible failure of the output of the Bias Oscillator.[37]
- The overwritten and interleaved audio indicates multiple passes either with intermittent or no erasure. The record amplifiers and tape transport motor drive need to be operating (a.c. electrical power needed) and the Bias Oscillator not working properly, for this to occur.
- The erase function was provided by the Bias Oscillator signal and applied to the erase head. The section of erased tape from the CVR indicates the Bias Oscillator was functioning and energising the erase head when the CVR stopped. The Bias Oscillator signal is common to both the record path and the erase path.

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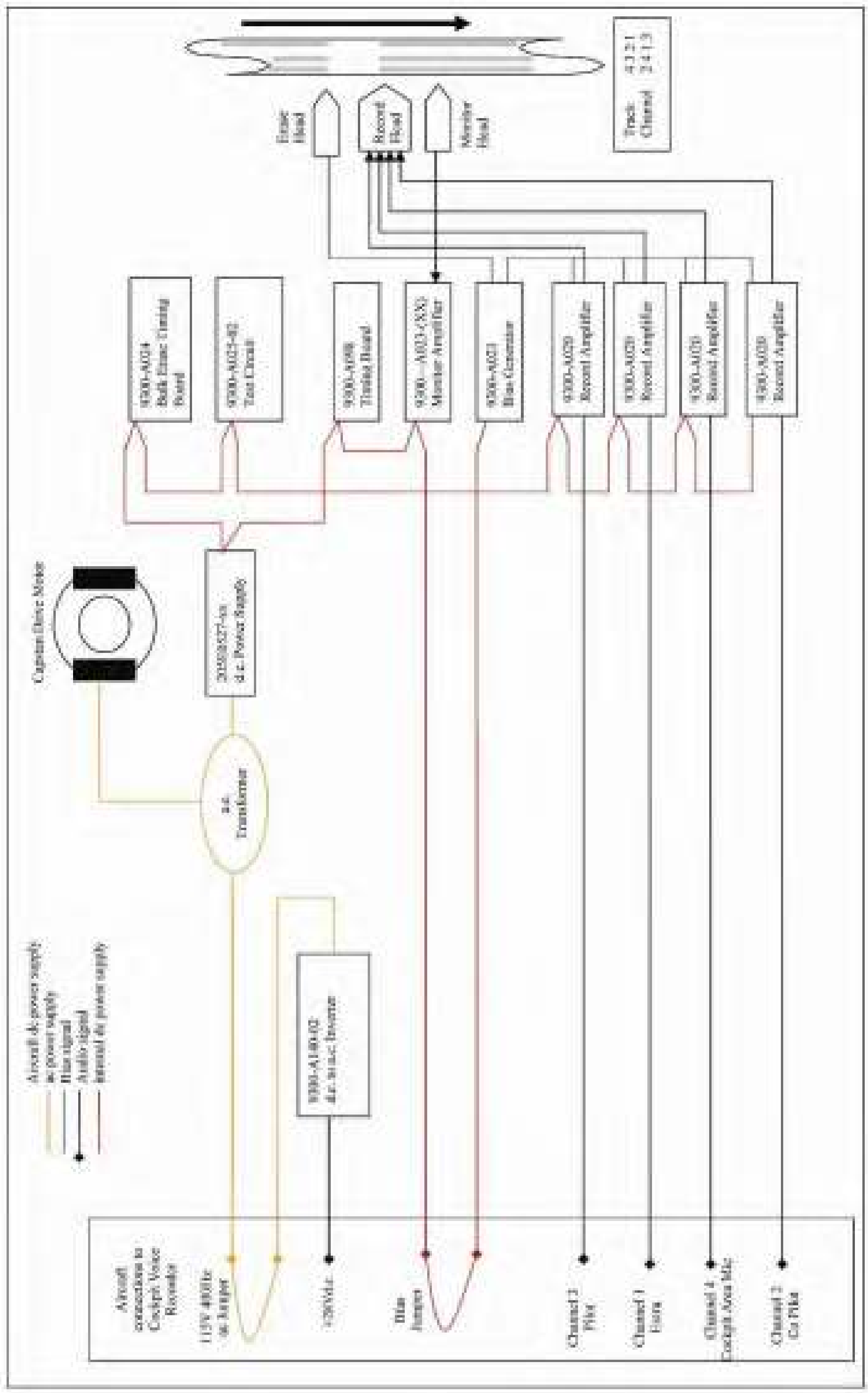
37 The Bias Oscillator card provides the electrical signal to the record amplifier and to the erase head via discrete connections.

Figure B-29: Simplified block diagram of the power supply and input signal electrical paths



Detection of the fault by recommended maintenance actions

Pre-Flight Functional Check

Civil aviation regulation 138 states, in part, that the pilot is to comply with instructions or procedures set out in the aircraft flight manual.

The M7 flight manual and L-3 installation and operation manual relies on the deflection of a meter movement across a scale to indicate a ‘go’ or ‘no-go’ condition.

The M-7 flight manual instructs the crew to observe the pointer in the green band. However, the L-3 installation and operation manual describes the pointer rising into the green band as giving more of an oscillating action while switching between channels.

The presence of the interference signal would not be readily apparent to the crew as the interference signal spike would be masked by the oscillating action of the pointer during the test sequence. Although it is included as a note in the M-7 flight manual, crew are not required to listen to the audio via the control panel monitor jack. Thus, an opportunity to detect the presence of the interference spikes and fragmented audio may not have been utilised. Also limiting detection was the characteristic of the spikes not being as prevalent when the aircraft was parked.

L-3 Complete Audio System Test

The test is performed by listening to audio from each of the cockpit microphones at the control unit headset jack, also a recommended procedure by M-7 Aerospace.

The recording from VH-TFU had passages several seconds long where the audio was recorded in a normal manner.

This test would be more likely to detect the fault in the CVR fitted to VH-TFU than the pre-flight test detailed in the M7 flight manual. However, the random sound generated by the presence of the spike may be interpreted as induced random system noise and disregarded by the person monitoring the audio. The intermittent nature of the fault, coupled with the short duration of spoken voice, may appear to provide a satisfactory test sequence and confirm the unit as being serviceable, when in fact it isn’t.

M-7 Audio system verification

This test is quite comprehensive and requires the recording of audio from each cockpit microphone. The recommended duration of two minutes recording on each track is of adequate length to allow an objective assessment of the recorder’s functional status.

This test would detect a fault of the type present in the CVR from VH-TFU. The recording duration would capture many instances of the interference signal showing that it was a repetitive event and should not be ignored. The recording duration specified would also have been adequate to detect the fragmented speech.

Operator pre-flight check

The aircraft pre-flight checklist did not include a functional test of the CVR or FDR. The NOTAC issued after the accident, directed crews to test the CVR and FDR prior to a flight. It is probable that the crew of VH-TFU did not test the CVR prior to the flight, as it was not included in the checklist.

Tape medium CVR unit obsolescence

The L-3 Communications Aviation Recorders (L-3AR) model A100/A100A CVR, was introduced to field service in 1966. In 1999, L-3AR advised all known users of the impending obsolescence of the reel tape and other overhaul and replacement parts. This was again reiterated by L-3AR in 2004 at the Aeronautical Radio Incorporated (ARINC) Avionics Maintenance Conference.

In Service Letter No. 2754, dated 12 March 1998, Universal Avionics Systems Corporation advised that their model CVR-80 CVR unit can no longer be repaired or overhauled due to parts which are unique and no longer procurable.

Both the L-3AR model A100/A100A and the Universal CVR-80 CVR unit is manufactured to Federal Aviation Administration (FAA) Technical Standard Order (TSO) C84 for CVR. The TSO specifies colour, form factor, generic functionality and crashworthiness. This TSO was cancelled by the FAA in May 1996.

In 1988, a working group comprising of regulatory and certifying authorities, aircraft manufacturers, aircraft operators and accident investigation specialists, convened under the auspices of the European Organisation for Civil Aviation Equipment (EUROCAE). EUROCAE developed a document, ED-56, specifying the Minimum Operational Performance Specification (MPS) for CVR System.

In preparing ED-56, the working group recognised that current standards (developed in 1963) did not adequately address issues that had evolved since then. Issues included the design and increased recording duration to allow the investigation of incidents and the need for an accurate recording time-base (tolerances of ± 7% were allowed). Advances in recording technology by utilising solid state devices were also considered. Requirements for increased crashworthiness with complementary specific testing criteria, were developed to ensure manufacturers of flight recorders could provide a consistent level of ‘survivability’. The criteria was developed in response to the inability of tape-based recorders to survive a fire and impact regime demonstrated in several large passenger aircraft accidents.

A review of ED-56 resulted in ED-56A which, significantly, introduced recommended maintenance practices to ensure the continued serviceability of the installed CVR system. ED-56A also introduced several new specifications including requirements and guidance specific to the use of solid-state storage media, recording duration in accordance with ICAO Standards and Recommended Practices and aligning crash survival criteria with ED-55[38].

The revised document, ED-56A, was published in December 1993, and was subsequently legislated in August 1996 by the FAA as TSO-C123a. All currently

38 ED-55 refers to the flight data recorder system

manufactured CVR units conform to TSO-C123a or its Joint Airworthiness Authority (JAA) equivalent.

In March 2003, EUROCAE published the Minimum Operational Performance Standards (MPS) for Crash Protected Airborne Recording Systems, known as document ED-112. ED-112 supersedes ED-55 and ED56A and contains the complete contents of the two previous documents. ED-112 also clarifies and harmonises some of the common requirements of both CVR and FDR systems as well as providing additional guidance for on-board aircraft testing of flight recorder systems and prohibiting magnetic tape, wire and photographic methods of recording. ED-112 also introduces new standards addressing the current and future requirements for recording Communication, Navigation and Surveillance/Air Traffic Management (CNS/ATM) data link messaging, image recording, automatically deployable recorders, combined recorders and independent power supplies.

On 1 June 2006, the FAA made effective TSO-C123b, which requires all new models of CVR to meet the MPS of EUROCAE document ED-112. The order has no affect on existing recorders.

At the time of the investigation, CASA had not implemented TSO-C123b for Australian operators.

APPENDIX B FINDINGS

Contributing factors

- It is considered likely that the CVR unit developed a fault that may have been present in either the Bias Oscillator or the internal d.c. power supply for some time prior to the accident. A conversation regarding an airways clearance, recorded on the 27 April 2005, indicated the fault had been present, at least, since that time.
- The fault in the CVR had stopped the unit from functioning as intended, but had not been discovered or diagnosed by the flight crew or maintenance personnel.

Other Safety factors

- The operator performed a pre-flight functional check on three other aircraft in the fleet that were fitted with CVR units. The test detected two unserviceable CVR units.

Other key findings

- The presence of previous flights and the fragmented nature of the recorded audio indicated a fault in the CVR unit.
- Due to the extent of fire and heat damage, the examination of the printed circuit assemblies could not provide physical evidence relating to the failure of the CVR unit.
- Audio present on the CVR recording indicated flight crew performing appropriate communications, intra cockpit and with air traffic control and other aircraft relating to the operation of VH-TFU.
- Audio present on the CVR recording indicated operation of the GPWS fitted to VH-TFU through the recording of several GPWS generated aural alerts. Other aural alerts were also recorded.
- No audio recovered from the CVR recording could be confirmed as having been recorded during the accident flight.

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APPENDIX B SAFETY ACTION

ATSB safety action

Following the accident, the ATSB issued recommendation R20060005 on 10 February 2006, which stated the following:

> The ATSB recommends that the Civil Aviation Safety Authority review the maintenance requirements for cockpit voice recording systems and flight data recording systems against international standards such as EUROCAE ED-112 and ICAO Annex 6 with the aim of improving their reliability and increasing the availability of data to investigators.

On 22 May 2006 CASA responded and stated the following:

> The maintenance and testing requirements for flight data recorders (FDR) and cockpit voice recorders (CVR) are not explicitly defined in Australian regulations. ICAO Annex 6 requirements are accepted as the minimum requirement to be met by operators when submitting Schedules of Maintenance for CASA approval. ICAO Annex 6, Part 1, Attachment D, Flight Recorders, provides guidance for pre-flight checking, inspection and calibration of flight data recording and cockpit voice recording systems.
>
> CASA guidance in relation to flight data recorder maintenance is set out in CAAP 42L-4(0), and includes reference to ICAO Annex 6 and EUROCAE ED-112.
>
> In light of this recommendation, CASA will review the maintenance requirements for flight data recorders and cockpit voice recorders against the relevant international standards, and will consider in particular whether minimum requirements for such maintenance should be prescribed.
>
> In the interim, CASA will review the existing guidance material with a view to providing more specific maintenance interval guidelines.
>
> CASA will be providing additional training in the maintenance of FDR/CVR systems for airworthiness personnel. This will enhance their knowledge in these systems and will assist them when evaluating aircraft systems of maintenance.

At the time of the report, the recommendation was on Monitor status.

Operator safety action

Following the accident the operator issued a Notice to Aircrew (NOTAC) that directed aircrews to test the CVR and FDR units prior to each flight, and to use the AFM for guidance. The operator subsequently issued revision two of the pre-flight checklist on 20 September 2006 that included a test of the CVR and FDR.

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APPENDIX B ABBREVIATIONS

AAIB	Air Accident Investigation Branch UK
AD	Airworthiness Directive
AFM	Airplane Flight Manual
ATA	Airline Transport Association
ATC	Air Traffic Control
ATSB	Australian Transport Safety Bureau
a.c.	alternating current
CAM	Cockpit Area Microphone
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CDROM	Compact Disc Read Only Memory
CMM	Component Maintenance Manual
CVR	Cockpit Voice Recorder
d.c.	direct current
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration USA
F.S.	Fuselage Station
GNSS	Global Navigation Satellite System
GPWS	Ground Proximity Warning System
ICA	Instructions for Continued Airworthiness
ICAO	International Civil Aviation Organisation
JAA	Joint Airworthiness Authority
L-3AR	L-3 Communications Aviation Recorders
NOTAC	Notice To Air Crew
NTSB	National Transportation Safety Board USA
RNAV	Radio Navigation
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
TSO	Technical Standard Order
ULB	Underwater Locator Beacon

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APPENDIX C: EXTRACT FROM HONEYWELL GPWS MK VI WARNING SYSTEM PILOT'S GUIDE

MODE 2

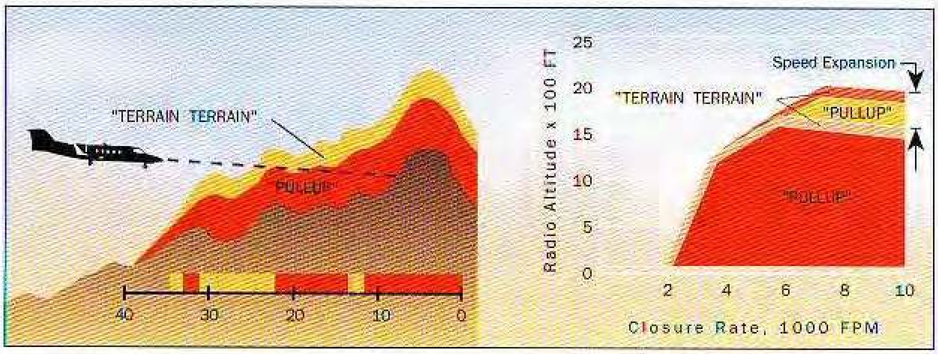
EXCESSIVE CLOSURE RATE TO TERRAIN

Mode 2 provides protection for situations where the terrain is rising excessively fast underneath the aircraft with respect to aircraft flight path. Since there are no forward-looking sensors in the MK VI GPWS, the GPWC uses radio altitude, airspeed, and vertical speed information to compute excessive CLOSURE RATES with terrain. If radio altitude begins to decrease rapidly and there is no excessive rate of descent present, terrain must be coming up under the aircraft flight path. The GPWC therefore sees a

060-4087-000 Rev. B • Effective Date April 2001
MK VI Warning System Pilot's Guide 7

closure rate to terrain. The faster the aircraft is traveling, the faster the closure rate is for a given terrain profile.

The chart below shows Mode 2A, which is active in routine flight operations, (Flaps NOT in landing configuration, FLAP OVERRIDE NOT selected). When the closure rate is high enough, the alert message **"TERRAIN-TERRAIN"** is heard once and the red GPWS warning lamp is illuminated. This is followed immediately by the continuous warning message **"PULL-UP"** until the closure is no longer present and the envelope is exited.



Upon exiting the warning envelope, aural warning messages cease, but the red GPWS warning lamp remains on until the aircraft has climbed approximately 300 feet barometric altitude from where the last **"PULL-UP"** message was heard. This is to help ensure that the recovery maneuver is continued to a safe altitude after closure rate with terrain is reduced. The red GPWS warning lamp will then extinguish.

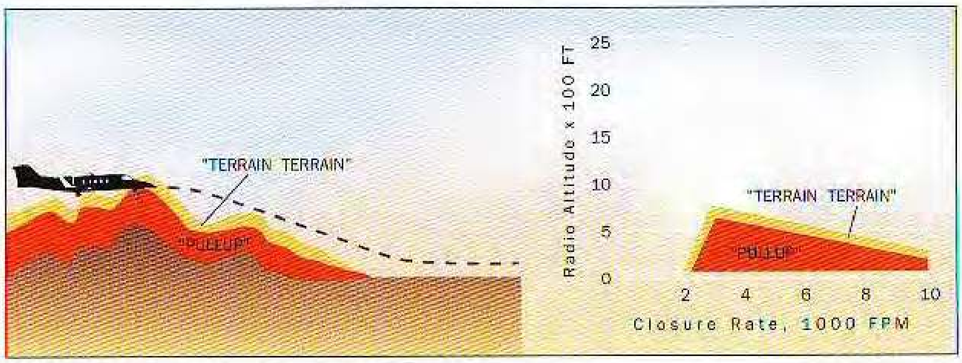
The Speed Expansion area at the top of the warning envelope is to provide additional warning time for aircraft flying at approximately 220 knots or faster.

This is automatically done in the GPWC and does not require any flight crew action.

Mode 2B warning envelopes are shown in the chart below. Mode 2B is active during the approach phase of flight:

- Flaps ARE in landing configuration, or
- FLAP OVERRIDE is selected, or
- Aircraft is on a Glideslope AND NOT more than 1.3 dots below beam center line, and
- G/S CANCEL function has NOT been selected.

Note that the warning envelope is much smaller. This is to allow flight paths closer to terrain as is normal during approach situations, without nuisance warnings to the crew.



Should the Mode 2B envelope be penetrated with landing gear down AND flaps in landing configuration (or FLAP OVERRIDE selected), a repetitive **"TERRAIN-TERRAIN"** message is heard and the red GPWS warning lamp is illuminated. No **"PULL-UP"** warning will occur.

Otherwise, Mode 2B alert and warning messages are the same as Mode 2A: a single **"TERRAIN-TERRAIN"** message followed by repetitive **"PULL-UP"** warnings.

In either case, when the Mode 2B envelope is exited, voice messages will cease and the red GPWS warning lamp will extinguish immediately.

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APPENDIX D: ESTIMATED AIRCRAFT WEIGHT AND BALANCE

Regulatory requirements regarding load sheets

Civil Aviation Order (CAO) 20.16.1 required that both the operator and the pilot in command were to ensure that a load sheet was carried in the aircraft and, for those aircraft engaged in regular public transport services, that a copy of the load sheet was retained on the ground at the aerodrome of departure.

A copy of the load sheet for the flight from Bamaga to Lockhart River for VH-TFU on 7 May 2005 was not located at Bamaga and a copy was not found at the accident site. Current and former employees of the operator reported that it was not routine practice for load sheets to be left at Bamaga.

Aircraft weight limitations

The following weight limitations applied to VH-TFU:

Maximum take-off weight	7,484 kg
Maximum landing weight	7,110 kg
Maximum zero fuel weight	6,577 kg

Aircraft empty weight

The aircraft's *Weight and Balance Record*, dated 10 March 2005, listed the empty weight of VH-TFU as being 4,388.7 kg. Empty weight was the mass of the aircraft in the 19 passenger-seat configuration and included full oils and unusable fuel.

Passenger and carry-on baggage weight

The operator's operations manual indicated that standard passenger weights could be used to calculate the load on company aircraft. It indicated that for seating capacities of between 10 and 19 seats, that a standard weight of 85 kg for a male occupant and 69 kg for a female occupant could be used. These weights were to include a carry on baggage allowance of 6 kg. There were no standard weights listed in the operations manual for aircraft with a seating capacity of more than 20 seats. There were no standard weights listed for checked baggage. The manual stated that the pilot in command was to ensure that all checked baggage was weighed prior to loading on the aircraft.

Civil Aviation Advisory Publication (CAAP) 235-1(1) *Standard Passenger and Baggage Weights* was a publication produced by the Civil Aviation Safety Authority (CASA) to assist operators in complying with Civil Aviation Regulations 1988 (CAR), r. 235. CAR 235 dealt with the loading of aircraft during the take-off phase of flight and required that an aircraft not be loaded above its maximum take-off weight or its performance limited weight.

CAAP 235-1(1) indicated that standard passenger weights could be used when compiling a load sheet for certain aircraft. Section 15 of the CAAP indicated that for an aircraft with a maximum seating capacity of between 20 and 39 seats (including crew seats) the standard passenger weights were 84 kg for a male occupant and 69 kg for a female occupant. This weight did not include an allowance for cabin baggage. The CAAP also indicated that for the purposes of baggage, no standard weight was given in the publication and it was up to each operator to decide whether to weigh all baggage or carry out their own survey to calculate standard weights for baggage and carry on baggage.

Three female and 10 male passengers boarded the aircraft at Bamaga for the flight to Lockhart River. The investigation estimated the total weight of the two male crew and 13 passengers as 1,305 kg. This figure was based on the CAAP standard passenger weights, which were more conservative than the operations manual, and assumed that each flight crew member and passenger had 6 kg of carry-on baggage.

Checked baggage weight

A passenger/cargo manifest document was subsequently provided to the investigation and indicated that only one piece of baggage, weighing 15 kg, was checked in by a passenger at Bamaga for the flight to Cairns. There was no record of other passenger baggage being checked in at Bamaga. However, several suitcases were found at the accident site. The estimation of the total baggage checked in at Bamaga was 255 kg, which assumed that the other 12 passengers each checked in a 20 kg bag, which was a standard airline allowance.

Fuel weight

The following fuel figures calculated by the investigation used information from the aircraft's *Flight/Maintenance Log*, fuel invoices and release notes, and estimated fuel burn figures that were derived from a fuel flight plan, which used the forecast wind velocities at the flight levels flown by the crew. The fuel burn figures also included an allowance for the actual time intervals as determined from the air traffic control and common traffic advisory frequency automated voice recordings.

The operator's flight crews recorded fuel burn and remaining fuel on board in the aircraft's *Flight/Maintenance Log* in pounds, as the aircraft fuel gauges and fuel totaliser were calibrated in that unit of measurement. The following estimation used a specific gravity of 0.79[39] for the aviation turbine fuel carried on the aircraft.

---

39 Specific gravity is the density of a material expressed as a decimal fraction of the density of water at 4 degrees C. The specific gravity of aviation turbine fuel is typically 0.80 kg/l at 15 degrees C. As the temperature of the fuel increases, the specific gravity decreases. A specific gravity of 0.79 kg/l was used to estimate the fuel weight as the aircraft was refuelled in a tropical area.

