APPENDICES

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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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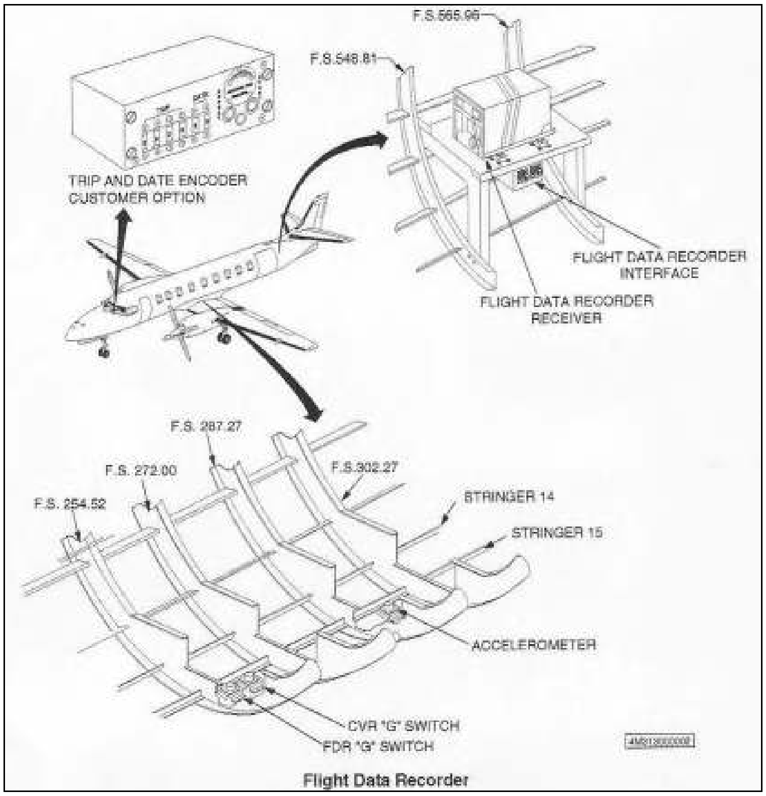
1 Area navigation global navigation satellite system (RNAV (GNSS)) approach.

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

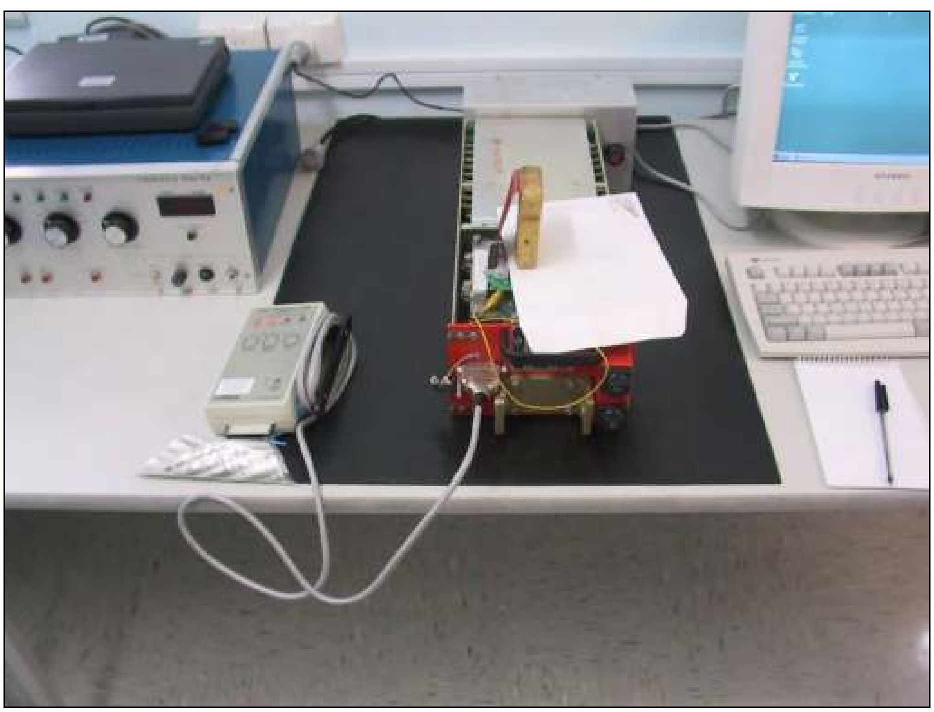
Figure A-5: FDR (foreground) at the ATSB laboratory in Canberra

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

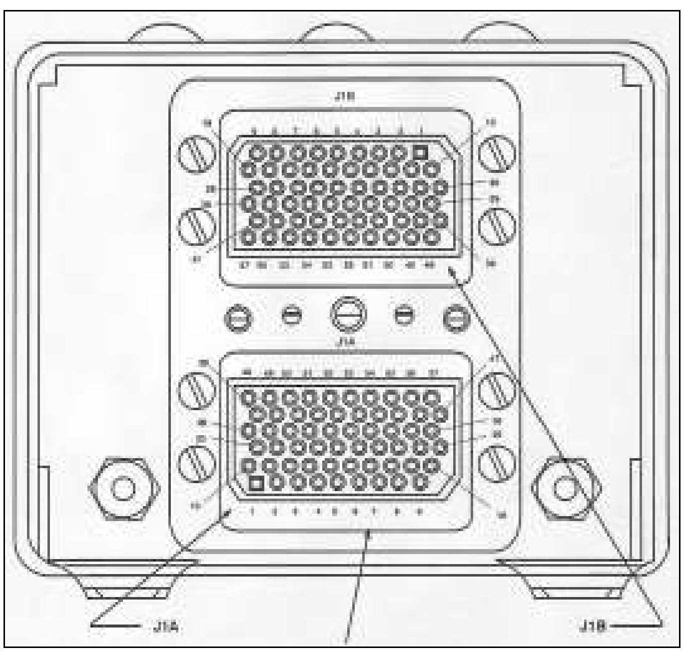
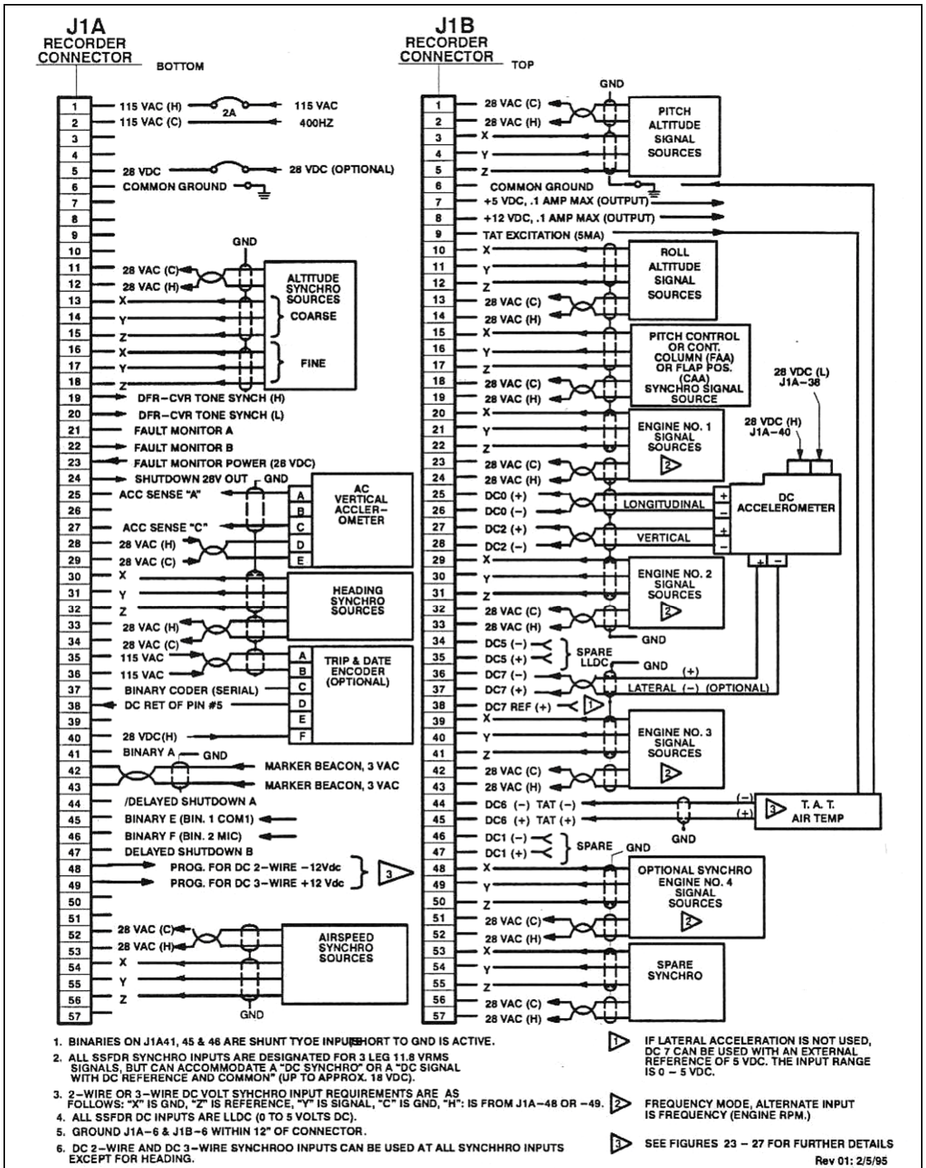