	Pounds	Litres	Kg
Fuel on board at Cairns Completion of previous day's operations	700		318
Add Fuel loaded at Cairns		800	632
Fuel on board – departure from Cairns			*950*
Less Estimated fuel burn off Cairns – Lockhart River – Bamaga	-1,342		-609
Estimated fuel on board – arrival at Bamaga			*341*
Add Fuel loaded at Bamaga		800	632
Estimated fuel on board – departure from Bamaga			*973*
Less Estimated fuel burn off Bamaga – Lockhart River	-491		-223
Estimated fuel on board – time of accident			*750*

Estimated aircraft weight

The following table summarises the estimated weight of the aircraft at the time of the accident, using the figures discussed above.

	kg
Aircraft basic weight	4,389
Estimated weight of crew, passengers and carry-on baggage	1,305
Estimated weight of checked baggage	255
Estimated zero fuel weight	*5,949*
Estimated weight of fuel on board at time of accident	750
Estimated weight of aircraft at time of accident	*6,699*

At this estimated weight, the aircraft was below the maximum take-off and landing weights specified in the aircraft's *Approved Airplane Flight Manual*.

Centre of gravity range

Type certificate data sheet A18SW, which was issued by the US Federal Aviation Administration and covered the SA227-DC aircraft (including VH-TFU), indicated that the centre of gravity range was between 262.8 inches (6,675 mm) and 277 inches (7,036 mm) behind the datum at 16,500 lbs (7,484 kg). The range at 11,000 lbs (4,990 kg) and below was 257 inches (6,528 mm) and 277 inches (7,036 mm). There was straight-line variation between the points.

Passenger loading

The passengers on the flight from Cairns to Bamaga had been assigned seats by the ground agent in Cairns prior to departure. This seat assignment was completed using a seat allocation chart provided by the operator. Interviews with the passengers revealed that when they boarded the aircraft they could sit wherever they desired and the crew did not enforce the assigned seating allocation as determined by the agent.

The actual seating of the passengers for the flight from Bamaga to Lockhart River could not be ascertained, as the disruption of the aircraft during the impact sequence did not allow the determination of the seating positions of occupants.

Baggage loading

The aircraft's seat allocation chart indicated that the maximum load in the front baggage compartment was 150 kg. The chart also indicated that the rear baggage compartment was divided into two zones with a maximum allowable load in forward zone of 216 kg and the rear zone of 148 kg.

Loading scenarios

The aircraft's centre of gravity remained in the specified range in the following two loading scenarios:

- the passengers were seated in accordance with the aircraft's seat allocation chart and 100 kg of the checked baggage was loaded in the front baggage compartment with the remaining 155 kg in the rear baggage compartment. The centre of gravity remained in the range if all the checked baggage was loaded in the rear compartment
- the passengers all elected to sit at the front of the aircraft, with the male passengers all seated forward of the female occupants, and 100 kg of the checked baggage was loaded into the front baggage compartment with the remaining baggage in the rear.

The aircraft's centre of gravity moved outside the specified range in the following scenarios:

- the passengers all elected to sit at the front of the aircraft, with the male passengers all seated forward of the female occupants, and 150 kg of the checked baggage was loaded into the front baggage compartment with the remaining baggage in the rear
- the passengers elected to sit at the rear of the aircraft with the male passengers located behind the female occupants and all the checked baggage was loaded into the rear baggage compartment.

The investigation considered that it was unlikely that all the passengers would have all been seated at either the front or the rear of the aircraft and there would have been some empty seats throughout the aircraft cabin. It also considered that the checked baggage would have been divided between the front and rear baggage compartments.

For all loading scenarios, the weight of VH-TFU was below the maximum take-off and landing weights for the aircraft. However, due to the fact that the load sheet relating to the accident flight was not located, the investigation could not conclusively determine the position of the aircraft's centre of gravity.

APPENDIX E: TRANSCRIPT OF RADIO TRANSMISSIONS FROM VH-TFU

The following table is a transcript of the radio transmissions made to and from VH-TFU on the accident flight from Bamaga to Lockhart River.

Legend:

TFU	VH-TFU
SEC	Air traffic control sector controller
CTAF	Common Traffic Advisory Frequency
PAR	VH-PAR, an AC500 aircraft in the Lockhart River area
FW	Brisbane flightwatch operator
[…]	Unknown
PIC	Transmission from pilot in command
CP	Transmission from copilot

Symbol Decode

?	Unidentified source addressee
// //	Explanatory Note or Editorial Insertion
( )	Words open to other interpretation

Time	From	To	Transmission
1110:14	TFU (PIC)	FW	Flightwatch flightwatch tango foxtrot uniform taxi
	FW	TFU	Tango foxtrot uniform flightwatch standby
1111:07	FW	TFU	Aircraft calling flightwatch for taxi go ahead
1111:09	TFU (PIC)	FW	Yeah good day tango foxtrot uniform IFR metro taxies Bamaga runway one three for Lockhart River
	FW	TFU	Tango foxtrot uniform
1112:56	FW	TFU	Tango foxtrot uniform flightwatch from Brisbane centre air traffic no additional IFR traffic to the MBZ
1113:01	TFU (PIC)	FW	Tango foxtrot uniform cheers
1113:14		?	//Unknown transmission/microphone keying – There was no corresponding transmission on either sector, flightwatch or the Horn Island CTAF//
1114:28	TFU (CP)	SEC	Brisbane centre tango foxtrot uniform departure
	SEC	TFU	Tango foxtrot uniform go ahead
1114:33	TFU (CP)	SEC	Tango foxtrot uniform departed Bamaga time one one on climb flight level one eight zero estimating Lockhart River time four three
	SEC	TFU	Tango foxtrot uniform confirm that’s your final level
1114:49	TFU (CP)	SEC	Aah negative one seven zero now tango foxtrot uniform
	SEC	TFU	Tango foxtrot uniform copied no additional IFR traffic flight level one seven zero
1114:59	TFU (CP)	SEC	No additional one seven zero tango foxtrot uniform
1124:31	SEC	TFU	Tango foxtrot uniform contact me now one two two decimal one
1124:36	TFU	SEC	Tango foxtrot uniform one two two decimal one on climb flight level one seven zero
	SEC	TFU	Tango foxtrot uniform centre
1133:06	TFU (CP)	SEC	Centre tango foxtrot uniform has left flight level one seven zero request traffic
1133:12	SEC	TFU	Tango foxtrot uniform IFR traffic is papa alpha romeo an aero commander conducting a coastal flight to the north of Lockhart one thousand feet and below flight plan estimate for Lockhart River at time four zero
1133:28	TFU (CP)	SEC	Copied papa alpha romeo tango foxtrot uniform

Time	From	To	Transmission
1134:19	SEC	TFU	Tango foxtrot uniform papa alpha romeo has just given his position on HF he's five five miles to the north of Lockhart tracking coastal Lockhart on the hour still below one thousand feet area QNH for you is one zero one one
1134:31	TFU (CP)	SEC	One zero one one and copied papa alpha romeo tango foxtrot uniform
1135:24	TFU (CP)	SEC	Centre tango foxtrot uniform frequency change to Lockhart River CTAF one two six seven contact HF on the ground six six one zero
	SEC	TFU	Tango foxtrot uniform thanks if you can talk to papa alpha romeo either on area or a chat frequency he hasn't got you as traffic yet
1135:43	TFU (CP)	SEC	[....] tango foxtrot uniform
1135:48	TFU (CP)	SEC/All stations	All stations to the northwest of Lockhart River tango foxtrot uniform IFR metro is on descent through one zero thousand for Lockhart River we'll be estimating Lockhart River at time three eight papa alpha romeo believe you are traffic
1136:18	TFU (CP)	CTAF/All stations	All stations in the Lockhart River CTAF tango foxtrot uniform IFR metroliner is on descent through niner thousand for Lockhart River estimating Lockhart River at three nine and papa alpha romeo are you reading
1136:50	TFU (CP)	SEC/PAR	Papa alpha romeo tango uniform foxtrot
1139:56	TFU (CP)	CTAF/All stations	All stations Lockhart River tango foxtrot uniform doing the runway one two RNAV approach at whisky golf tracking for whisky India
1140:26	TFU (CP)	CTAF/PAR	Papa alpha romeo go ahead
1140:33	TFU (CP)	CTAF/PAR	Ah fairly dismal really [a]bout nine hundred foot […] //garbled - 'clearing' or 'clearance'//
1143:39			Time of accident

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APPENDIX F: HONEYWELL GPWS MK VI SIMULATION

Metroliner

Lockhart River, QLD, Australia (YLHR)

May 07, 2005

FACTUAL INFORMATION

On 7 May 2005, a Fairchild Metroliner SA227-DC, registered VH-TFU, with two pilots and 13 passengers, was being operated under instrument flight rules (IFR) on a scheduled passenger service from Bamaga to Cairns via Lockhart River, Qld.

The crew reported departure from Bamaga at 1111 eastern standard time with an intention to climb to FL170 (17,000 ft). At 1133 they advised air traffic control that they had left FL170 and at 1136 reported being on descent passing 9,000 ft with an estimated time of arrival at Lockhart River of 1139.

The crew subsequently reported that they were conducting the Lockhart River Runway 12 RNAV approach, and that they were at waypoint Whisky Golf (LHRWG), tracking for Whisky India (LHRWI). Whisky India is located 12 NM prior to the missed approach point of the Lockhart River Runway 12 RNAV approach.

At 1158, when the crew had not reported having landed at Lockhart River, air traffic control declared an uncertainty phase. When attempts to contact the aircraft failed, a search was commenced. At 1625 the burnt wreckage of the aircraft was located in the Iron Range National Park on the north-western slope of 'South Pap', a heavily timbered ridge, approximately 11 km north-west of Lockhart River. All occupants were fatally injured and the aircraft was destroyed by impact forces and the post-impact fire.

The aircraft had cut a swath of less than 100 m through heavy timber on the steep slope and came to rest at an elevation of 1,210 ft above mean sea level (amsl) about 90 ft below the top of the ridge.

The aircraft entered the forest canopy at a descent angle of between 3 and 5 degrees. Damage to the propellers and engines was consistent with both engines producing power at impact. An intense, fuel-fed, post-impact fire destroyed most of the aircraft fuselage, including much of the instrument panel and avionics. The accident site is located on the published Lockhart River 12 RNAV final approach track. At that point in the approach, the minimum obstacle clearance altitude was 2,060 ft amsl.

Information obtained from the Bureau of Meteorology estimated that the weather conditions in the Lockhart River area at the time of the accident were overcast with broken low cloud with a base between 500 ft and 1,000 ft above mean sea level. The wind was from the south-east at between 10 and 15 knots, with occasional squally showers and intermittent drizzle. Those general conditions were confirmed by persons at Lockhart River.

The pilot in command had accrued a total of 6025.2 hours flying experience, of which 2977.6 hours were on the Metroliner aircraft type. The copilot had accrued a total of 653.4 hours flying experience, of which 148.0 hours were as a copilot on the Metroliner aircraft type.

The aircraft was fitted with a cockpit voice recorder (CVR) and a flight data recorder (FDR). Both recorders were recovered from the accident site, secured and taken to the Australian Transport Safety Bureau's laboratory for examination and data download.

Preliminary analysis of the 30 minute CVR tape indicated that it contained a mixture of electrical pulses and fragments of conversations, some identified from previous flights. While analysis of the CVR tape is continuing, it is likely that no useful data on the accident flight will be recovered. It is unclear which of the two pilots was flying the aircraft at the time of the accident.

The FDR contained approximately 100 hours of useful data which has been assessed as being of reasonably good quality and contains data relating to the accident flight.

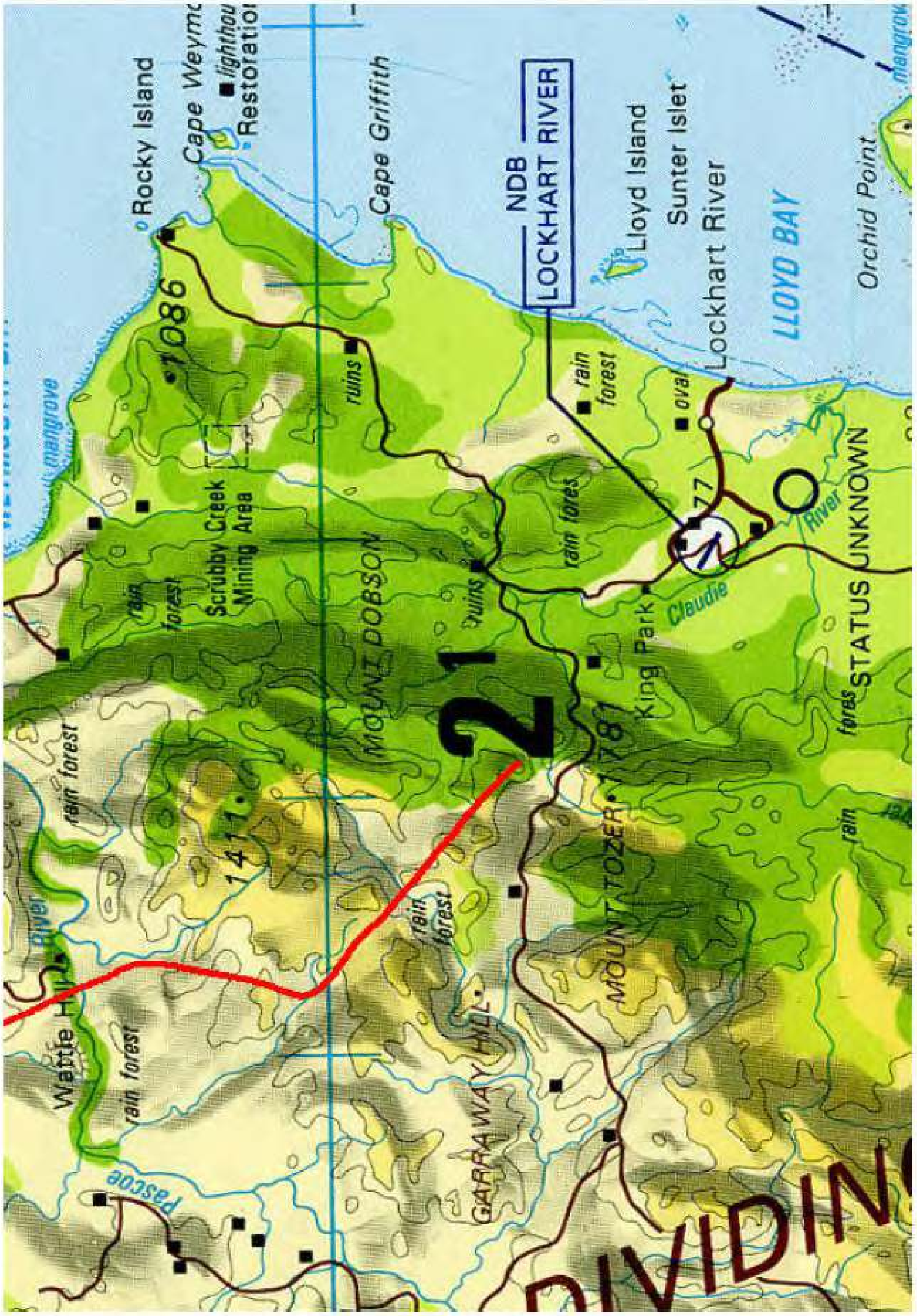
That information indicates that the engines were delivering power at the time of impact.

Preliminary data indicates that both engines were delivering around 30% to 35% torque, which is consistent with the approach power configuration. The aircraft had been descending at a constant rate, but with some turbulence evident, over the 50 seconds prior to the impact.

The aircraft, serial number DC-818 B, was manufactured in December 1992. The aircraft's *Flight/Maintenance Log* dated 6 May 2005 (the day prior to the accident) indicated that the aircraft had completed 26,875.5 hours and 28,527 cycles. Scheduled maintenance was due at 26,932.0 hours and 28,565 cycles.

1

March 23, 2007
REV. E
Honeywell



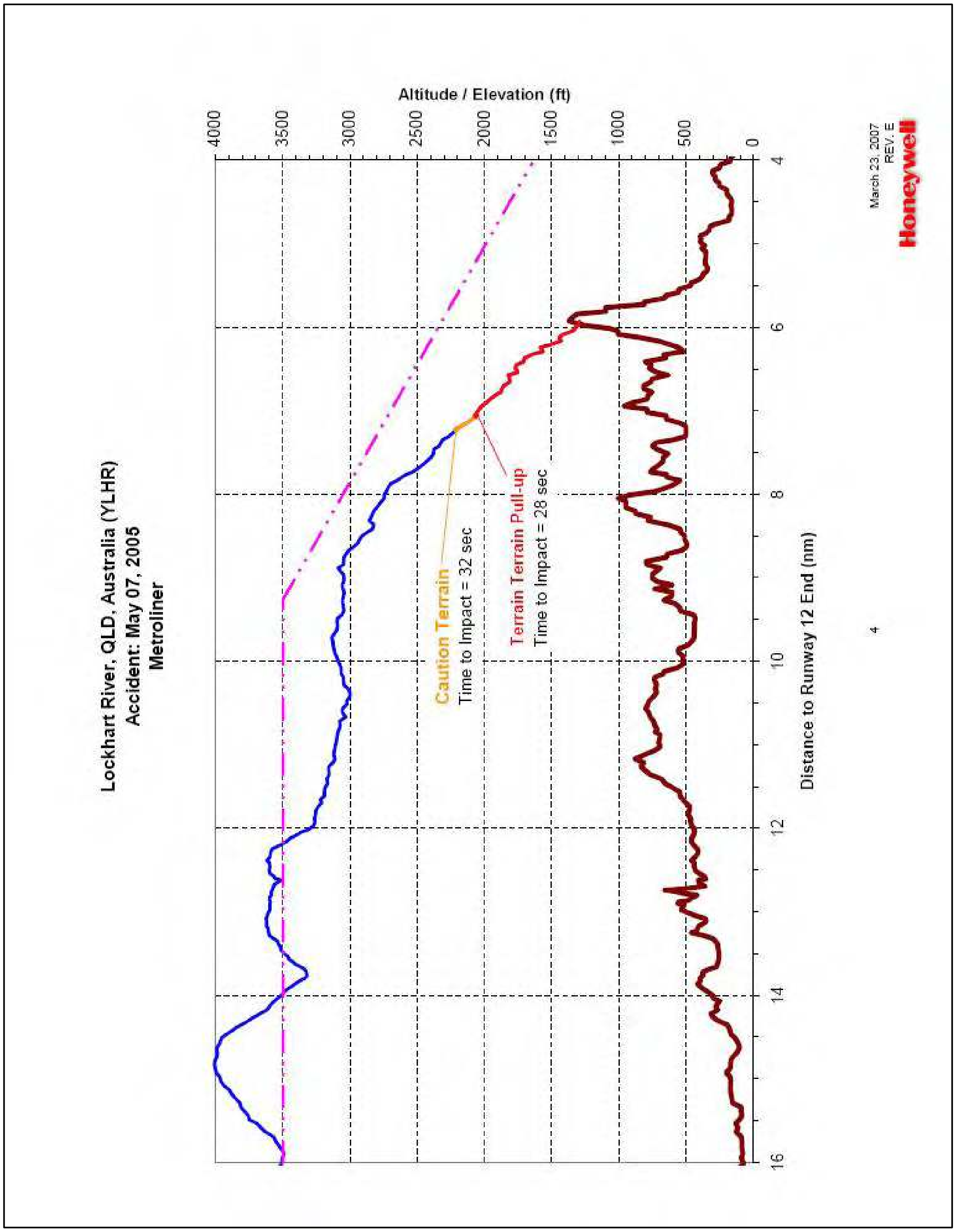
2

March 23, 2007
REV. E
Honeywell

EGPWS MK-VI

Accident Simulation

Part Number: 965-1180
Software Version: -024
Terrain Database Version: TDB-440 PACIFIC



Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner
Altitude / Elevation (ft)
4000
3500
3000
2500
2000
1500
1000
500
0
Caution Terrain
Time to Impact = 32 sec
Terrain Terrain Pull-up
Time to Impact = 28 sec
16
14
12
10
8
6
4
Distance to Runway 12 End (nm)
4
March 23, 2007
REV. E
Honeywell

March 23, 2007
REV. E
Honeywell

5

40 seconds before impact

6

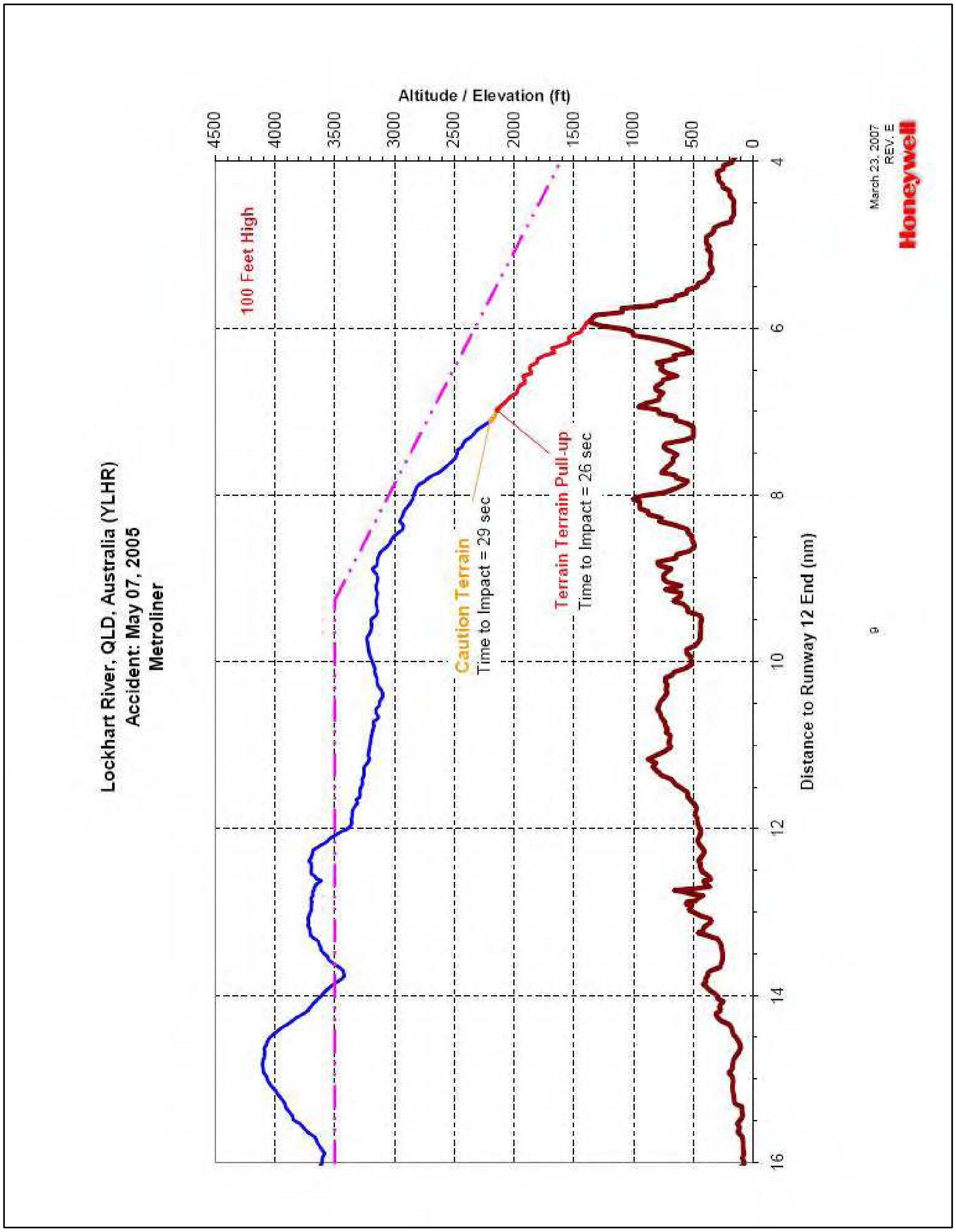
March 23, 2007
REV. E
Honeywell

"Caution Terrain"

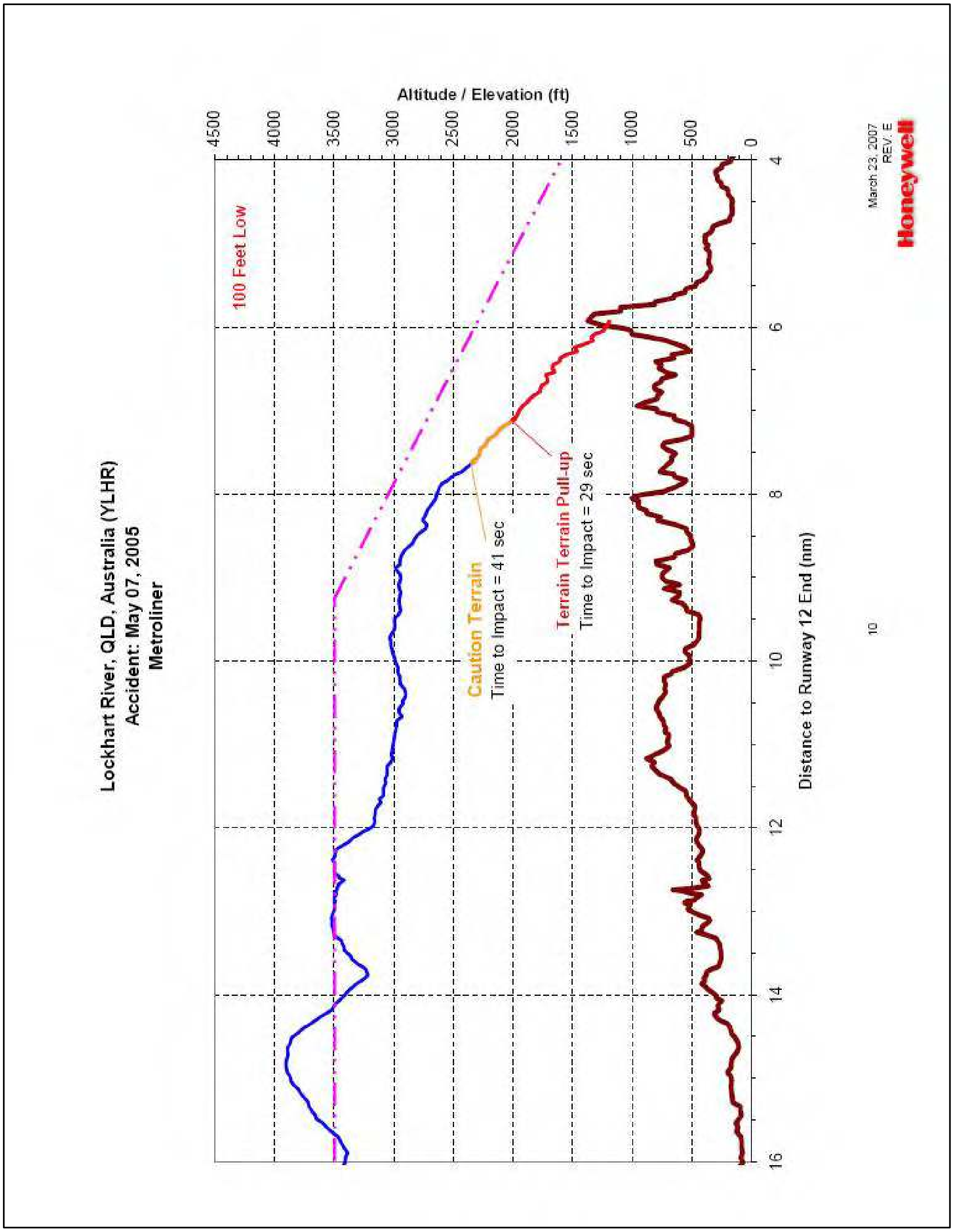
32 seconds before impact

March 23, 2007
REV. E
Honeywell

“Terrain Terrain Pull-up”
28 seconds before impact



Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner
Altitude / Elevation (ft)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
100 Feet High
Caution Terrain
Time to Impact = 29 sec
Terrain Terrain Pull-up
Time to Impact = 26 sec
4
6
8
10
12
14
16
Distance to Runway 12 End (nm)
March 23, 2007
REV. E
Honeywell



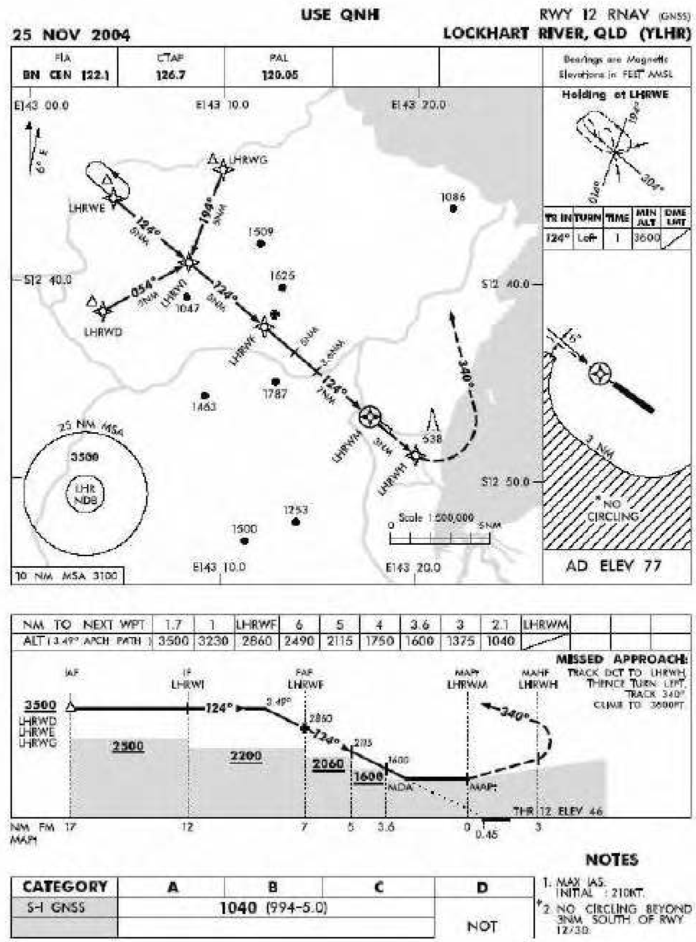
Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner
Altitude / Elevation (ft)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
100 Feet Low
Caution Terrain
Time to Impact = 41 sec
Terrain Terrain Pull-up
Time to Impact = 29 sec
16
14
12
10
8
6
4
Distance to Runway 12 End (nm)
10
March 23, 2007
REV. E
Honeywell

EGPWS MK-VI

Normal Approach Simulation

Part Number: 965-1180
Software Version: -024
Terrain Database Version: TDB-440 PACIFIC

March 23, 2007
REV. E
Honeywell



12

March 23, 2007
REV. E
Honeywell

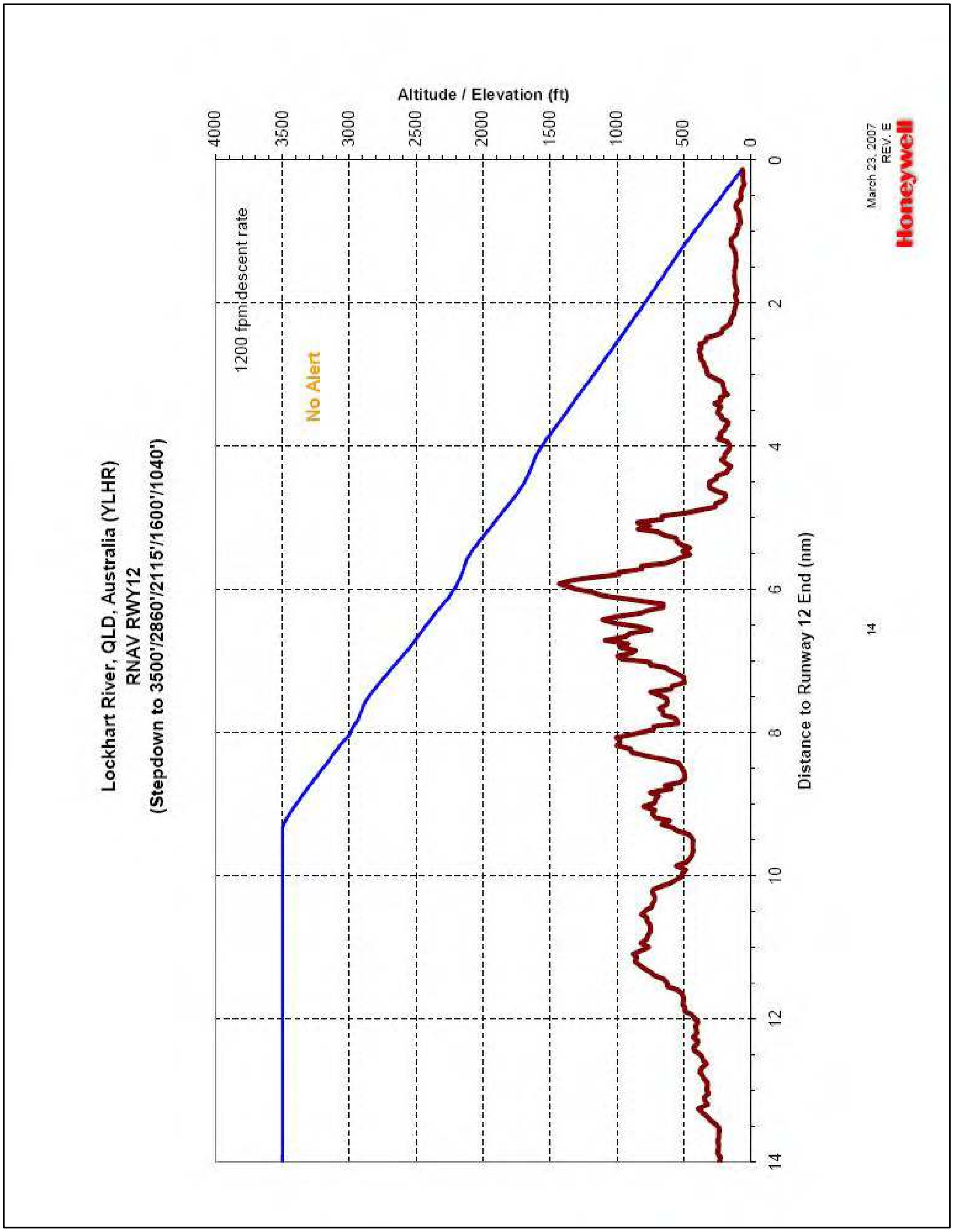
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, and the landing flaps were set soon after the landing gear was down.

Case 1:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -960 fpm

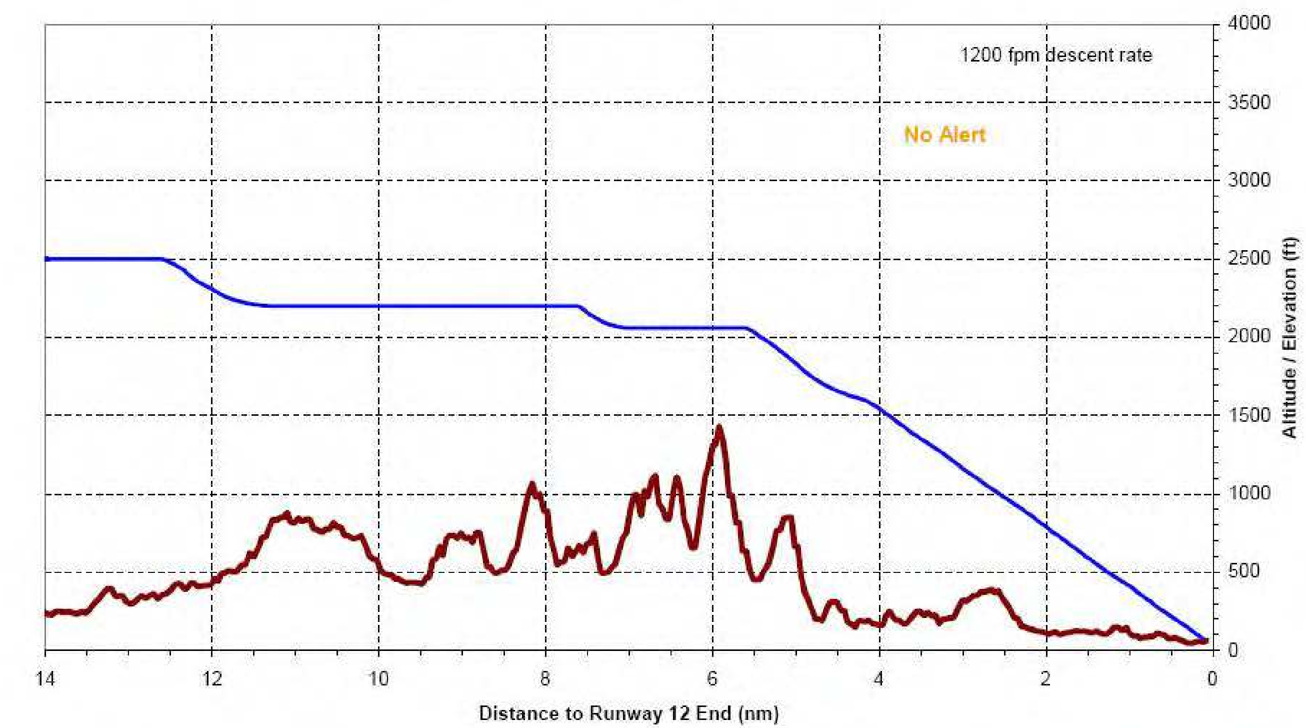
No alert or warning occurred during the entire approach.

Case 2:
Step down altitude: 2500' / 2200' / 2060' / 1600' / 1040'
Descent Rate: -1200 fpm

No alert or warning occurred during the entire approach.


Lockhart River, QLD, Australia (YLHR)
RNAV RWY12
(Stepdown to 3500'/2860'/2115'/1600'/1040')
1200 fpm descent rate
No Alert
Altitude / Elevation (ft)
Distance to Runway 12 End (nm)
14
March 23, 2007
REV. E
Honeywell

Lockhart River, QLD, Australia (YLHR)
RNAV RWY12
(Stepdown to 2500'/2200'/2060'/1600'/1040')



15

March 23, 2007
REV. E
Honeywell

GPWS MK-VI

Accident Simulation

Part Number: 965-0686-001

March 23, 2007
REV. E
Honeywell

The following simulation of the classic MKVI GPWS computer relies heavily on an estimated radio altitude value. The actual radio altitude value was not recorded on the flight recorder. The estimated radio altitude value is derived by using the estimated 3D flight path of the aircraft and the best available digital elevation model (DEM). Because of this the results must be used with caution as the actual radio altitude values as seen by the GPWS computer could be quite different.

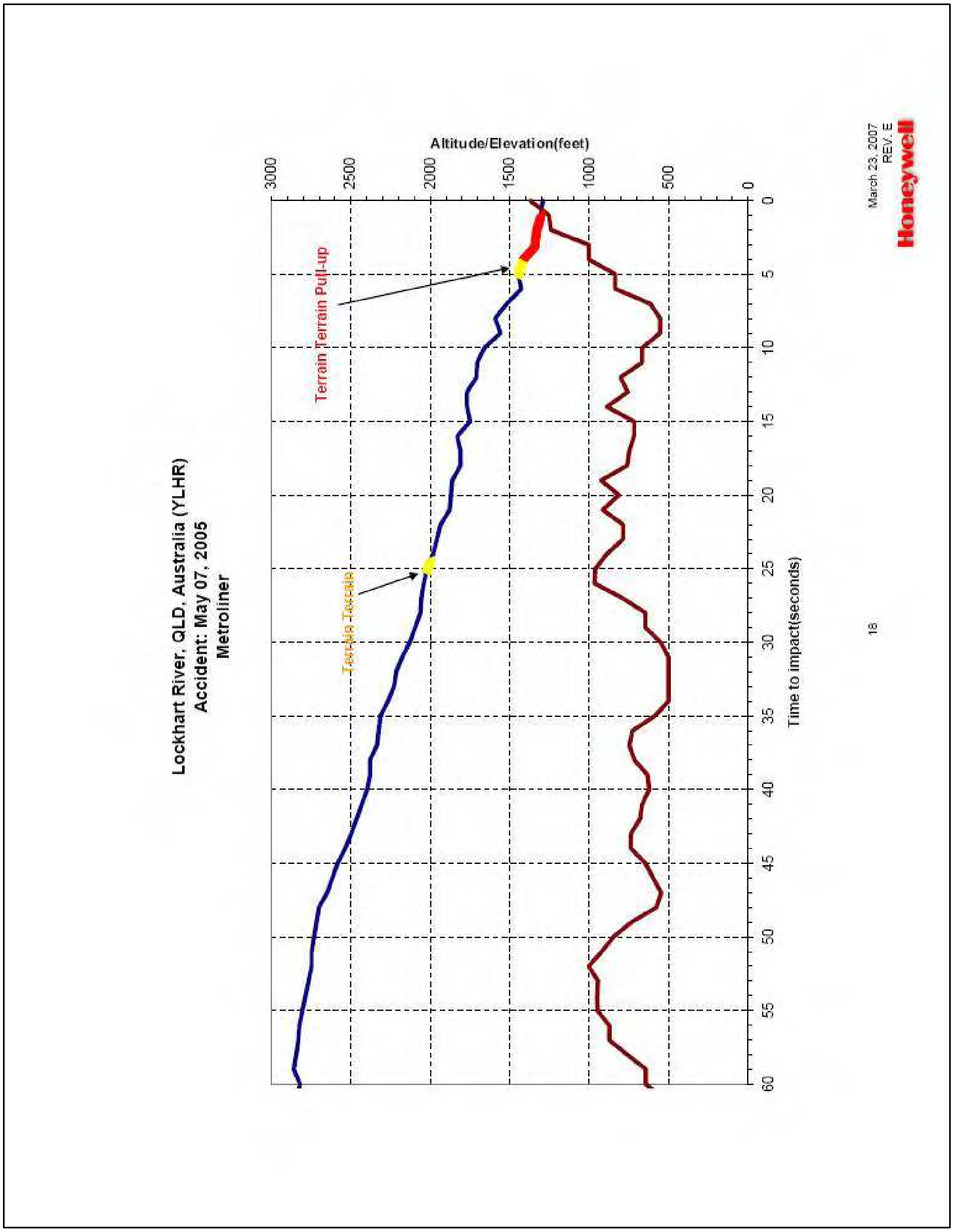
The simulation assumes that the flaps were not in landing configuration and that the landing gear was down. Also the simulation assumes that the cockpit GPWS DESENS or Flap Override switch was not activated.

The following table shows the results of the GPWS simulation.

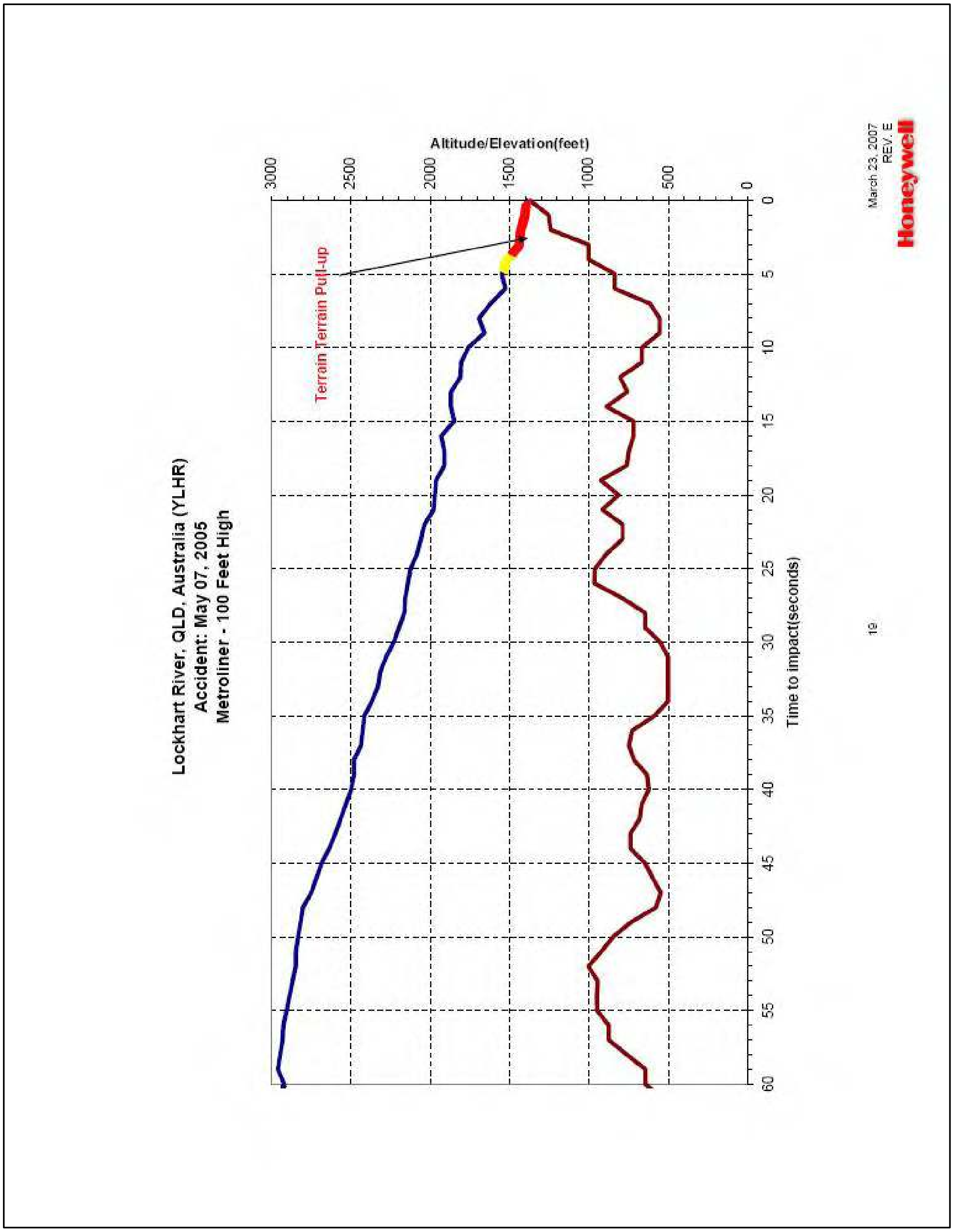
Time to impact	Voice message - event
25.15	"TERRAIN-TERRAIN"
24.4	Voice off.
5.1	"TERRAIN-TERRAIN PULL UP"

In addition two additional simulations where run in which the assumed aircraft altitude was modified by 100 feet. The first has the altitude increased by 100 feet the second decreased by 100 feet.