Figure A-12: Pin assignment[7]



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.

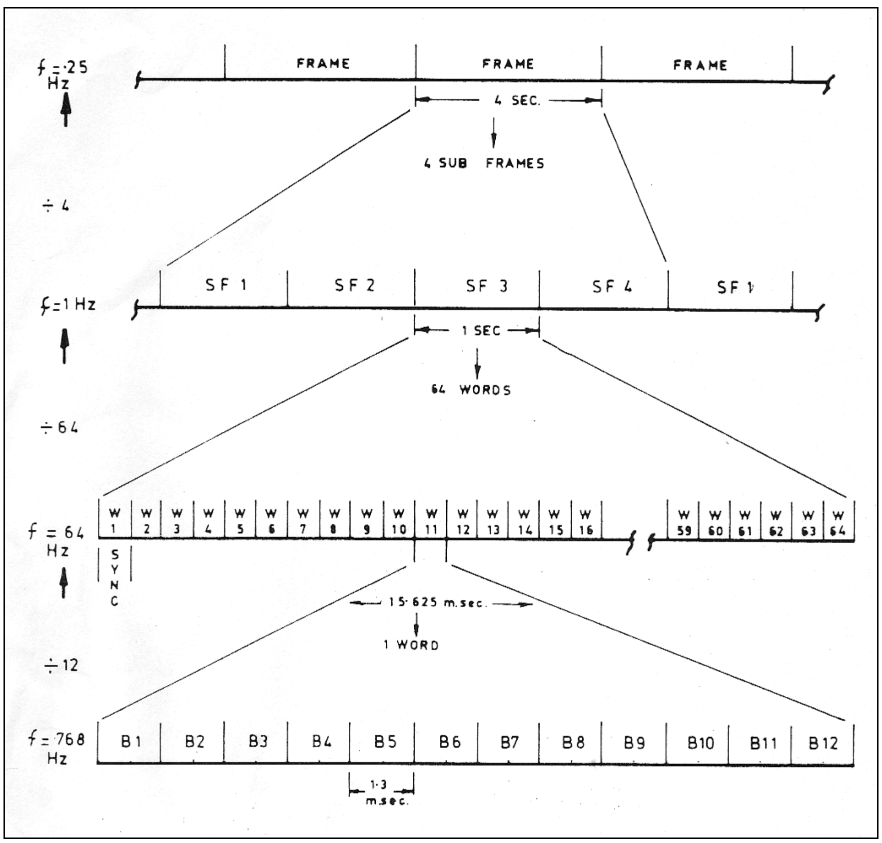
Data frame format

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

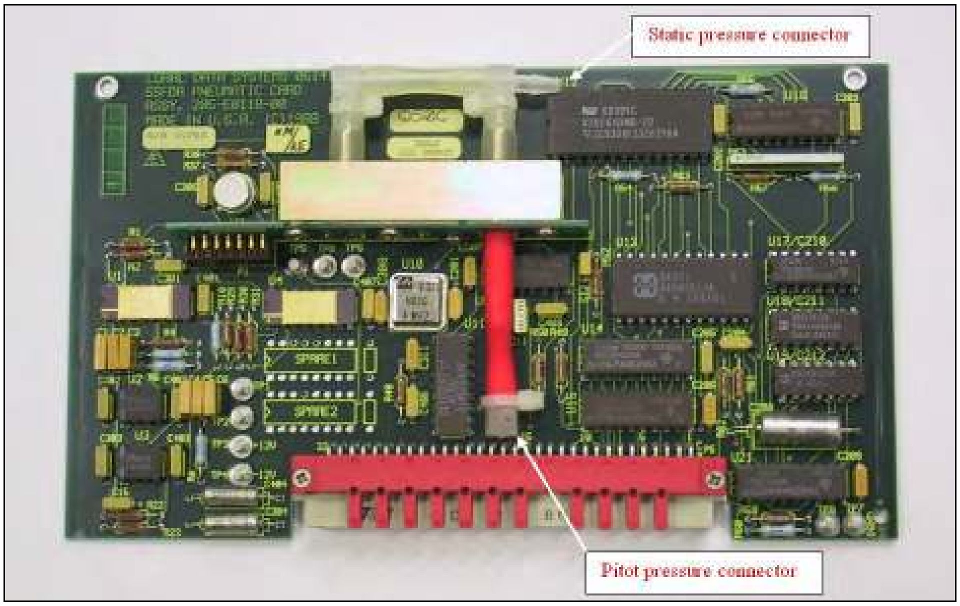
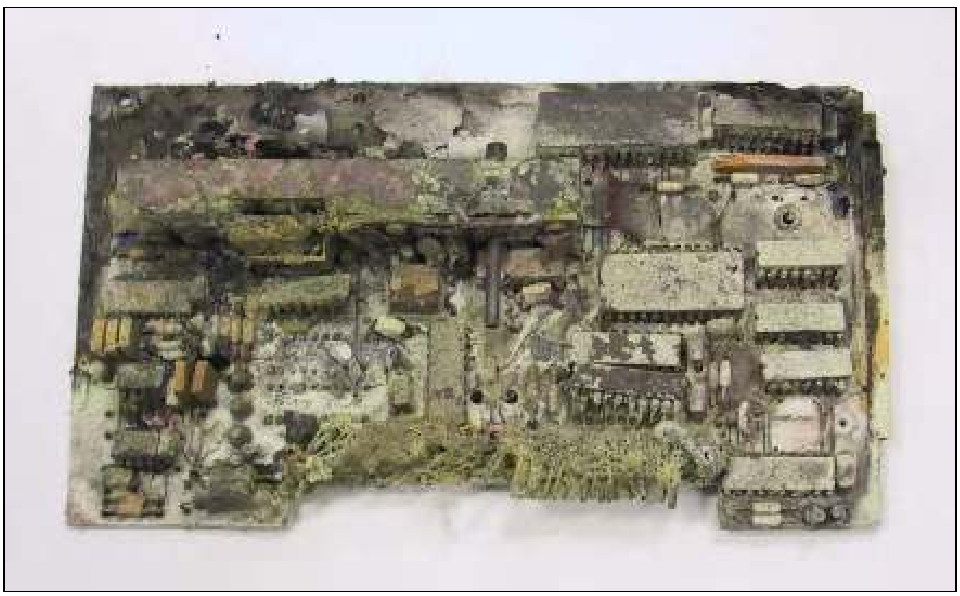


Figure A-16: Pneumatic printed circuit board from VH-TFU