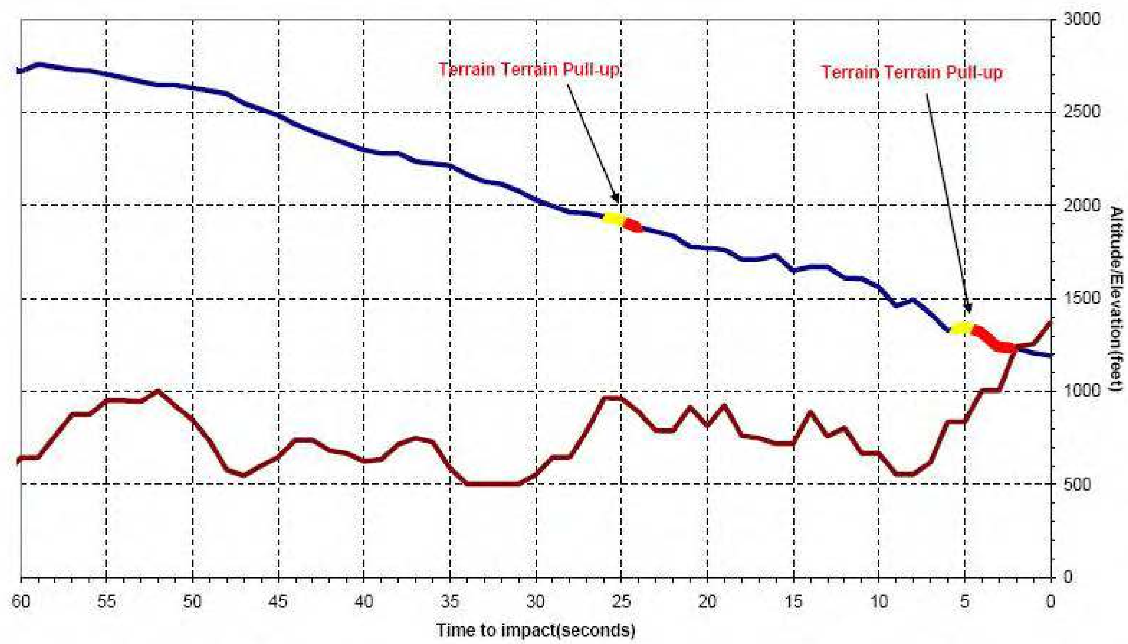
If the GPWS DESENS or Flap Override switch was activated NO GPWS alerts would be issued. This is depicted in the final chart.



Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner
Altitude/Elevation(feet)
3000
2500
2000
1500
1000
500
0
Terrain Terrain Pull-up
Terrain Terrain
0
5
10
15
20
25
30
35
40
45
50
55
60
Time to impact(seconds)
18
March 23, 2007
REV. E

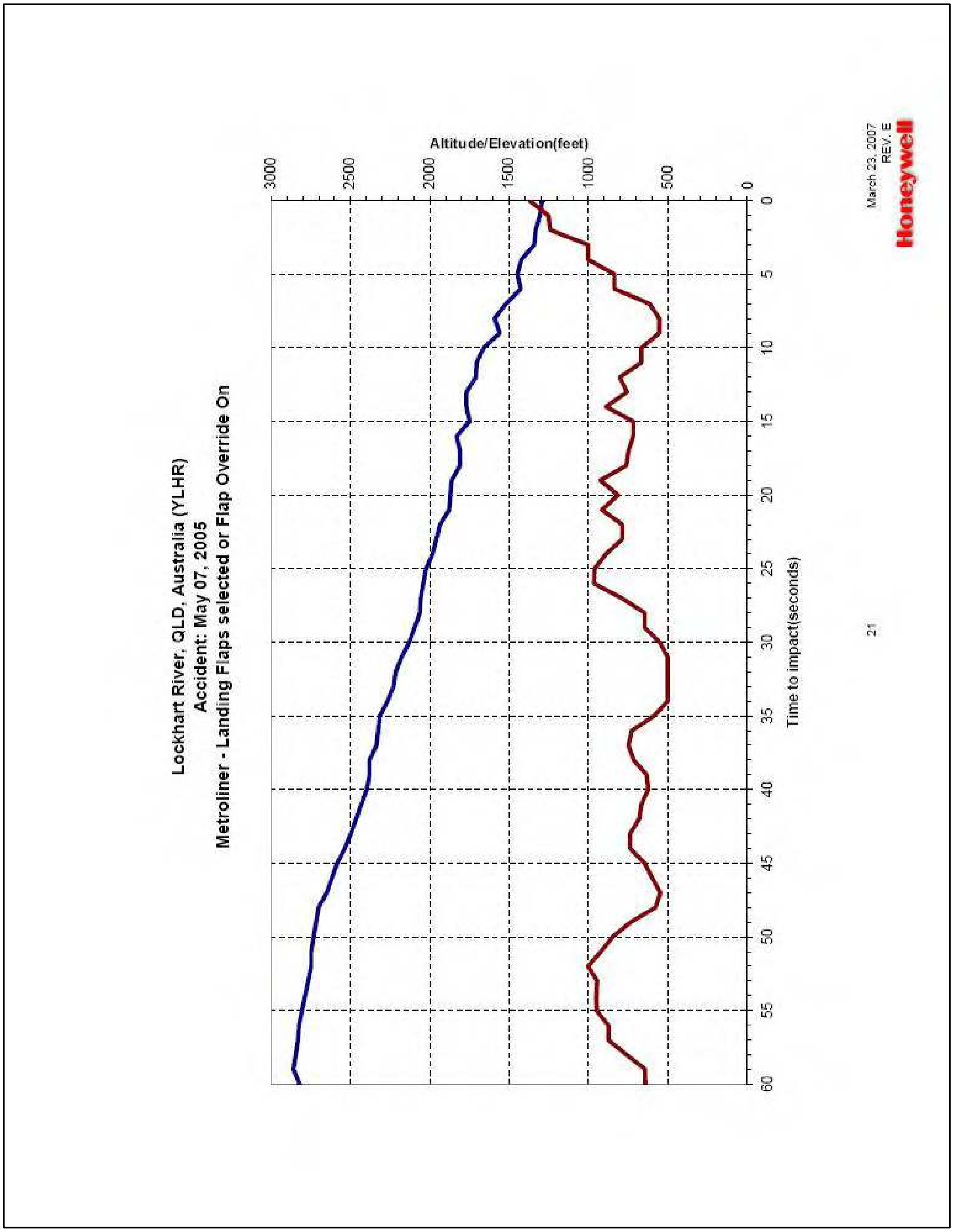

Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner - 100 Feet High
Altitude/Elevation(feet)
3000
2500
2000
1500
1000
500
0
Terrain Terrain Pull-up
Time to impact(seconds)
0
5
10
15
20
25
30
35
40
45
50
55
60
19
March 23, 2007
REV. E
Honeywell

Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner - 100 Feet Low



20

March 23, 2007
REV. E
Honeywell



Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner - Landing Flaps selected or Flap Override On
Altitude/Elevation(feet)
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
55
60
Time to impact(seconds)
21
March 23, 2007
REV. E
Honeywell

GPWS MK-VI

Normal Approach Simulation’s

Part Number: 965-0686-001

March 23, 2007
REV. E

Honeywell

Case 1

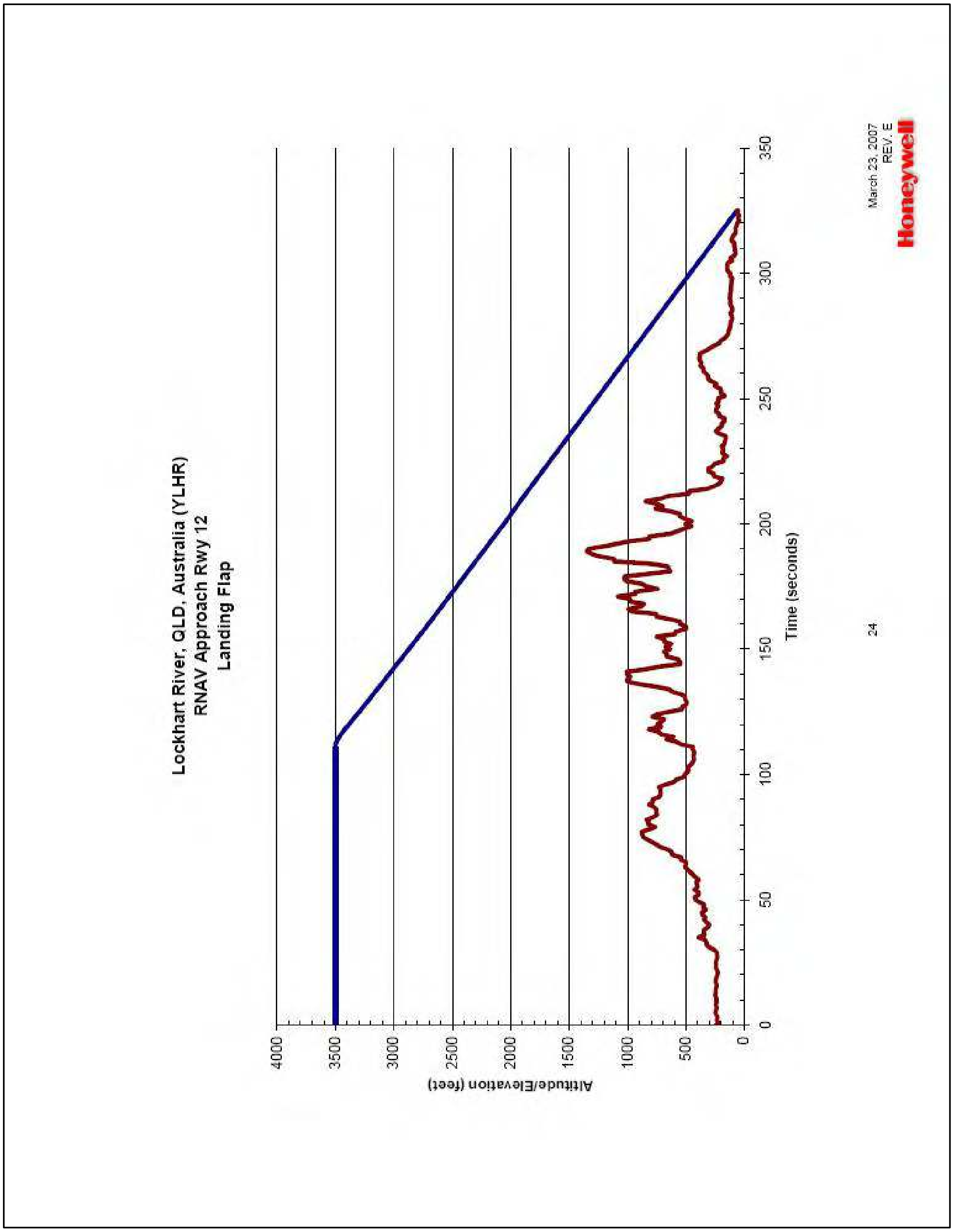
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, and the landing flaps were set soon after the landing gear was down.

Case 1A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -960 fpm

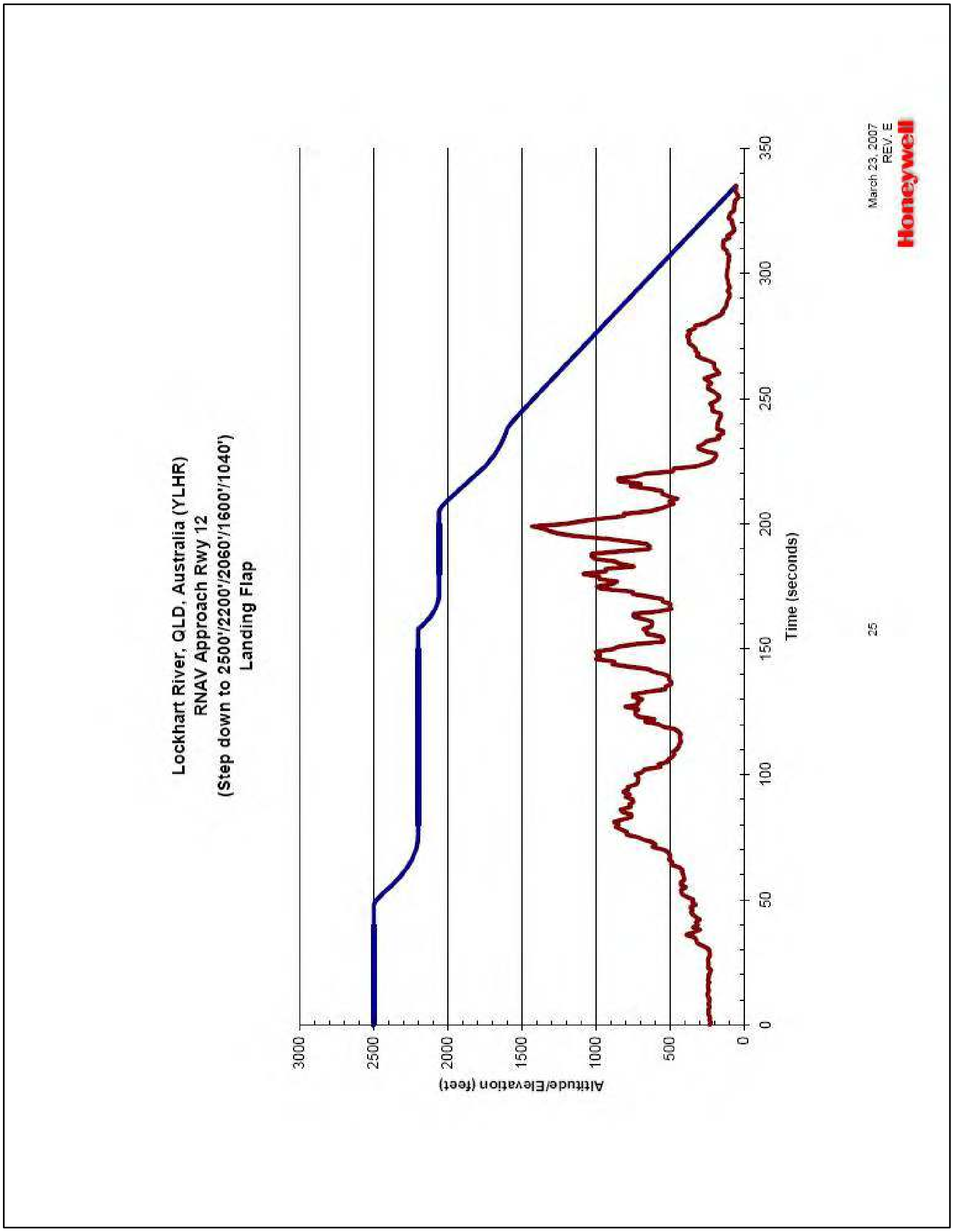
No alert or warning occurred during the entire approach.

Case 1B:
Step down altitude: 2500' / 2200' / 2060' / 1600' / 1040'
Descent Rate: -1200 fpm

No alert or warning occurred during the entire approach.



Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
Landing Flap
Altitude/Elevation (feet)
4000
3500
3000
2500
2000
1500
1000
500
0
Time (seconds)
0
50
100
150
200
250
300
350
24
March 23, 2007
REV. E
Honeywell



Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
(Step down to 2500'/2200'/2060'/1600'/1040')
Landing Flap
Altitude/Elevation (feet)
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
Time (seconds)
25
March 23, 2007
REV. E

Case 2

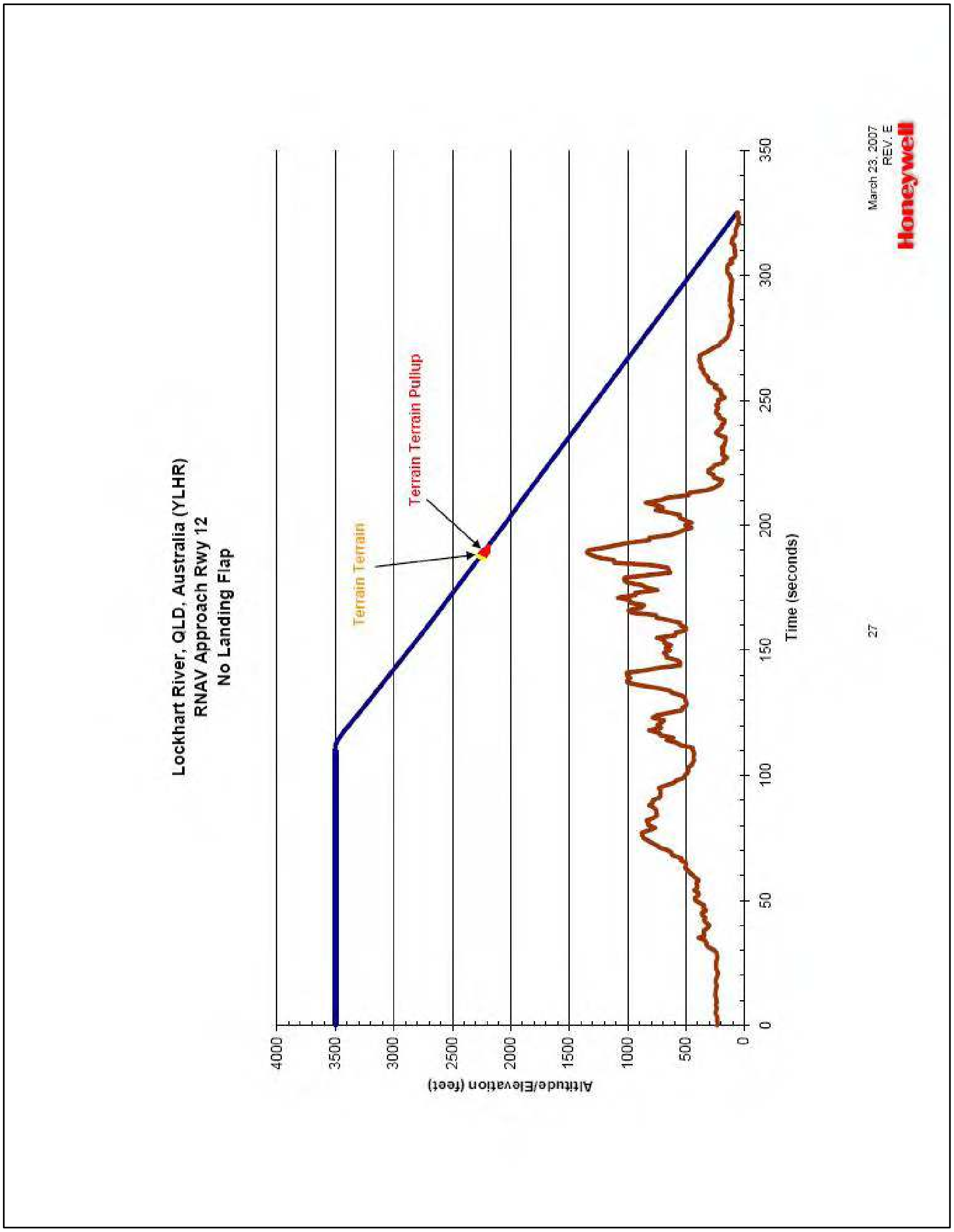
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, but the landing flaps were not set.

Case 2A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -960 fpm

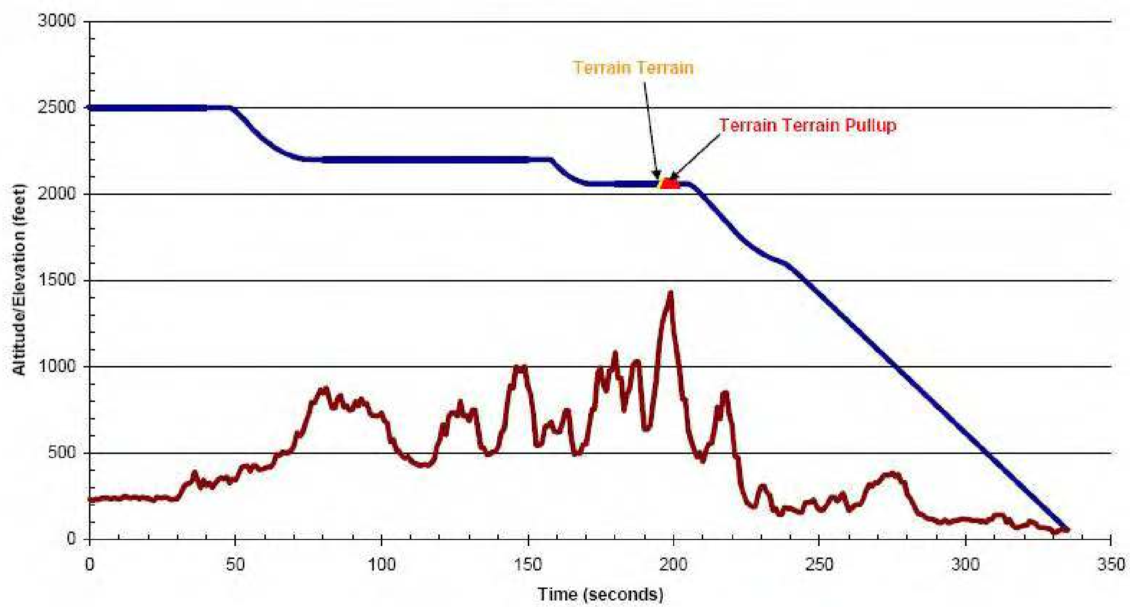
Mode 2A alerts/warnings were issued as shown in the plot below.

Case 2B:
Step down altitude: 2500' / 2200' / 2060' / 1600' / 1040'
Descent Rate: -1200 fpm

Mode 2A alerts/warnings were issued as shown in the plot below.


Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
No Landing Flap
Terrain Terrain
Terrain Terrain Pullup
Altitude/Elevation (feet)
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
Time (seconds)
27
March 23, 2007
REV. E
Honeywell

Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
(Step down to 2500'/2200'/2060'/1600'/1040')
No Landing Flap



March 23, 2007
REV. E

Honeywell

Case 3

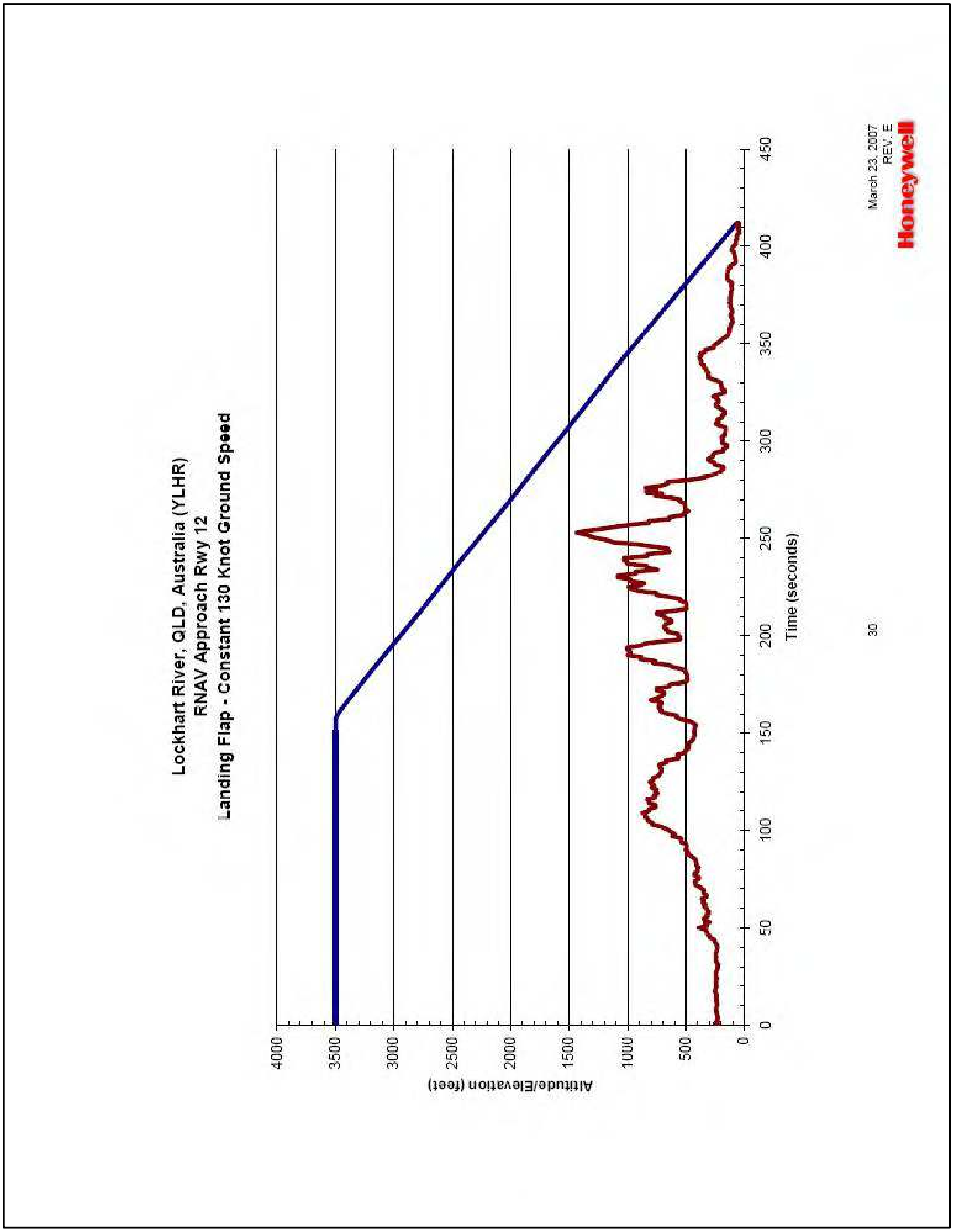
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, and the landing flaps were set soon after the landing gear was down. The scenario is same as Case 1, except a constant ground speed of 130 knots was used throughout the approach.

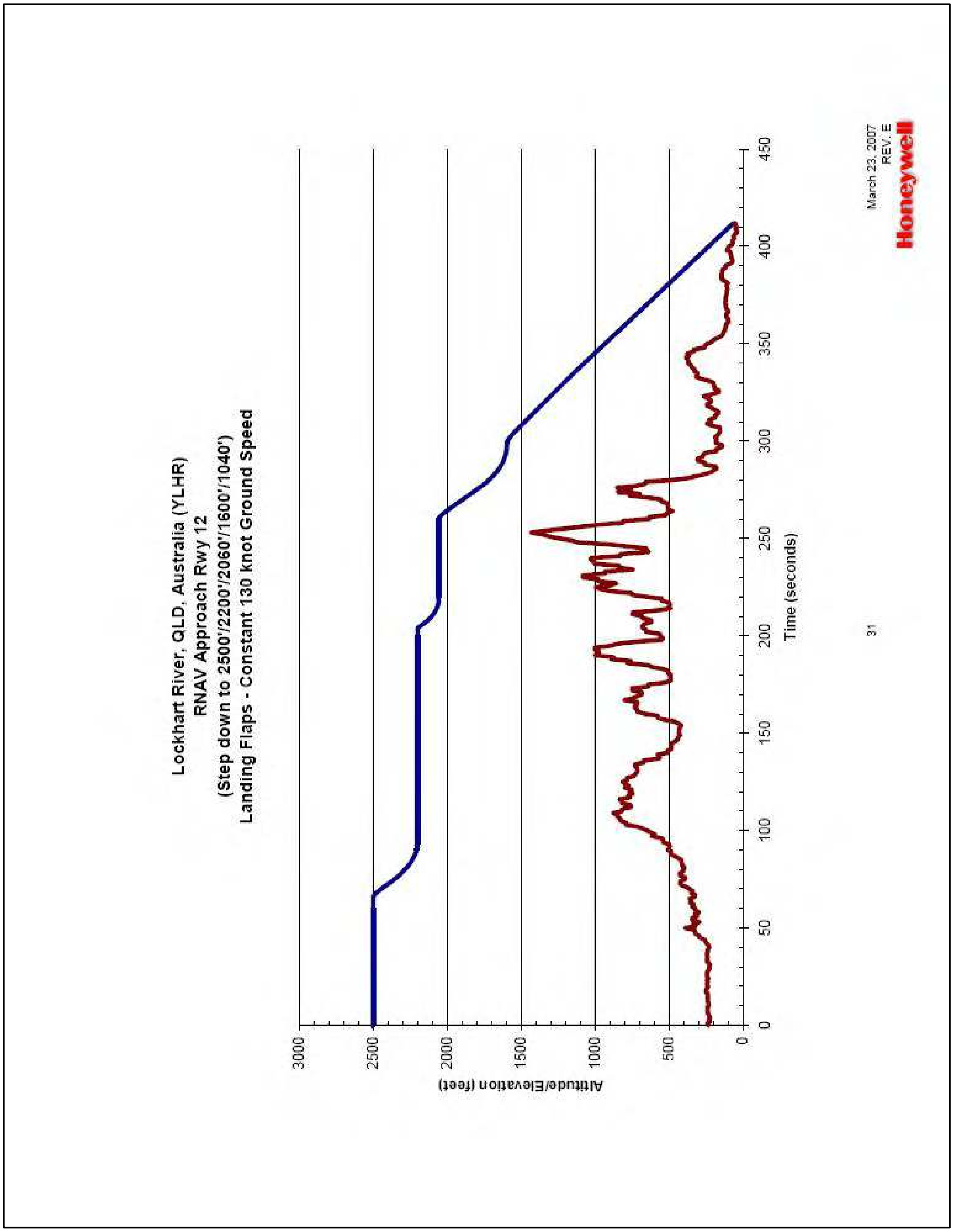
Case 3A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -800 fpm

No alert or warning occurred during the entire approach.

Case 3B:
Step down altitude: 2500' / 2200' / 2060' / 1600' / 1040'
Descent Rate: -1200 fpm

No alert or warning occurred during the entire approach.


Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
Landing Flap - Constant 130 Knot Ground Speed
Altitude/Elevation (feet)
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
Time (seconds)
30
March 23, 2007
REV. E
Honeywell


Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
(Step down to 2500'/2200'/2060'/1600'/1040')
Landing Flaps - Constant 130 knot Ground Speed
Altitude/Elevation (feet)
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
Time (seconds)
31
March 23, 2007
REV. E
Honeywell

Case 4

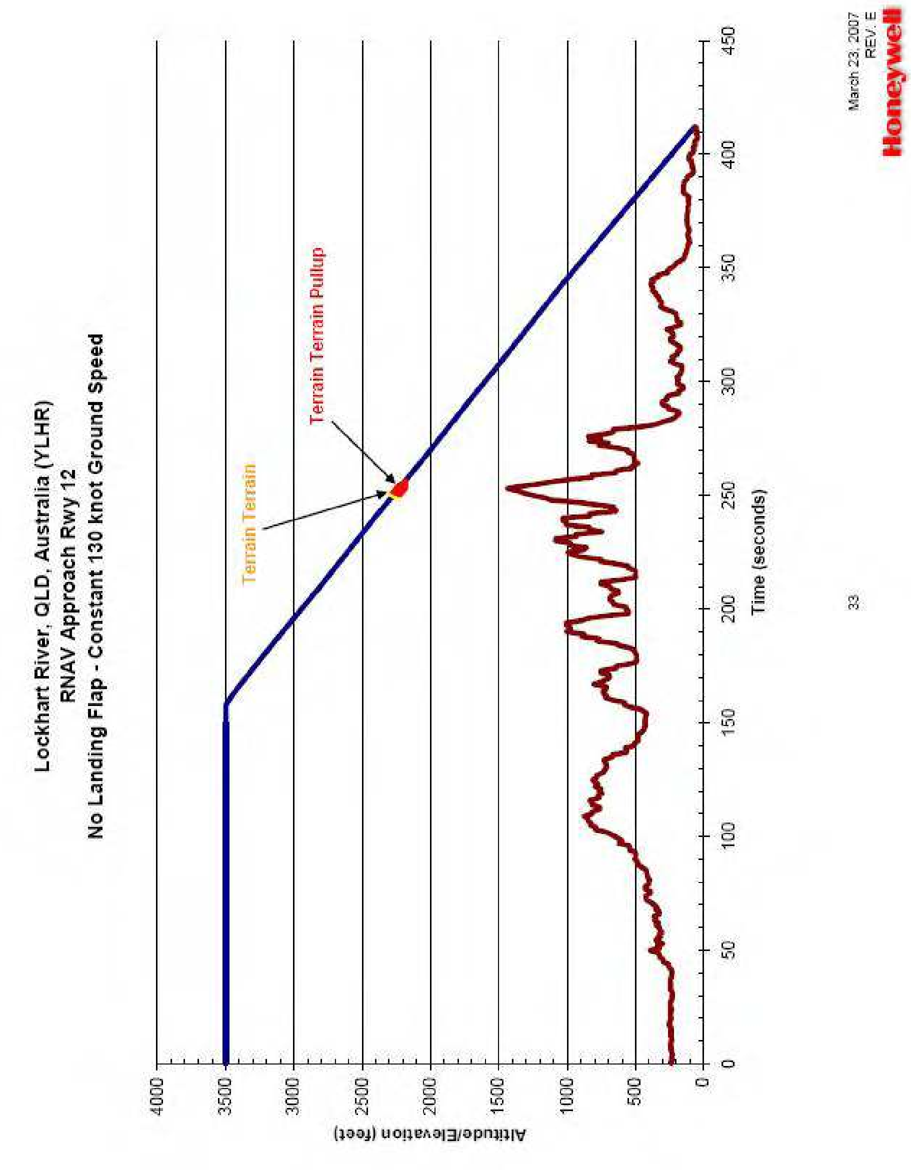
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, but the landing flaps were not set. The scenario is same as Case 2, except a constant ground speed of 130 knots was used throughout the approach.

Case 4A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -800 fpm

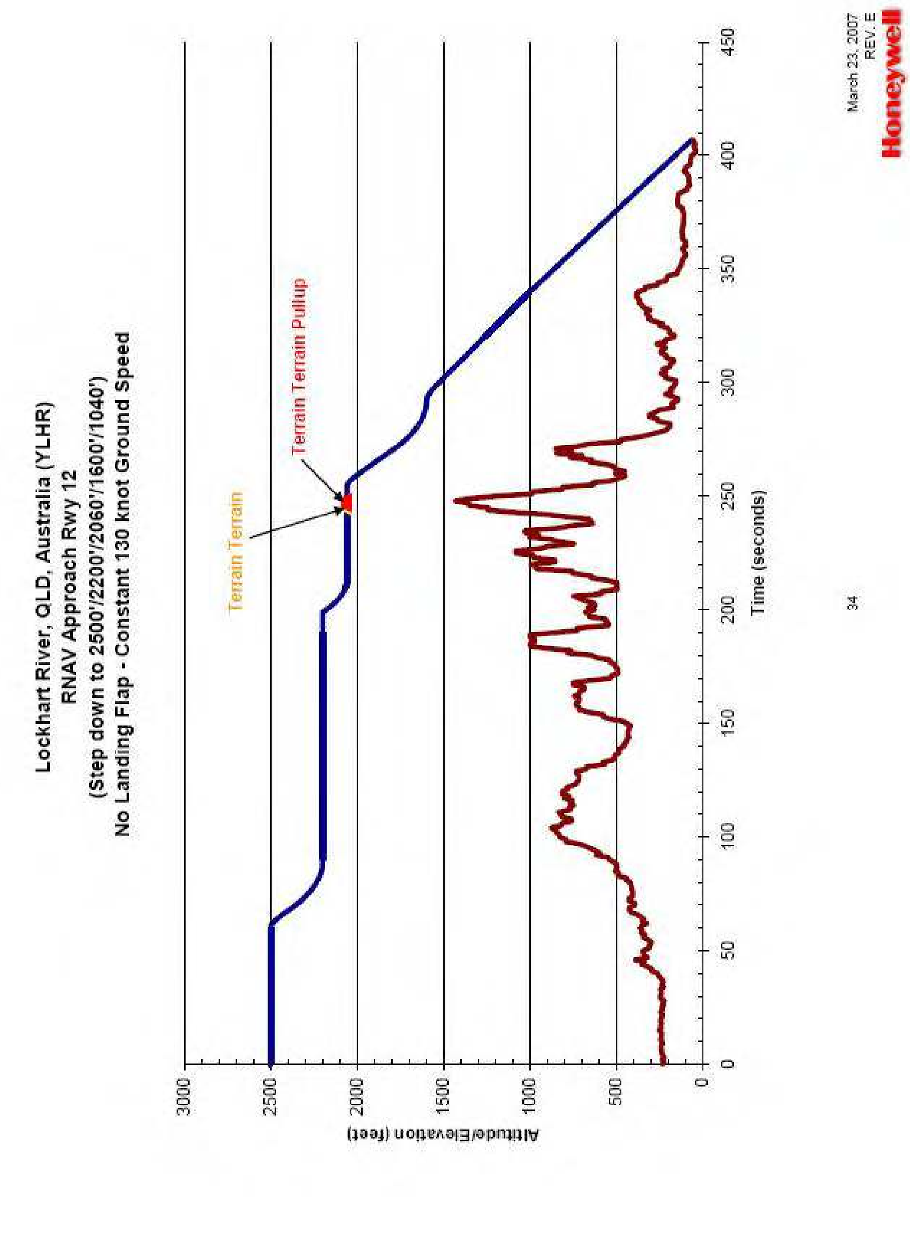
Mode 2A alerts/warnings were issued as shown in the plot below.

Case 4B:
Step down altitude: 2500' / 2200' / 2060' / 1600' / 1040'
Descent Rate: -1200 fpm

Mode 2A alerts/warnings were issued as shown in the plot below.



Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
No Landing Flap - Constant 130 knot Ground Speed
Altitude/Elevation (feet)
Time (seconds)
Terrain Terrain
Terrain Terrain Pullup
March 23, 2007
REV. E
Honeywell
33



Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
(Step down to 2500'/2200'/2060'/1600'/1040')
No Landing Flap - Constant 130 knot Ground Speed
Terrain Terrain
Terrain Terrain Pullup
Altitude/Elevation (feet)
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
Time (seconds)
34
March 23, 2007
REV. E
Honeywell

RNAV approach to runway 12 using FDR data from previous flight

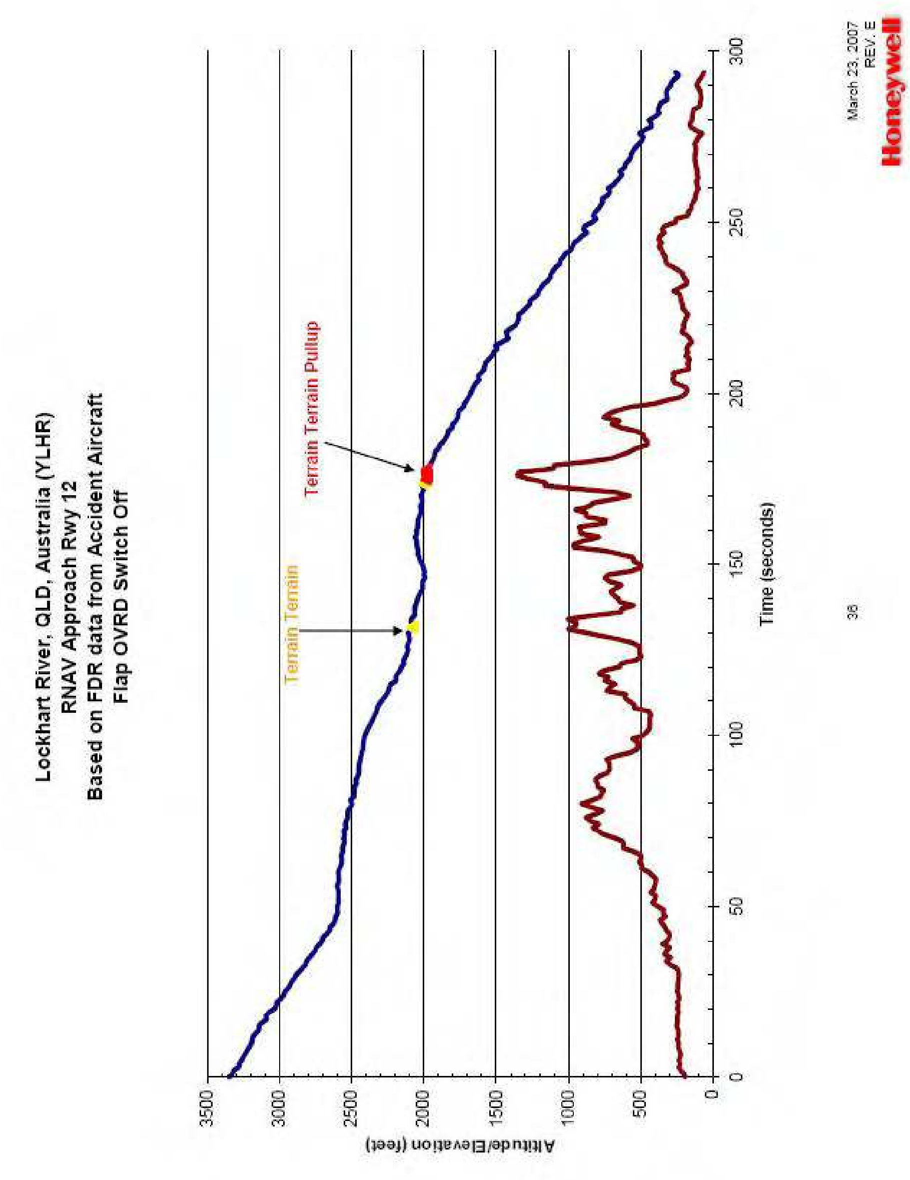
The accident aircraft has made a previous successful approach to runway 12. This data was captured on the flight recorder. This data was used to simulate the GPWS. As was done for the actual accident simulation presented above the radio altitude values where derived from a digital elevation model (DEM).

Case 1A – Flap OVRD Switch Off

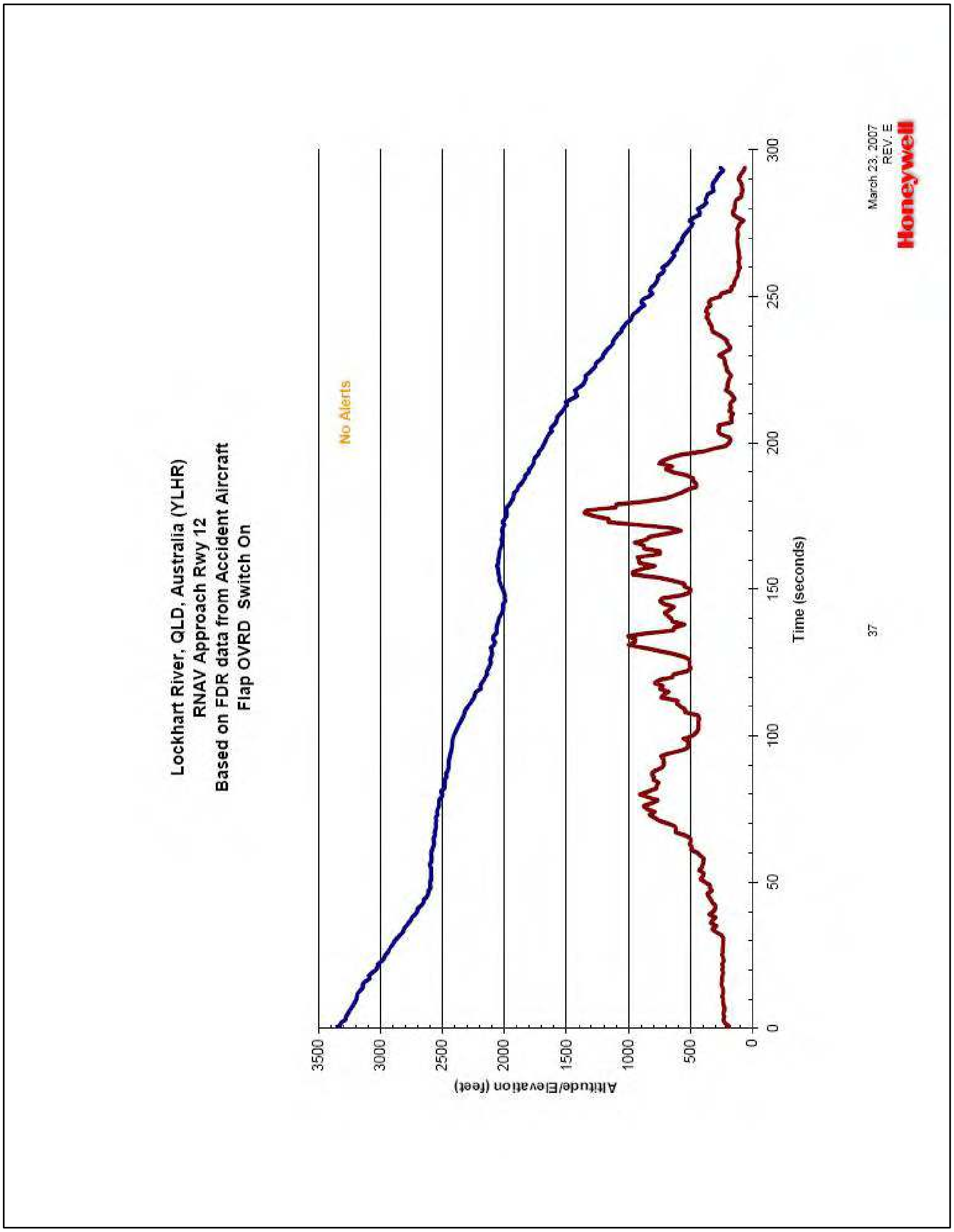
Mode 2A alerts/warnings were issued as shown in the plot below.

Case 1B – Flap OVRD Switch On

No alerts



Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
Based on FDR data from Accident Aircraft
Flap OVRD Switch Off
Terrain Terrain
Terrain Terrain Pullup
Altitude/Elevation (feet)
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
Time (seconds)
36
March 23, 2007
REV. E
Honeywell


Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
Based on FDR data from Accident Aircraft
Flap OVRD Switch On
No Alerts
Altitude/Elevation (feet)
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
Time (seconds)
37
March 23, 2007
REV. E

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APPENDIX G: EXTRACTS FROM TRANSAIR'S OPERATIONS MANUAL – GPS NON PRECISION APPROACH, DESCENT AND GPWS PROCEDURES

8.3.2.6 GPS Non Precision Approaches

GPS NPAs are stand-alone approaches and do not overlay, ie match a ground based approach. This means it is not possible to monitor the approach using a ground based aid. It is important, therefore, that pilot(s) remain situationally aware throughout the approach.

Pilot(s) should ensure the correct switching for H.S.I information. Where the aircraft is operated by two pilots, all GPS switching shall be carried out by the NFP on confirmation from the FP.

NOTE: **Activation of the GPS NPA will cancel the active plan and install the NPA as the active plan. Tracking will then be provided to the initial approach fix chosen by the pilot.**

8.3.2.7 The NPA Approach

Notes:

1. The following paragraphs are 'generic' to NPA approaches and are included to indicate the steps and actions required to execute a typical NPA.

2. Procedures specific to the GPS/NPA fitted to the aircraft are to be found in the aircraft Part B or the GPS handbook carried in the aircraft.

The external GPS APPR switch should be set to the ARM position 30 NM from the destination aerodrome. Once the approach is armed, the unit will provide a transition from 5.0 to 1.0 NM CDI scale, and down to 0.3 NM within 2.0 NM of the FAF.

Arm Approach Mode

- The Altimeter setting of the destination aerodrome shall be entered. You will be prompted.

Need pres – press Nav

Alt 5120 f/t prs:
1015hpa

S 27 23.000 E 153 07 .120
F/r WPT YBBN

Failure to enter an accurate QNH will affect the GPS accuracy.

- The preferred IAF shall be selected from the approach page:

BN RWY 14 GPS APPR
BBNWA
BBNWB
BBNWC

- Sequencing of the approach waypoints is now automatic, providing the aircraft is flown via the "fly- by" and "fly-over" waypoints.

- Within 2 nm of the final approach fix an automatic prediction of RAIM will be made. Should the prediction not be valid the following annunciation will be made.

No RAIM FAF to MAP

If this annunciation is observed, the "APPR" annunciation will not illuminate passing the FAF and the CDI scale will remain at +/- 1.0NM.

- A missed approach may be initiated at anytime after passing the FAF by pressing the D→ Key and checking the MAP is the next waypoint.

- Provided the RAIM warning ceases when the missed approach is selected, the GPS can be used for the missed approach.

- Should the RAIM warning remain then an alternate means for the missed approach shall be used, including DR.

8.3.2.8 Limitations

For operations using GPS, the following requirements shall be met:

Aircraft

i. current AFM Supplement
ii. Company SOPs and GPS manual shall be accessible during flight

Flight Crew

Flight crew are to:

- hold endorsements for GPS Primary means navigation and GPS/NPA
- have been assessed as proficient
- meet the GPS recency requirements

8.3.2.9 Standard Operating Procedures

Preflight

i. check if alternate is required
ii. obtain a GPS RAIM prediction for destination via AVFAX/NAIPS
iii. check current GPS NOTAM information
iv. check AFM for current supplement
v. check for GPS operating procedures
vi. check data card is valid for entire flight
vii. conduct RAIM prediction for destination aerodrome
viii. check Flight Plan is correctly loaded, with the last route segment being **the aerodrome** if intending to conduct a GPS NPA
ix. check destination GPS position agrees with Approach plate position
x. check validity of all flight plan positions (**both crew shall agree on this confidence check**).
xi. ensure "Day VMC use only" is not annotated on the approach plate

En route

i. if not previously checked, conduct a check of flight plan position against en-route chart prior to arrival at position**. Both crew shall agree on this confidence check**
ii. 15 minutes prior to top of descent, conduct a further RAIM prediction for destination.
iii. conduct approach briefing. Emphasis is to be placed on the operation and modes used.

Descent

i. The FP shall call for GPS selections. The NFP shall action selections on confirmation from the FP.

Note: Activation of the GPS NPA will cancel the active Flight Plan and tracking guidance will be to the Initial Approach Fix selected.

Note: Distance information will be to the next position in the approach <u>not</u> the destination.

2.8 Cruise and Descent

Company pilots shall conduct appropriate altimeter cross-checks when passing through the transition altitude or transition level on climb or descent.

Icing Conditions – Company Turboprop powered aircraft

If icing conditions are encountered or ice has built up on the intakes select both ignition switches to override. Select one intake/prop heat on once intake is free of ice select other intake/prop heat – when both engines have been visibly deiced and ice shedding has ceased, return ignition switches to the normal position.

Select de-icer boots when ice builds up to ½ - 1 inch deposits. When ice breaks off select the de-icer boots off again. If using in the automatic mode, ensure the ice builds up to ½ inch thickness between cycles.

Select the windshield heat to high only if necessary to clear ice from the windscreen after descent to warmer altitudes has not melted ice on low setting.

Trend Data & Troubleshooting

En route, Company pilots shall record engine data both in flight and on the ground to aid maintenance in finding an instrument indication error or an engine problem. General guidelines are discussed which emphasize the need for regular trend data recordings, for an engine stabilisation period and for consistency in setting bleed and accessory loads while recording.

In-flight trend data should be recorded as often as possible, but on a regular basis. Typically, this is at least once every day or every 4-6 hours. Pilots should avoid intermittent periods of data recording since this may complicate trend interpretation or may bias trends to a fixed period in time.

Data should be recorded during the cruise after the engine has stabilised for 5 minutes or more. Best results are achieved if data can be taken at similar flight conditions.

- Altitude +/- 5000 feet of typical cruise altitude
- Airspeed +/- 10 knots of typical cruise airspeed
- Engine RPM +/- 10% RPM of typical engine cruise setting
- Stabilise engine for a minimum of 5 mins prior to taking data

Nominal bleed and accessory power loads on both engines should be set prior to beginning the stabilisation period. Use of anti-ice bleed, or recording trend data in icing conditions, is not recommended. All pilots shall follow the following procedures when recording trend data in order to maintain a consistent trend program.

- Engine bleed set ON for normal pressurisation
- Engine anti-ice OFF
- Ignition OFF
- Surface de-ice OFF
- Both generators ON and under normal load

Having satisfied the stabilisation requirements, the parameters listed on the engine trend data sheet shall recorded. Special attention should be given to methods used in reading aircraft gauges. Gauges with poor resolution or gauges located in positions difficult to read can lead to data that may be misinterpreted. The parallax effect may also contribute to misinterpreting trends.

Descent

The FP shall determine the descent point. The NFP shall obtain the surface information from the ATIS, AWIB or TAFOR. He shall complete the landing data card and advise the FP who will cross check the details.

When setting the destination QNH, the priority for the selection of the QNH source shall be as follows:

1	ATS	4	TAF
2	ATIS	5	Area QNH
3	AWIB		

Whenever a new QNH is set, the altimeters shall be cross checked. The lowest reading altimeter shall be used as the reference for any instrument approach minima.

Descent point shall be calculated by multiplying the number of thousands of feet above destination airfield elevation by 2. This distance is valid provided there is no terrain, weather or ATC restrictions. If such restrictions exist, appropriate adjustments may be required. Descent will normally be made at Vmo –10 kts. In Class G airspace reduce to 210 kts below 5,000 ft. ATC may required a 240 kts descent from up to 60 nm from touchdown. This profile is achieved by initially descending at cruise power. High speed descents must be discontinued when:

- approaching areas of known or forecast turbulence
- terminal airspace below 10,000 ft where 250 kt restrictions are in force (see Jeppesen)

During the descent, the NFP shall monitor the cabin rate of descent and the descent profile. He shall also call approaching all assigned altitude when 1000 ft above. When operating OCTA, the lowest safe altitude shall be set in the assigned altitude system. A descent below LSALT shall not be carried out until the crew are satisfied they are in visual or VMC conditions.

2.9 Visual Approach

The pilot need not commence or may discontinue an instrument approach procedures provided:

By Day – within 30 nm of destination aerodrome at an altitude not below the LSALT/MSA for the route segment, the appropriate step of the DME Arrival Procedure, or the MDA for the procedure being flown, the aircraft is established

a. Clear of cloud; and
b. In sight of ground or water; and
c. With an in flight visibility not less than 5000 m; and
d. Subsequently can maintain 'a' 'b' and 'c' above at an altitude not less than 500 ft above terrain or water to within the circling area.

By Night – at an altitude not below the LSALT/MSA for the route segment, the appropriate step of the DME Arrival Procedure, or the MDA for the procedure being flown, the aircraft is established:

e. Clear of cloud
f. In sight of ground or water;
g. With an inflight visibility not less than 5000 m; and
h. Within the circling area

i. Within 5 nm (7 nm for a runway equipped with an ILS) of the aerodrome aligned with the runway centreline and established not below the "'on slope' indication on the VASIS; or
j. Within 10 nm (14 nm for runways 16 L and 34 R at Sydney) of the aerodrome, established not below the glideslope with less than full scale azimuth deflection,

2.10 Instrument Approach

Prior to any instrument approach, the PIC shall ensure a 'crew briefing' is completed in accordance with the following.

Prior to commencing the descent, the crew shall review the approach chart. The FP shall brief the NFP on the following:

- Title and validity of the approach chart
- Any departure from routine maneuvering to the initial approach altitude
- Holding pattern direction, altitude, time and DME limits
- Commencement altitude
- On ILS/LLZ the 'glide path' check altitude and position
- On VOR and NDB approach, altitude at the procedure turn
- All altitude limitations during the approach
- MDA or DH altitude and visibility
- Circling minima and any circling restrictions
- Field elevation or runway threshold elevation
- Missed approach heading and altitude
- For circling approach, the circuit entry, direction and minimum circling altitude.

The FP shall call for the required navigation aids to be tuned and identified as required.

When an ILS or VOR approach is to be flown, the FP shall use the flight director (where fitted). The NFP shall monitor the approach and call any deviation from the approach procedure**.**

At 400 ft AGL on final approach the NFP shall call *"Check Gear Down"*. The FP shall check that he/she has 3 green gear lights and respond *"Three Greens"*. The NFP shall the call *"Flaps ..."* and confirm that the aeroplane has been cleared to land, or if in Class G airspace that the runway is clear.

The landing checklist shall be completed no later than the OM or 1000' AGL in VMC.

During an instrument or a visual approach, the NFP shall monitor the FP and advise him of any of the following:

- For NDB approach tracking error in excess of 5 degrees
- For VOR approach tracking error in excess of 1 dot
- For ILS approach tracking or glide path error in excess of 1 dot
- Altitude error in excess of 100 feet

- Nominated indicated airspeed deviation in excess of 10 kts
- Rate of descent on final in excess of 1000 feet per minute
- Approaching instrument approach altitude restriction
- Altitude of 500', 200' and 100' above the minima altitude if IMC
- Approaching minima
- At the minima (or before)
  - If visual '*Runway Visual and position*'
- At the minima and not visual
  - '*Minima not Visual – Go round*'

8.3.5 Ground Proximity Warning System Procedures

Company Requirements

All Company turbine engine aeroplanes operated under the IFR that:

- carry 10 or more passengers

shall be fitted with a serviceable GPWS.

Avoidance Procedures

By day only, if conditions are VMC, all alerts received by the crew shall be evaluated by visual inspection of the flight path and the approach being conducted. Should avoidance measures be required, the PIC shall ensure the necessary actions are taken immediately.

By night and in IMC, FP shall immediately adopt the following procedures:

Position	**Warning**	**Action**
After takeoff/go round	'DON'T SINK'	Ensure correct climb attitude is selected and continue climb at V2 or Vxse until safe height.
Final Approach	'MINIMA'	If visual land. If not visual, complete Missed Approach Procedure
Instrument Approach	'SINK RATE' or 'BELOW G/S'	Check approach profile and prepare for missed approach.
Descent	'SINK RATE' or	Immediate apply go-around power and set the

'PULL UP' go-around attitude

Company pilots shall follow the above procedures then advise ATC of the 'GPWS WARNING' and revise clearances or approach expectations.

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APPENDIX H: SUMMARY OF CASA OVERSIGHT OF TRANSAIR FROM 1998 TO 7 MAY 2005

The following table summarises CASA's regulatory oversight of Transair for the period from 1 January 1998 to 7 May 2005, including significant events relating to the issuing of, and variations to, Transair's AOC, along with audits and their findings, and other significant events relating to the surveillance of Transair in a timeline sequence. Where a reference has been made to an AOC being issued, this indicated that a variation had been made to the AOC and the original expiry date was still valid. Where a reference has been made to an AOC renewal, this indicated that a new expiry date for the AOC had been made.

Date	Event and Comments
16/1/1998	CASA wrote to all AOC holders (including Transair) outlining their legal responsibilities under the *Civil Aviation Act 1988*.
1/6/1998	AOC 426646-3 issued to Transair for the period 1/6/1998 to 31/10/1998. The certificate was reissued to allow the addition of a helicopter type to the operation.
18/5/1998	An operator port inspection was carried out by CASA of Transair's helicopter operations. The inspection resulted in 3 NCNs being issued. The following is a list of areas indicated by NCN: • 1 x NCN dealt with maintenance requirements prior to flight • 1 x NCN dealt with carriage of prescribed documents on an aircraft • 1 x NCN dealt with operations manual requirements The inspectors who conducted the inspection produced a summary report and included the following recommendations: • The number of recurring NCNs gives CASA cause for concern. • Transair do not appear to have adequate control of the helicopter operations. • The chief pilot/managing director is expanding his operation into Papua New Guinea (PNG) and is unavailable much of the time. • A significant number of meetings between CASA and [chief pilot] have failed to adequately address the problems. • Recommend that consideration be given to removing helicopter operations from the Lessbrook Pty Ltd (Transair) AOC.
17/6/1998	Following an operator meeting with Transair, CASA noted that the Transair chief pilot was also the chief pilot of the PNG operation.
17/7/1998	Transair requested the addition of Metro III and Metro 23 aircraft to their AOC. CASA did not act on the addition of the Metro III as this was already on the Transair AOC.
20/7/1998	CASA indicated in an email that it had concerns not only with Transair's helicopter operation but also with Transair moving into international operations and the fact that the Transair chief pilot was spending a lot of time away in PNG as a result. The email indicated that part of the reason

Date	Event and Comments
	for the increased surveillance in the coming year would be due to the chief pilot's expected absence in PNG working with Trans Air PNG.
20/7/1998	CASA summary of surveillance carried out on Transair indicated that the operator had improved helicopter operations considerably; however they would still be subject to increased surveillance in the coming year.
20/7/1998	AOC 426646-4 issued to Transair for the period 20/7/1998 to 31/10/1998. The certificate was reissued to allow the addition of Metro 23 aircraft to the operation.
31/7/1998	CASA became aware of another operator being involved in an incident using an aircraft that was operating on Transair's AOC without CASA's knowledge. The aircraft was a Metro III.
3/8/1998	Note on CASA file indicating that it had some concern about the Transair chief pilot – the note indicated he was 'spread very thin (with his operations both here and in PNG).' The note indicated that the amount of surveillance at the helicopter operation would decrease so that increased surveillance of Transair's other activities could take place.
3/9/1998	CASA informed Transair that it would be conducting an unwarned audit the following morning. The reasons for the audit indicated that CASA had concern about the number of management personnel and the check and training organisation, given the diverse nature of the operations carried out by Transair. CASA also indicated that there have been several instances of passenger carrying operations being carried out under the Transair AOC, but the aircraft and crews belonged to other organisations who did not hold the appropriate approval under their AOCs.
11/9/1998	CASA wrote to Transair and indicated that as a result of the audit and other surveillance activities (ramp checks and spot surveillance) that it intended to impose further conditions on the Transair AOC. The further conditions specified that the aircraft to be operated under the AOC would be listed by type, registration and serial number. The letter also drew the Transair chief pilot's attention to the requirements of section 27, 28BD and 28BE of the *Civil Aviation Act 1988*.
23/10/1998	AOC 426646-5 issued for the period 23/10/1998 to 31/1/1999.
29/10/1998	AOC 426646-6 issued for the period 29/10/1998 to 31/1/1999. The AOC was changed to add a helicopter type and to permit media operations.
10/12/1998	AOC 426646-7 issued for the period 10/12/1998 to 31/1/1999. The AOC was changed to include the conduct of aerial work operations.
27/1/1999	AOC 426646-8 renewed for the period 27/1/1999 to 31/8/1999. The AOC was changed to remove a helicopter type no longer being used and the addition of an aircraft type.
30/3/1999	Transair applied for regular public transport (RPT) Operations to be added to its AOC. The application was to conduct RPT freight operations between Cairns and Port Moresby.

<table>
<tr><th>Date</th><th>Event and Comments</th></tr>
<tr><td>15/4/1999</td><td>The Transair chief pilot purchased a copy of the CASA Air Operator Certification Manual (AOC Manual).</td></tr>
<tr><td>7/6/1999</td><td>AOC 426646-9 issued for the period 7/6/1999 to 31/8/1999. The AOC was changed to allow the addition of an aircraft type.</td></tr>
<tr><td>1/9/1999</td><td>AOC 426646-10 renewed for the period 1/9/1999 to 31/8/2000. The AOC was changed to permit the following operations:
Charter operations in Papua New Guinea in VH-TFQ subject to the approvals issued by the Papua New Guinea government.</td></tr>
<tr><td>3/9/1999</td><td>Transair supplied additional information in support of their application to have RPT freight operations added to their AOC.</td></tr>
<tr><td>24/9/1999</td><td>Transair indicated in a letter to CASA that they would be fitting predictive ground proximity warning systems (GPWS) to a number of Transair aircraft. This included the Metro aircraft that were on its AOC. The letter also indicated that crew would be trained via a controlled flight into terrain awareness video and that the Transair Operations Manual would be amended to reflect the training. There was no date indicating when this would be completed.</td></tr>
<tr><td colspan="2">Commencement of first RPT cargo only international operations</td></tr>
<tr><td>29/10/1999</td><td>AOC 426646-11 issued to Transair for the period 29/10/1999 to 31/8/2000. This AOC was issued to allow the inclusion of RPT cargo only international operations. The Metro 23 aircraft type was added to the AOC.
The CASA Flying Operations AOC Checklist regarding the Transair application indicated that, of the 50 items on the checklist, five had been marked not applicable and the remainder noted as ‘nil change’.
The flying operations inspector, who signed that checklist on 30 September 1999, recommended that the AOC be issued as there was no change to the operation other than the reclassification to RPT and that the operation ‘had been running for two years on a charter basis, with no significant deficiencies reported’.
The CASA Airworthiness AOC Checklist, signed by an airworthiness inspector on 1 October 1999, contained 24 items which were noted as ‘nil change’, apart from two items noting that the formal application was complete and a compliance statement was not required.
There was no record on CASA files that some of the procedures specified in the AOC Manual had been followed, such as assessment of the suitability of Transair’s operations manual for RPT operations, inspection of Transair’s facilities at the aerodromes to be used and the conducting of proving flights or CASA observation flights on the proposed RPT routes.</td></tr>
<tr><td>6/12/1999</td><td>CASA conducted unscheduled surveillance of Transair at Cairns to ascertain if the correct aircraft was being used on the International RPT freight operation to Papua New Guinea. It was subsequently discovered that Transair were using an unapproved aircraft on the freight operation.</td></tr>
</table>

Date	Event and Comments
11/12/1999	CASA gave approval to Transair to conduct passenger carrying operations between Christmas Island and Jakarta, Indonesia. This approval was in the form of an instrument rather than a reissue of Transair's AOC.
14/12/1999	As a result of surveillance and a meeting with the company, CASA wrote to Transair and indicated that it was removing international RPT operations from Transair's AOC.
15/12/1999	AOC 426646-12 issued for the period 15/12/1999 to 31/8/2000. The AOC was changed to allow the following operations: • Operations between remote islands The following was removed from the AOC: • RPT cargo only international operations
20/12/1999 to 23/12/1999	First systems based audit of Transair by CASA. The audit covered the following elements of Transair's operation: • Helicopter operations • International operations • Management control • Maintenance control The audit team consisted of: • 3 x Flying Operations Inspectors • 1 x Airworthiness Inspector The audit resulted in 22 non-compliance notices (NCNs) and 17 audit observations (AO) being issued. The following is a list of areas indicated by NCN and AO. • 1 NCN dealt with inadequate corporate oversight and management, and inadequate numbers of qualified personnel, as outlined in Section 28BE and Section 28BF of the *Civil Aviation Act 1988* • 1 NCN dealt with flight crew record keeping as outlined in Section 28BH of the *Civil Aviation Act 1988* • 1 NCN dealt with imposed conditions on an AOC • 7 NCNs dealt with the *Transair Operations Manual* • 1 NCN dealt with flight check systems in aircraft • 1 NCN dealt with maintenance schedules • 1 NCN dealt with maintenance certification requirements • 1 NCN dealt with maintenance on aircraft • 1 NCN dealt with flight time records • 3 NCNs dealt with AOC requirements • 1 NCN dealt with aircraft endorsements • 1 NCN dealt with emergency procedures • 2 NCNs dealt with flight and duty time • 5 AOs dealt with the *Transair Operations Manual*

Date	Event and Comments
	• 6 AOs dealt with maintenance control • 2 AOs dealt with organisational structure • 2 AOs dealt with document control • 1 AO dealt with aircraft performance • 1 AO dealt with safety management
23/12/1999	AOC 426646-13 issued for the period 23/12/1999 to 31/8/2000. The AOC was changed to allow the addition of an aircraft type.
7/1/2000	Transair responded to a number of the NCNs raised during the December 1999 audit and indicated among other things in the response: It is our intention to introduce a Quality Assurance System to ISO 9001 standard (or the year 2000 equivalent) incorporating a safety system modelled on the examples discussed in the CASA publication 'Aviation Safety Management An Operator's Guide'.
14/1/2000	As a result of the December 1999 audit and the extent of non-compliance found, CASA drafted a show cause notice against Transair's chief pilot. In a meeting with the chief pilot an acceptable alternative course of action was agreed to by CASA. This course of action included: • The establishment of a position of Quality Manager to introduce and manage a comprehensive safety management system within the company. • Engagement of an external organisation to train all company managers in quality system safety, including auditing. • CASA to provide an expert to present system safety concepts to all company managers. • All amendments to company manuals as a result of the recent audit to be completed within 30 days. • Current manuals found to be of poor quality even after engaging a contract writer. All manuals therefore to be totally re-written and based on JAR 119/121 format and meeting all current CASA requirements. • Weekly progress reports to be provided to CASA to confirm progress of above items. This is to be followed by monthly progress/assessment meetings for 3 months in order to ensure satisfactory progress is being made. • Special audits to be undertaken at the end of March to confirm that Company meets AOC issue standards. Normal scheduled audit to be undertaken in mid-May. Following the meeting CASA again noted on file its concern that most of the problems stemmed from the chief pilot 'attempting to personally do too much'. At the meeting the chief pilot indicated to CASA that he was fully aware of the seriousness of the matter and was willing to commit resources to meet his safety obligations. CASA agreed that Transair would be given the opportunity to fulfil the action plan in order to bring the company into full compliance with the legislation. The CASA manager responsible indicated that he would monitor this process and would personally attend the monthly progress meetings. Examination of the CASA files revealed no objective evidence that, apart from the advertisement for the position of Safety Officer and the late

Date	Event and Comments
	lodgement of the *Transair Operations Manual* (see 3/8/2000), any of these actions appeared to have been complied with by Transair.
17/1/2000	Transair wrote to CASA outlining the steps that they would be taking comply with the alternative course of action. This letter indicated that an advertisement for the position of Safety Officer and Quality Control Manager would be advertised the following weekend. It also indicated that they were meeting with an external consultant to provide training to all relevant managers. The letter requested that CASA provide a specialist to deliver a system safety course with Transair's managers.
20/1/2000	Transair provided evidence of advertising the position of Safety Officer to CASA.
25/2/2000	Transair nominated the current maintenance controller for approval. CASA subsequently approved the nominated person.
March 2000	CASA completed a safety trend indicator (STI) assessment of Transair. The STI revealed the following findings: • Key personnel experience • Procedure/process change • Organisation size change • Requests for corrective action (RCA) • Difficult operating conditions • Performance limit • Inadequate documentation • Inadequate processes in practice • Immature safety system • No corrective action system The STI weighted score was 17.25. The CASA surveillance procedures indicated that a weighted score above 7 was classified as a 'high risk'.
12/5/2000	Transair forwarded an AOC legislation compliance statement to CASA.
19/5/2000	Transair requested variations to AOC. These variations covered the following subject areas: • The addition of international charter for all regions outside Australia. • The addition of international airline licence to cover Cairns – Port Moresby – Gurney – Cairns. • Changes to aircraft registrations. • Addition of helicopter types. • Removal of an aircraft type. • Addition of animal control and sling load operations in helicopters to list of approved operations.
17/2/2000 to 11/9/2000	Transair applied for and received variations to its AOC on a number of issues including:

Date	Event and Comments
	• Banner towing operations • Aerial culling operations • Addition and removal of several aircraft and types to the AOC • Permission to carry dangerous goods in aircraft not approved to carry them
22/5/2000	CASA wrote to Transair and informed them that a rewrite of the *Transair Operations Manual* in the new CASR 119 format was not illegal as had been indicated to Transair by a contract manual writer.
5/6/2000 to 11/6/2000	Scheduled audit of Transair by CASA. The audit covered the following elements of Transair's operation: • Management responsibility and authority • Training – dangerous goods • Load control • Routes and Ports • Ground Handling • Maintenance control • Special processes – dangerous goods • Internal audit • Incident recording and reporting The audit team consisted of: • 1 x Airworthiness Inspector • 1 x Dangerous goods inspector The audit resulted in 6 RCAs being issued, along with 11 AOs and 3 code B Aircraft Survey Reports (ASRs). The following is a list of areas indicated by RCA, AO and ASR: • 6 RCAs dealt with dangerous goods • 3 ASRs dealt with aircraft maintenance • 1 AO dealt with dangerous goods training • 4 AOs dealt with dangerous goods ground handling • 1 AO dealt with management responsibility • 1 AO dealt with routes and ports • 1 AO dealt with ground handling • 1 AO dealt with maintenance control • 1 AO dealt with internal audits • 1 AO dealt with incident recording and reporting
10/7/2000	CASA wrote to Transair asking for an update on the progress of the rewrite of the company manuals. This request is to allow the addition of an aircraft to the AOC.
3/8/2000	Rewrite of *Transair Operations Manual* sent to CASA.

<table>
<tr><th>Date</th><th>Event and Comments</th></tr>
<tr><td>31/8/2000</td><td>AOC 426646-14 issued for the period 31/8/2000 to 31/10/2000. The AOC was changed to remove an aircraft type that was no longer being operated.</td></tr>
<tr><td>26/10/2000</td><td>AOC 426646-15 renewed for the period 26/10/2000 to 31/10/2001. There were no changes from the previously issued AOC.</td></tr>
<tr><td>27/3/2001</td><td>Transair nominated an individual to act in position of Transair deputy chief pilot to assist when the current Transair chief pilot was absent. The individual was assessed by CASA and found to be unsatisfactory at interview.</td></tr>
<tr><td>27/3/2001 to 30/3/2001</td><td>Scheduled audit of Transair carried out by CASA. The audit covered the following elements of Transair’s operation:
Document control
Maintenance
Maintenance control
Company operations manual
The audit team consisted of:
1 x Airworthiness inspector
The audit resulted in 2 RCAs and 8 AOs being issued. The following is a list of areas indicated by RCA and AO:
1 RCA dealt with maintenance control manuals
1 RCA dealt with defect recording
6 AOs dealt with document control
2 AOs dealt with maintenance control</td></tr>
<tr><td>7/6/2001</td><td>Transair requested variations to its AOC. These variations covered the following subject areas:
The addition of international charter for all regions outside Australia.
The addition of international airline licence to cover Cairns – Port Moresby – Gurney – Carins.
Changes to aircraft registrations.
Addition of helicopter types.
Removal of an aircraft type.
Addition of animal control and sling load operations in helicopters to list of approved operations.</td></tr>
<tr><td>21/8/2001</td><td>CASA reapproved Transair’s check and training organisation under CAR 217 (3). CASA also indicated that the Transair Operations Manual was acceptable.</td></tr>
<tr><td>30/8/2001</td><td>Transair forwarded a new AOC legislative compliance statement to CASA.</td></tr>
</table>

Date	Event and Comments
September 2001	CASA completed a safety trend indicator assessment of Transair. The STI revealed the following findings: • Procedure/process changes • RCAs • Incident • Difficult operating conditions • Performance limit • Safety not priority • Immature safety system • No corrective action system • Inadequate communications The STI weighted score was 15.
3/9/2001 to 10/9/2001	Scheduled audit of Transair carried out by CASA. The audit covered the following elements of Transair's operation: • Control of records • Training pilots • LAME ground training • Handling • Information • Flight planning and dispatch • Rostering • Ground handling • Line operations The audit team consisted of: • 1 x Flying operations inspector • 1 x Airworthiness inspector The audit resulted in 2 RCAs and 10 AOs being issued. The following is a list of areas indicated by RCA and AO: • 1 RCA dealt with emergency procedures • 1 RCA dealt with operations manual contents • 2 AOs dealt with line operations • 1 AO dealt with quality and safety cell • 1 AO dealt with maintenance controller tasks • 2 AOs dealt with aircraft operational category • 1 AO dealt with aircraft maintenance category • 2 AOs dealt with maintenance systems • 1 AO dealt with equipment calibration
12/9/2001	Transair requested addition of RPT operations to PNG to be added to its AOC.

Date	Event and Comments
Commencement of Christmas Island (first international RPT passenger) operations	
17/9/2001	AOC 426646-16 issued for the period 17/9/2001 to 31/10/2001. The AOC was changed to allow the following operations: • RPT cargo operations in Papua New Guinea • RPT passenger operations between Christmas Island and Indonesia
Commencement of Bamaga (first Australian RPT passenger) operations	
17/9/2001	Data from Airservices Australia Customer Billing System (AvCharges) showed that from 17/9/2001 to 4/10/2001, Transair operated a Metro aircraft on the Cairns – Bamaga – Cairns route. From 22/9/2001 these flights were operated with a flight number.
2/10/2001	Transair requested addition of the Cairns – Bamaga – Cairns RPT route to its AOC.
5/10/2001	AOC 426646-17 issued for the period 5/10/2001 to 31/10/2004. Addition of Cairns – Bamaga – Cairns as an RPT route.
26/11/2001 to 30/11/2001	Scheduled audit of Transair by CASA. The audit covered the following elements of Transair's operation: • Control of documents • Line operations • Load control • Maintenance • Maintenance control • Performance • Routes and ports • Training pilots The audit team consisted of: • 1 x Flying operations inspector • 1 x Airworthiness inspector The executive summary of the audit indicated that because one other flying operations inspector had just completed 50 hours in-command-under-supervision flying with Transair, that this inspector would provide input into the audit on some elements. Examination of the CASA audit file did not reveal any objective evidence that this inspector had any input into the audit. The audit resulted in 4 RCAs and 6 AOs being issued. The following is a list of areas indicated by RCA and AO: • 1 RCA dealt with emergency procedures • 1 RCA dealt with maintenance control manuals • 1 RCA dealt with AOC conditions • 1 RCA dealt with emergency equipment and procedures • 1 AO dealt with the operations manual

Date	Event and Comments
	• 1 AO dealt with internal audits • 1 AO dealt with maintenance system manual • 1 AO dealt with certificate of registration holder • 2 AOs dealt with maintenance control manual
December 2001	CASA completed a safety trend indicator assessment of Transair. The STI revealed the following findings: • Organisation structure change • Procedure/process changes • Difficult operating conditions • Performance limit • Safety not priority • Immature safety system The STI weighted score was 12.
30/8/2002	AOC 426646-18 issued for the period 30/8/2002 to 31/10/2004. The AOC was changed to allow the addition of additional aerial work operations.
30/9/2002 to 4/10/2002	Scheduled audit of Transair carried out by CASA. The audit covered the following elements of Transair's operation: • Facilities and equipment • Ground handling • Information • Line operations • Maintenance • Management Responsibility and authority • Training pilot The audit team consisted of: • 4 x Flying operations inspectors The audit resulted in 7 RCAs and 3 AOs being issued. The following is a list of areas indicated by RCA and AO: • 1 RCA dealt with AOC conditions and requirements • 2 RCAs dealt with emergency equipment • 1 RCA dealt with aircraft operation requirements • 1 RCA dealt with AOC general conditions • 1 RCA dealt with maintenance schedules and instructions • 1 RCA dealt with refuelling of helicopters • 1 AO dealt with fuel policy • 1 AO dealt with operations manual • 1 AO dealt with helicopter landing sites

Date	Event and Comments
October 2002	CASA completed a safety trend indicator assessment of Transair. The STI revealed the following findings: • Organisation structure change • Procedure/process change • Difficult operating conditions • Performance limit • Safety not priority • Immature safety system The weighted STI score was 12.
19/12/2002	The pilot previously nominated as Transair deputy chief pilot in March 2001, was assessed as satisfactory and approval was granted for the person to act as Transair chief pilot when the approved chief pilot was away.
10/2/2003 to 14/2/2003	Scheduled audit of Transair by CASA. The audit covered the following elements of Transair's operation: • Line operations • Training – pilot The audit team consisted of: • 1 x Flying operations inspector The audit resulted in 1 AO being issued. The following is the area indicated by the AO: • 1 AO dealt with MEL procedures
May 2003	CASA completed a safety trend indicator assessment of Transair. The STI revealed the following findings: • Incident • Performance limit The STI weighted score was 3.
1/7/2003	Transair applied to have Cairns – Pormpuraaw – Kowanyama – Cairns added to its AOC as an RPT route.
1/7/2003	Transair applied to have Metro III VH-TFU added to AOC for RPT use.
15/7/2003	AOC 426646-19 issued for the period 15/7/2003 to 31/10/2004. Addition of VH-TFU to aircraft operated.
1/8/2003	AOC 426646-20 issued for the period 1/8/2003 to 31/10/2004. The AOC was changed to allow the addition of Pormuraaw and Kowanyama as RPT ports.

Date	Event and Comments
11/8/2003 to 22/8/2003	Scheduled audit of Transair carried out. The audit covered the following elements of Transair's operation: • Internal audit • Internal communications/consultation • Purchasing/subcontracting • Review of safety management systems • Training – pilots The audit team consisted of: • 1 x Flying operations inspector The audit resulted in 3 AOs being issued. The following is a list of areas indicated by AO: • 1 AO dealt with internal audit • 1 AO dealt with safety management • 1 AO dealt with insurance and pilot training
19/11/2003	Transair applied to have Gunnedah – Inverell – Sydney to be added to its AOC as an RPT route.
Commencement of NSW operations	
9/1/2004	AOC 426646-21 issued for the period 9/1/2004 to 31/10/2004. The AOC was changed to allow the following: • Addition of RPT ports – Gunnedah, Inverell, Sydney International • VH-TFQ and VH-TFG were added to AOC Schedule 2, Part 1 that listed aircraft approved for RPT operations • Addition of helicopter types for aerial work and charter operations
16/1/2004	AOC 426646-22 issued for the period 16/1/2004 to 31/10/2004. The AOC was changed to allow the addition of an aircraft type.
16/2/2004 to 20/2/2004	Scheduled audit of Transair carried out. The audit covered the following elements of Transair's operation: • Flight operations • Personnel, training and qualifications • Flight load manifest • Weight and balance control • Route structure The audit team consisted of: • 1 x Flying operations inspector The audit resulted in one RCA being issued. The following is a list of areas indicated by RCA: • 1 RCA dealt with air service operations - loading

Date	Event and Comments
27/2/2004	AOC 426646-23 issued for the period 27/2/2004 to 31/10/2004. The AOC was changed to allow the addition of Coonabarabran as an RPT port and an additional aircraft type.
31/3/2004	Transair applied to have Inverell – Brisbane – Inverell added to its AOC as an RPT route.
5/4/2004	Transair was given an exemption against CAO 82.3 5A.[40]
7/4/2004	AOC variation to add Inverell route approved by CASA Brisbane airline office acting manager using the standard form recommendation. The standard form recommendation indicated that all areas involved in the assessment of the application, including flying operations and airworthiness, had completed their assessment and were correct. The standard form recommendation was forwarded to the delegate in Canberra for approval and issue of the varied AOC.
8/4/2004	CASA airworthiness section completed their assessment of application to include Inverell route on AOC. The airworthiness inspector indicated that the application should not proceed as he was unsure that Transair had adequate systems of maintenance in place.
8/4/2004	AOC 426646-24 issued for the period 8/4/2004 to 31/10/2004. The AOC was issued by a delegate in Canberra. The AOC was changed to allow the addition of the following: • RPT passenger operations on the following route Inverell – Brisbane – Inverell No information addressing the airworthiness inspector's concerns was found on the CASA AOC file. The airworthiness inspector reported that he did not receive any feedback on the concerns that he had raised.
26/5/2004	Transair applied to have Inverell – Sydney – Cooma added to their AOC as an RPT route.
13/7/2004	AOC 426646-25 issued for the period 13/7/2004 to 31/10/2004. The AOC was changed to allow the addition of the following: • RPT passenger operations on the following route: Sydney – Cooma – Sydney
13/7/2004	Transair applied to have Inverell – Grafton – Taree – Sydney added to their AOC as an RPT route.
21/7/2004	CASA advised the Transair chief pilot that 'Under regulation 38 of the Civil Aviation Regulations 1988 you are hereby directed not to operate Fairchild SA 226-TC aircraft VH-TFQ in RPT operations until CASA is satisfied that the aircraft complies with the certification requirements of CAO 82.3 paragraph 6.1'. VH-TFQ had a certificate of airworthiness in the Normal category and it required a Transport category certificate to be operated on low capacity RPT operations.

40 CAO 82.3 (5A) dealt with the provision of radio communication confirmation systems at non-towered aerodromes at which RPT operations were being conducted.

Date	Event and Comments
23/7/2004	AOC 426646-26 issued for the period 23/7/2004 to 31/10/2004. The AOC was changed to allow the addition of the following: • RPT passenger operations on the following route – Grafton – Taree – Sydney • VH-TFQ was removed from AOC Schedule 2, Part 1 that listed aircraft approved for RPT operations • Correction to the type of operations
16/8/2004 to 20/8/2004	Scheduled audit of Transair carried out by CASA. The audit covered the following elements of Transair's operation: • Aircraft configuration control • Manuals • Flight operations • Personnel, training and qualifications • Route structures • Aircraft • Records and reporting systems • Maintenance organisation • Manual management • Air operator programmes and procedures • Operational release • Training programme • Approved routes and areas The audit team consisted of: • 1 x Flying operations inspector • 1 x Airworthiness inspector • 1 x Cabin safety inspector The audit resulted in 13 RCAs and 16 AOs being issued. As part of the audit, CASA inspectors conducted an en route inspection in Metro II aircraft VH-TFQ, operating an RPT flight on the Gunnedah – Taree – Sydney route. As a result of this inspection, one RCA and one AO were issued which made specific reference to VH-TFQ. The following is a list of areas indicated by RCA and AO: • 6 RCAs dealt with maintenance control manuals • 2 RCAs dealt with AOC requirements • 3 RCAs dealt with emergency procedures • 2 RCAs dealt with air service operations - loading • 1 AO dealt with defect reports • 1 AO dealt with maintenance release • 1 AO dealt with system of maintenance • 1 AO dealt with outsourced organisations

Date	Event and Comments
	• 1 AO dealt with maintenance training program • 1 AO dealt with communication systems • 2 AOs dealt with carry on baggage • 1 AO dealt with aircraft public address systems • 1 AO dealt with route structure and schedule • 1 AO dealt with flight dispatch • 1 AO dealt with document control • 2 AOs dealt with ground handling • 1 AO dealt with oxygen procedures and carriage of infants • 1 AO dealt with operational equipment
23/8/2004	Transair applied to have Lockhart River added to its AOC as an RPT port.
Commencement of Lockhart River operations	
28/8/2004	Data from AvCharges showed that from 28/8/2004 to 1/10/2004, Transair operated a Metro aircraft into Lockhart River on 14 days (this involved 22 landings). Most of these flights occurred on the RPT service from Cairns to Bamaga.
28/9/2004	A *Transair Hazard/Event Report* was submitted by the pilot in command of VH-TFQ operating an RPT flight on the Inverell – Gunnedah – Sydney route. The report related to a rejected takeoff at Gunnedah due to asymmetric power.
5/10/2004	AOC 426646-27 issued for the period 4/10/2004 to 31/10/2004. The AOC was changed to allow the addition of the following: • RPT passenger operations into Lockhart River
1/11/2004	AOC 426646-28 renewed for the period 1/10/2004 to 31/10/2007. There were no changes to the AOC.
20/1/2005	Transair applied to have Cessna 525 Citation VH-MOJ added to its AOC.
4/2/2005	A *Transair Hazard/Event Report* was submitted by the pilot in command of VH-TFQ operating an RPT flight on the Inverell – Gunnedah – Sydney route. The report related to a wake turbulence event while on approach to runway 34R at Sydney.
14/2/2005 to 9/3/2005	Scheduled audit of Transair carried out by CASA. The audit covered the following elements of Transair's operation: • Aircraft configuration control • Flight operations • Personnel, training and qualifications • Records and reporting • Maintenance organisation • Air operator programmes and procedures • Training programme

Date	Event and Comments
	• Approved routes and areas The audit team consisted of: • 1 x Flying operations inspector • 1 x Dangerous goods inspector • 1 x Cabin safety inspector • 1 x Airworthiness inspector The audit resulted in 9 RCAs and 5 AOs being issued. The following is a list of areas indicated by RCA and AO: • 4 RCAs dealt with system of maintenance issues • 1 RCA dealt with the briefing of passengers • 1 RCA dealt with the stowage of loose articles in the cabin • 3 RCAs dealt with dangerous goods issues • 3 AOs dealt with aircraft logbooks • 1 AO dealt with passenger handling and briefing • 1 AO dealt with the *Transair Operations Manual*
20/4/2005	AOC 426646-29 issued for the period 20/4/2005 to 31/10/2007. The AOC was changed to allow the addition of an aircraft type.
7/5/2005	VH-TFU collided with terrain while on approach to Lockhart River aerodrome.

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APPENDIX I: JOINT AVIATION AUTHORITIES NON-TECHNICAL SKILLS

Four non-technical skill categories have been defined[41] by the European Joint Aviation Authorities (JAA) as follows, along with representative behaviours that demonstrate each element within each marker:

- ***Cooperation*** is the ability to work effectively in a team/crew.
  - Team building and maintaining: Establishing atmosphere for open communication; encouraging inputs and feedback from other crew members; does not compete with others.
  - Consideration of others: Takes notice of suggestions from crew members even when they disagree; takes condition of other crew members into account; gives personal feedback.
  - Support of others: Giving help to other crew members in demanding situations; offers assistance.
  - Conflict solving: Keeps calm in interpersonal conflicts; suggests conflict solutions; concentrates on what is right rather than who is right.
- Effective ***leadership and managerial*** skills mean to achieve the joint task to completion within a motivated, fully functioning team through coordination and persuasion.
  - Use of authority and assertiveness: Ensures crew involvement and task completions; takes command if situation requires; reflects on the suggestions of others; motivates crew by appreciation and coaches when necessary.
  - Providing and maintaining standards: The compliance with essential standards (SOPs and others) should be ensured; intervenes in case of deviations from standards; if situation requires, non-standard procedures might be necessary to apply, but such deviations shall be announced and consulted in the crew; demonstrates will to achieve top performance.
  - Planning and coordination: Encourages crew participation in planning and task completion; plans are clearly stated and confirmed; changes plan if necessary but with crew consultation; clearly states goals and boundaries for task completion.
  - Workload management: Clear prioritisation of primary and secondary operational tasks; based on a sound planning, tasks are distributed appropriately among the crew; adequate time given to complete tasks; signs of stress and fatigue are communicated and taken into account as performance affecting factors.

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41 CAA (2006). *Crew Resource Management (CRM) Training*. (CAP 737). UK Civil Aviation Authority.

- ***Situation awareness*** is a pilot's ability to accurately perceive what is in the cockpit and outside the aircraft, or, as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.
    - Awareness of aircraft systems: Monitors and reports changes in systems' states; acknowledges entries and changes to systems.
    - Awareness of environment: Collects information about the environment (position, weather, air traffic, terrain); shares key information about environment with crew; contacts outside resources to maintain situational awareness when needed.
    - Awareness of time and anticipation of future events: Discusses time constraints with crew; discusses contingency strategies; identifies possible future problems.
- ***Decision making*** is the process of reaching a judgment or choosing an option.
    - Problem definition/ diagnosis: Gathers information to identify problem; reviews causal factors with other crew members.
    - Option generation: States alternative options; asks crew members for options.
    - Risk assessment & option selection: Considers and shares estimated risk of alternative options; talks about possible risks for action in terms of crew limits; confirms and states selected option or agreed action.
    - Outcome review: Checks outcome against plan.

APPENDIX J: SUMMARY OF SIGNIFICANT CFIT DESCENT APPROACH AND LANDING ACCIDENTS IN AUSTRALIA

Many of the early Australian airline accidents resulted from controlled flight into terrain (CFIT). The disappearance of an Avro X airliner, 'Southern Cloud', registered VH-UMF, in March 1931 with the loss of two crew and six passengers was the first major airline disaster in Australia. When the wreckage was found 27 years later in the Snowy Mountains, it was evident that the aircraft had flown into terrain while en route between Sydney and Melbourne. The aircraft had no instrument navigation equipment and the crew became lost in cloud. Although a CFIT, the accident had not occurred on descent or approach to land. That pattern started to emerge with the introduction of radio navigational aids.

On 25 October 1938, an Australian National Airways Douglas DC-2, Kyeema, registered VH-UYC, on a scheduled flight from Adelaide to Melbourne, descended into the western slopes of the Dandenong Ranges, over 35 km east of Essendon Airport, Vic. in daylight. The crew misidentified their descent point and, having overflown their intended destination, descended into the low cloud. The crew of 4 and 14 passengers perished in the accident. One of the factors in the circumstances leading to the accident was the failure of the crew to request a direction finder bearing from the aerodrome, to confirm their position.

On 17 May 1946 an Ansett Airways Lockheed 10B, Ansalanta, registered VH-UZP, on a scheduled flight from Melbourne to Adelaide, flew into the ground north of Parafield Airport, SA. The crew was making an instrument let-down at night, in low cloud and rain. Although the aircraft was substantially damaged, the 2 crew and 10 passengers escaped from the overturned wreckage, without any significant injury.

Most notable of the post-World War 2 CFIT accidents to Australian airlines occurred on 10 June 1960, when a Trans Australia Airlines Fokker F27, 'Abel Tasman', registered VH-TFB, on a scheduled flight from Brisbane, descended into the ocean near Mackay, Qld with the loss of all 4 crew and 25 passengers. The accident occurred while the crew was making a visual approach to land at night.

The introduction of more radio-navigation aids across the country and the increasing availability of radio-navigation receivers for all aircraft, including general aviation aircraft, increased the potential for CFIT accidents occurring during descent or approach to land. The more recent development of satellite-based navigation systems and the ability to use this equipment to make an instrument approach has increased significantly the number of locations for potential CFIT accidents to occur during the descent or approach to land. It is not unreasonable to expect that satellite-based navigation would be a factor in more recent CFIT accidents.

The following selection of Australian CFIT occurrences from 1969 to 2005 during descent and approach to land, illustrates the need for awareness of the risk of CFIT during this phase of flight.

Selection of Australian CFIT occurrences during descent and approach to land

6 May 1969 VH-EXT Aerocommander 500S Scheduled-passenger

The aircraft collided with terrain near the Warracknabeal aerodrome, Vic, while the pilot was visually manoeuvring to land at night.

Fatalities: Nil (1 crew and 2 passengers injured)

30 May 1979 VH-KIB Cessna 402B Scheduled-passenger

The aircraft collided with trees in mountainous terrain, east of Strahan, Tas. The crew lost situational awareness while conducting a non-directional beacon (NDB) instrument approach in instrument meteorological conditions during daylight hours.

Fatalities: Nil (2 crew injured and 1 passenger not injured)

20 February 1984 VH-FSA Cessna 500 Citation Charter-cargo

The aircraft flew into the ground on final approach to runway 11 at Proserpine, Qld. The crew was making a VOR instrument approach to land at night during a rain squall.

Fatalities: 2 crew

7 April 1988 VH-HOX Piper PA-31 Chieftain Scheduled-passenger

The aircraft struck trees on an approach to land at Coffs Harbour, NSW. The pilot was attempting to land at night in rain and poor visibility.

Fatalities: 1 crew and 2 passengers (4 passengers injured)

28 September 1989 VH-AEB Beech B55 Baron Charter-passenger

The aircraft struck trees 19 km north, north-west of the aerodrome at Roma, Qld, while manoeuvring to land at night.

Fatalities: 1 crew and 4 passengers

11 May 1990 VH-ANQ Cessna 500 Citation Charter-passenger

The aircraft struck terrain while descending to land at Mareeba, Qld, in instrument visual meteorological conditions and deteriorating light.

Fatalities: 1 crew and 10 passengers

11 June 1993 VH-NDU Piper PA-31 Chieftain Scheduled-passenger

The aircraft struck trees on a hill while the pilot was manoeuvring to land after making a non-directional beacon instrument approach at Young, NSW at night in rain and poor visibility.

Fatalities: 2 crew and 5 passengers

14 January 1994 VH-BSS Aerocommander 690 Charter-cargo

The aircraft collided with the water 18 km south, south-east of the airport at Sydney, NSW, while the pilot was descending to land.

Fatalities: 1 crew

9 March 1994 VH-SWP Swearingen SA 226 Metroliner Charter-cargo

The aircraft struck a hill 16 km north-east of Tamworth, NSW, while approaching to land at night.

Fatalities: 1 crew

21 December 1994 VH-IAM Mitsubishi MU-2 Charter-cargo

The aircraft struck the ground 2 km from Runway 27 at Melbourne Airport, Vic. while the pilot was making an Instrument Landing System approach in instrument meteorological conditions at night.

Fatalities: 1 crew

27 April 1995 VH-AJS IAI 1124 Westwind Charter-cargo

The aircraft struck a ridge in hilly terrain 6 km north-west of the airport at Alice Springs, NT, while conducting a twin-locator NDB instrument approach in visual meteorological conditions at night.

Fatalities: 2 crew, 1 passenger

20 July 1998 VH-IXH Partenavia P68B Charter-cargo

The aircraft struck a hill south of the aerodrome at Wagga Wagga, NSW in instrument meteorological conditions during daylight hours. The pilot had reported commencing a GPS arrival procedure.

Fatalities: 1 crew and 1 passenger

10 December 2001 VH-FMN Beech B200C Super King Air Airwork-ambulance

The aircraft struck trees 5 km north of the aerodrome at Mount Gambier, SA, while the pilot was manoeuvring to land at night.

Fatalities: 1 crew (1 passenger injured)

15 May 2003 VH-AMR Beech B200C Super King Air Airwork-ambulance

The aircraft struck the water 15 km north of the aerodrome at Coffs Harbour, NSW while the pilot was making a RNAV (GNSS) approach in instrument meteorological conditions during daylight. The aircraft was substantially damaged but the pilot subsequently made a successful emergency landing.

Fatalities: Nil (1 crew and 3 passengers not injured)

28 July 2004 VH-TNP Piper PA-31T Cheyenne Private-business

The aircraft struck a ridge in mountainous terrain, 33 km south-east of the aerodrome at Benalla, Vic, after the pilot reported commencing an RNAV (GNSS) approach to land. Although daylight, weather conditions were poor, with extensive low cloud, rain and reduced visibility in the area.

Fatalities: 1 crew and 5 passengers

7 May 2005 VH-TFU Fairchild SA 227 Metroliner Scheduled-passenger

The aircraft collided with a ridge 11 km north-west of the aerodrome at Lockhart River, Qld. The crew were flying an RNAV (GNSS) instrument approach to land in conditions of low cloud during daylight hours.

Fatalities: 2 crew and 13 passengers

8 July 2005 VH-OAO Piper PA-31 Chieftain Charter-passenger

The aircraft collided with terrain 5 km south of the aerodrome at Mount Hotham, Vic, while the pilot was manoeuvring to land in conditions of low cloud and poor visibility in snow and deteriorating light. The pilot had reported commencing an RNAV (GNSS) approach.

Fatalities: 1 crew and 2 passengers

APPENDIX K: FLIGHT SAFETY FOUNDATION CFIT CHECKLIST

Flight Safety Foundation

CFIT Checklist

Evaluate the Risk and Take Action

Flight Safety Foundation (FSF) designed this controlled-flight-into-terrain (CFIT) risk-assessment safety tool as part of its international program to reduce CFIT accidents, which present the greatest risks to aircraft, crews and passengers. The FSF CFIT Checklist is likely to undergo further developments, but the Foundation believes that the checklist is sufficiently developed to warrant distribution to the worldwide aviation community.

Use the checklist to evaluate specific flight operations and to enhance pilot awareness of the CFIT risk. The checklist is divided into three parts. In each part, numerical values are assigned to a variety of factors that the pilot/operator will use to score his/her own situation and to calculate a numerical total.

In *Part I: CFIT Risk Assessment,* the level of CFIT risk is calculated for each flight, sector or leg. In *Part II: CFIT Risk-reduction Factors*, Company Culture, Flight Standards, Hazard Awareness and Training, and Aircraft Equipment are factors, which are calculated in separate sections. In *Part III: Your CFIT Risk*, the totals of the four sections in *Part II* are combined into a single value (a positive number) and compared with the total (a negative number) in *Part I: CFIT Risk Assessment* to determine your CFIT Risk Score. To score the checklist, use a nonpermanent marker (do not use a ballpoint pen or pencil) and erase with a soft cloth.

Part I: CFIT Risk Assessment

Section 1 – Destination CFIT Risk Factors	Value	Score
Airport and Approach Control Capabilities:		
ATC approach radar with MSAWS	0	____
ATC minimum radar vectoring charts	0	____
ATC radar only	-10	____
ATC radar coverage limited by terrain masking	-15	____
No radar coverage available (out of service/not installed)	-30	____
No ATC service	-30	____
Expected Approach:		
Airport located in or near mountainous terrain	-20	____
ILS	0	____
VOR/DME	-15	____
Nonprecision approach with the approach slope from the FAF to the airport TD shallower than 2 ³/₄ degrees	-20	____
NDB	-30	____
Visual night "black-hole" approach	-30	____
Runway Lighting:		
Complete approach lighting system	0	____
Limited lighting system	-30	____
Controller/Pilot Language Skills:		
Controllers and pilots speak different primary languages	-20	____
Controllers' spoken English or ICAO phraseology poor	-20	____
Pilots' spoken English poor	-20	____
Departure:		
No published departure procedure	-10	____
Destination CFIT Risk Factors Total	(–)	____

1 CFIT Checklist (Rev. 2.3/1,000/r)

Section 2 – Risk Multiplier

	Value	Score
Your Company's Type of Operation (select only one value):		
Scheduled	1.0	____
Nonscheduled	1.2	____
Corporate	1.3	____
Charter	1.5	____
Business owner/pilot	2.0	____
Regional	2.0	____
Freight	2.5	____
Domestic	1.0	____
International	3.0	____
Departure/Arrival Airport (select single highest applicable value):		
Australia/New Zealand	1.0	____
United States/Canada	1.0	____
Western Europe	1.3	____
Middle East	1.1	____
Southeast Asia	3.0	____
Euro-Asia (Eastern Europe and Commonwealth of Independent States)	3.0	____
South America/Caribbean	5.0	____
Africa	8.0	____
Weather/Night Conditions (select only one value):		
Night — no moon	2.0	____
IMC	3.0	____
Night and IMC	5.0	____
Crew (select only one value):		
Single-pilot flight crew	1.5	____
Flight crew duty day at maximum and ending with a night nonprecision approach	1.2	____
Flight crew crosses five or more time zones	1.2	____
Third day of multiple time-zone crossings	1.2	____

Add Multiplier Values to Calculate Risk Multiplier Total ____

Destination CFIT Risk Factors Total × Risk Multiplier Total = CFIT Risk Factors Total (−) ____

Part II: CFIT Risk-reduction Factors

Section 1 – Company Culture

	Value	Score
Corporate/company management:		
Places safety before schedule	20	____
CEO signs off on flight operations manual	20	____
Maintains a centralized safety function	20	____
Fosters reporting of all CFIT incidents without threat of discipline	20	____
Fosters communication of hazards to others	15	____
Requires standards for IFR currency and CRM training	15	____
Places no negative connotation on a diversion or missed approach	20	____

115-130 points	Tops in company culture
105-115 points	Good, but not the best
80-105 points	Improvement needed
Less than 80 points	High CFIT risk

Company Culture Total (+) ____ *

Section 2 – Flight Standards

Specific procedures are written for:	Value	Score
Reviewing approach or departure procedures charts	10	_____
Reviewing significant terrain along intended approach or departure course	20	_____
Maximizing the use of ATC radar monitoring	10	_____
Ensuring pilot(s) understand that ATC is using radar or radar coverage exists	20	_____
Altitude changes	10	_____
Ensuring checklist is complete before initiation of approach	10	_____
Abbreviated checklist for missed approach	10	_____
Briefing and observing MSA circles on approach charts as part of plate review	10	_____
Checking crossing altitudes at IAF positions	10	_____
Checking crossing altitudes at FAF and glideslope centering	10	_____
Independent verification by PNF of minimum altitude during stepdown DME (VOR/DME or LOC/DME) approach	20	_____
Requiring approach/departure procedure charts with terrain in color, shaded contour formats	20	_____
Radio-altitude setting and light-aural (below MDA) for backup on approach	10	_____
Independent charts for both pilots, with adequate lighting and holders	10	_____
Use of 500-foot altitude call and other enhanced procedures for NPA	10	_____
Ensuring a sterile (free from distraction) cockpit, especially during IMC/night approach or departure	10	_____
Crew rest, duty times and other considerations especially for multiple-time-zone operation	20	_____
Periodic third-party or independent audit of procedures	10	_____
Route and familiarization checks for new pilots		
Domestic	10	_____
International	20	_____
Airport familiarization aids, such as audiovisual aids	10	_____
First officer to fly night or IMC approaches and the captain to monitor the approach	20	_____
Jump-seat pilot (or engineer or mechanic) to help monitor terrain clearance and the approach in IMC or night conditions	20	_____
Insisting that you fly the way that you train	25	_____

300-335 points	Tops in CFIT flight standards
270-300 points	Good, but not the best
200-270 points	Improvement needed
Less than 200	High CFIT risk

Flight Standards Total (+) _____ *

Section 3 – Hazard Awareness and Training

	Value	Score
Your company reviews training with the training department or training contractor	10	_____
Your company's pilots are reviewed annually about the following:		
Flight standards operating procedures	20	_____
Reasons for and examples of how the procedures can detect a CFIT "trap"	30	_____
Recent and past CFIT incidents/accidents	50	_____
Audiovisual aids to illustrate CFIT traps	50	_____
Minimum altitude definitions for MORA, MOCA, MSA, MEA, etc.	15	_____
You have a trained flight safety officer who rides the jump seat occasionally	25	_____
You have flight safety periodicals that describe and analyze CFIT incidents	10	_____
You have an incident/exceedance review and reporting program	20	_____
Your organization investigates every instance in which minimum terrain clearance has been compromised	20	_____

You annually practice recoveries from terrain with GPWS in the simulator	40	_____
You train the way that you fly	25	_____

285-315 points	Tops in CFIT training	**Hazard Awareness and Training Total** (+) _____ *
250-285 points	Good, but not the best	
190-250 points	Improvement needed	
Less than 190	High CFIT risk	

Section 4 – Aircraft Equipment

Aircraft includes:	**Value**	**Score**
Radio altimeter with cockpit display of full 2,500-foot range — captain only	20	_____
Radio altimeter with cockpit display of full 2,500-foot range — copilot	10	_____
First-generation GPWS	20	_____
Second-generation GPWS or better	30	_____
GPWS with all approved modifications, data tables and service bulletins to reduce false warnings	10	_____
Navigation display and FMS	10	_____
Limited number of automated altitude callouts	10	_____
Radio-altitude automated callouts for nonprecision approach (not heard on ILS approach) and procedure	10	_____
Preselected radio altitudes to provide automated callouts that would not be heard during normal nonprecision approach	10	_____
Barometric altitudes and radio altitudes to give automated "decision" or "minimums" callouts	10	_____
An automated excessive "bank angle" callout	10	_____
Auto flight/vertical speed mode	-10	_____
Auto flight/vertical speed mode with no GPWS	-20	_____
GPS or other long-range navigation equipment to supplement NDB-only approach	15	_____
Terrain-navigation display	20	_____
Ground-mapping radar	10	_____

175-195 points	Excellent equipment to minimize CFIT risk	**Aircraft Equipment Total** (+) _____ *
155-175 points	Good, but not the best	
115-155 points	Improvement needed	
Less than 115	High CFIT risk	

Company Culture _______ + Flight Standards _______ + Hazard Awareness and Training _______
+ Aircraft Equipment _______ = CFIT Risk-reduction Factors Total (+) _______

*** If any section in Part II scores less than "Good," a thorough review is warranted of that aspect of the company's operation.**

Part III: Your CFIT Risk

Part I CFIT Risk Factors Total (−) _____ + Part II CFIT Risk-reduction Factors Total (+) _____

= CFIT Risk Score (±) _____

A negative CFIT Risk Score indicates a significant threat; review the sections in Part II and determine what changes and improvements can be made to reduce CFIT risk.

APPENDIX L: FLIGHT SAFETY FOUNDATION APPROACH AND LANDING (ALAR) TOOLKIT, STANDARD OPERATING PROCEDURES

Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

Standard Operating Procedures Template

[The following template is adapted from U.S. Federal Aviation Administration (FAA) Advisory Circular 120-71, *Standard Operating Procedures for Flight Deck Crewmembers*.]

A manual or a section in a manual serving as the flight crew's guide to standard operating procedures (SOPs) may serve also as a training guide. The content should be clear and comprehensive, without necessarily being lengthy. No template could include every topic that might apply unless it were constantly revised. Many topics involving special operating authority or new technology are absent from this template, among them extended-range twin-engine operations (ETOPS), precision runway monitor (PRM), surface movement guidance system (SMGS), required navigation performance (RNP) and many others.

The following are nevertheless viewed by industry and FAA alike as examples of topics that constitute a useful template for developing comprehensive, effective SOPs:

- Captain's authority;
- Use of automation, including:
  - The company's automation philosophy;
  - Specific guidance in selection of appropriate levels of automation;
  - Autopilot/flight director mode selections; and,
  - Flight management system (FMS) target entries (e.g., airspeed, heading, altitude);
- Checklist philosophy, including:
  - Policies and procedures (who calls for; who reads; who does);
  - Format and terminology; and,
  - Type of checklist (challenge-do-verify, or do-verify);
- Walk-arounds;
- Checklists, including:
  - Safety check prior to power on;
  - Originating/receiving;
  - Before start;
  - After start;
  - Before taxi;
  - Before takeoff;
  - After takeoff;
  - Climb check;
  - Cruise check;
  - Approach;
  - Landing;
  - After landing;
  - Parking and securing;
  - Emergency procedures; and,
  - Abnormal procedures;
- Communication, including:
  - Who handles radios;
  - Primary language used with air traffic control (ATC) and on the flight deck;
  - Keeping both pilots "in the loop";
  - Company radio procedures;
  - Flight deck signals to cabin; and,
  - Cabin signals to flight deck;

- Briefings, including:
  - Controlled-flight-into-terrain (CFIT) risk considered;
  - Special airport qualifications considered;
  - Temperature corrections considered;
  - Before takeoff; and,
  - Descent/approach/missed approach;
- Flight deck access, including:
  - On ground/in flight;
  - Jump seat; and,
  - Access signals, keys;
- Flight deck discipline, including:
  - "Sterile cockpit"[1];
  - Maintaining outside vigilance;
  - Transfer of control;
  - Additional duties;
  - Flight kits;
  - Headsets/speakers;
  - Boom mikes/handsets;
  - Maps/approach charts; and,
  - Meals;
- Altitude awareness, including:
  - Altimeter settings;
  - Transition altitude/flight level;
  - Standard calls (verification of);
  - Minimum safe altitudes (MSAs); and,
  - Temperature corrections;
- Report times; including:
  - Check in/show up;
  - On flight deck; and,
  - Checklist accomplishment;
- Maintenance procedures, including:
  - Logbooks/previous write-ups;
  - Open write-ups;
  - Notification to maintenance of write-ups;
  - Minimum equipment list (MEL)/dispatch deviation guide (DDG);
  - Where MEL/DDG is accessible;
  - Configuration deviation list (CDL); and,
  - Crew coordination in ground deicing;
- Flight plans/dispatch procedures, including:
  - Visual flight rules/instrument flight rules (VFR/IFR);
  - Icing considerations;
  - Fuel loads;
  - Weather-information package;
  - Where weather-information package is available; and,
  - Departure procedure climb gradient analysis;
- Boarding passengers/cargo, including:
  - Carry-on baggage;
  - Exit-row seating;
  - Hazardous materials;
  - Prisoners/escorted persons;
  - Firearms onboard; and,
  - Count/load;
- Pushback/powerback;
- Taxiing, including:
  - Single-engine;
  - All-engines;
  - On ice or snow; and,
  - Prevention of runway incursion;
- Crew resource management (CRM), including crew briefings (cabin crew and flight crew);
- Weight and balance/cargo loading, including:
  - Who is responsible for loading cargo and securing cargo; and,
  - Who prepares the weight-and-balance data form; who checks the form; and how a copy of the form is provided to the crew;
- Flight deck/cabin crew interchange, including:
  - Boarding;
  - Ready to taxi;
  - Cabin emergency; and,
  - Prior to takeoff/landing;
- Takeoff, including:

- Who conducts the takeoff;
- Briefing, VFR/IFR;
- Reduced-power procedures;
- Tail wind, runway clutter;
- Intersections/land and hold short operations (LAHSO) procedures;
- Noise-abatement procedures;
- Special departure procedures;
- Use/nonuse of flight directors;
- Standard calls;
- Cleanup;
- Loss of engine, including rejected takeoff after V_1 (actions/standard calls);
- Flap settings, including:
  - Normal;
  - Nonstandard and reason for; and,
  - Crosswind; and,
- Close-in turns;

- Climb, including:
  - Speeds;
  - Configuration;
  - Confirm compliance with climb gradient required in departure procedure; and,
  - Confirm appropriate cold-temperature corrections made;
- Cruise altitude selection (speeds/weights);
- Position reports to ATC and to company;
- Emergency descents;
- Holding procedures;
- Procedures for diversion to alternate airport;
- Normal descents, including:
  - Planning top-of-descent point;
  - Risk assessment and briefing;
  - Use/nonuse of speedbrakes;
  - Use of flaps/gear;
  - Icing considerations; and,
  - Convective activity;
- Ground-proximity warning system (GPWS) or terrain awareness and warning system (TAWS)[2] recovery ("pull-up") maneuver;
- Traffic-alert and collision avoidance system (TCAS)/ airborne collision avoidance system (ACAS);
- Wind shear, including:
  - Avoidance of likely encounters;
  - Recognition; and,
  - Recovery/escape maneuver;
- Approach philosophy, including:
  - Precision approaches preferred;
  - Stabilized approaches standard;
  - Use of navigation aids;
  - FMS/autopilot use and when to discontinue use;
  - Approach gate[3] and limits for stabilized approaches, (Table 1);
  - Use of radio altimeter; and,
  - Go-arounds (plan to go around; change plan to land when visual, if stabilized);
- Individual approach type (all types, including engine-out approaches);
- For each type of approach:
  - Profile;
  - Flap/gear extension;
  - Standard calls; and,
  - Procedures;
- Go-around/missed approach, including:
  - Initiation when an approach gate is missed;
  - Procedure;
  - Standard calls; and,
  - Cleanup profile; and,
- Landing, including:
  - Actions and standard calls;
  - Configuration for conditions, including:
    - Visual approach;
    - Low visibility; and,
    - Wet or contaminated runway;
  - Close-in turns;
  - Crosswind landing;
  - Rejected landing; and,
  - Transfer of control after first officer's landing.

Table 1
Recommended Elements of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1, November 2000)

References

1. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says that "10,000 feet" should be height above ground level during flight operations over high terrain.]
2. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.
3. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

APPENDIX M: MEDIA RELEASE

Final ATSB investigation report on Lockhart River 15-fatality aviation accident

The ATSB has released a 500-page final report into Australia's worst civil aviation accident since 1968. The report spells out contributing safety factors involving the pilots, the operator and the regulator as well as other safety factors, and has made further recommendations to improve future safety.

An Australian Transport Safety Bureau team of a dozen investigators has taken nearly two years of painstaking investigation to complete the final report since the tragic accident on 7 May 2005 which killed both pilots and all 13 passengers. Three ATSB factual reports, a research report and ten safety recommendations were released in the interim. The investigation was complicated by an inoperative cockpit voice recorder, no witnesses, and the extent of destruction of the aircraft.

The ATSB found that a mechanically serviceable Metro 23 aircraft operated by Transair was unintentionally flown into South Pap ridge in poor weather during a satellite-based instrument approach, probably because the crew lost situational awareness in low cloud.

The experienced 40-year old pilot in command was very likely flying the aircraft but was reliant on the 21-year old copilot to assist with the high cockpit workload. He knew the copilot was not trained for this type of complex instrument approach. Despite the weather and copilot inexperience, the pilot in command also used approach and descent speeds and a rate of descent greater than specified in the *Transair Operations Manual*, and exceeded the recommended criteria for a stabilised approach. The pilot in command had a history of such flying.

The investigation found significant limitations with Transair's pilot training and checking, including superficial training before pilot endorsements and no 'crew resource management'. Deficiencies also existed in the supervision of flight operations and standard operating procedures for pilots. There were also significant limitations in the way Transair managed safety, Transair's management processes and because the chief pilot was over-committed with additional roles as CEO, the primary check and training pilot, and working regularly in Papua New Guinea.

The regulatory oversight was also not as good as it could have been, especially when Transair moved from a charter to a regular passenger transport operator and was growing rapidly in Australia. In addition to the serious pilot and company contributory factors, if CASA's guidance to inspectors on management systems and its risk assessment processes had been more thorough, the accident may not have occurred.

The ATSB investigation also identified a range of other safety issues which could not be as clearly linked to the accident because of limited evidence. These included shortcomings in the design of the navigation chart used and the possibility of poor crew communication in the cockpit.

The ATSB hopes that this final report will assist the families and friends of those who perished in this tragedy to move towards closure, and will lead to further improvements in aviation safety to ensure that such an accident never happens again.

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