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.

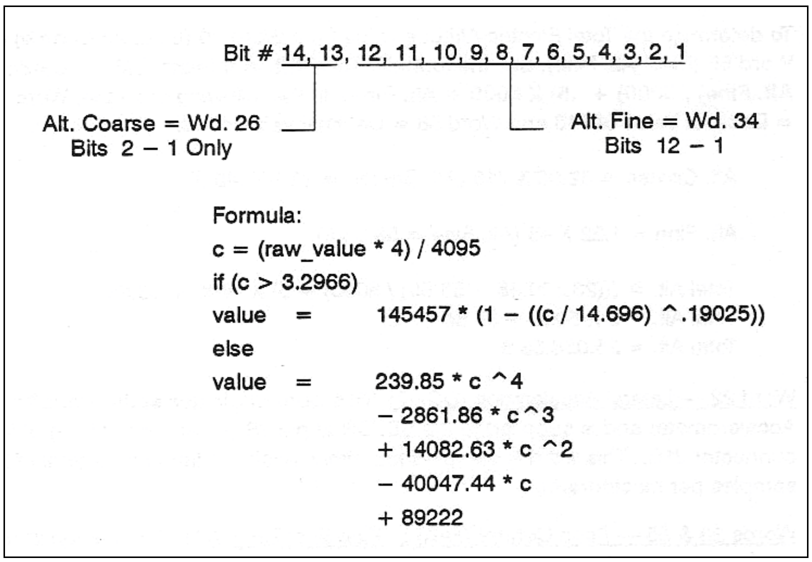
During climb and initial cruise after takeoff from Cairns the aircraft was under radar coverage from the secondary surveillance radar at Redden Creek (16º 51´ 38.7″ South and 145º 44´ 38.7″ East).

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

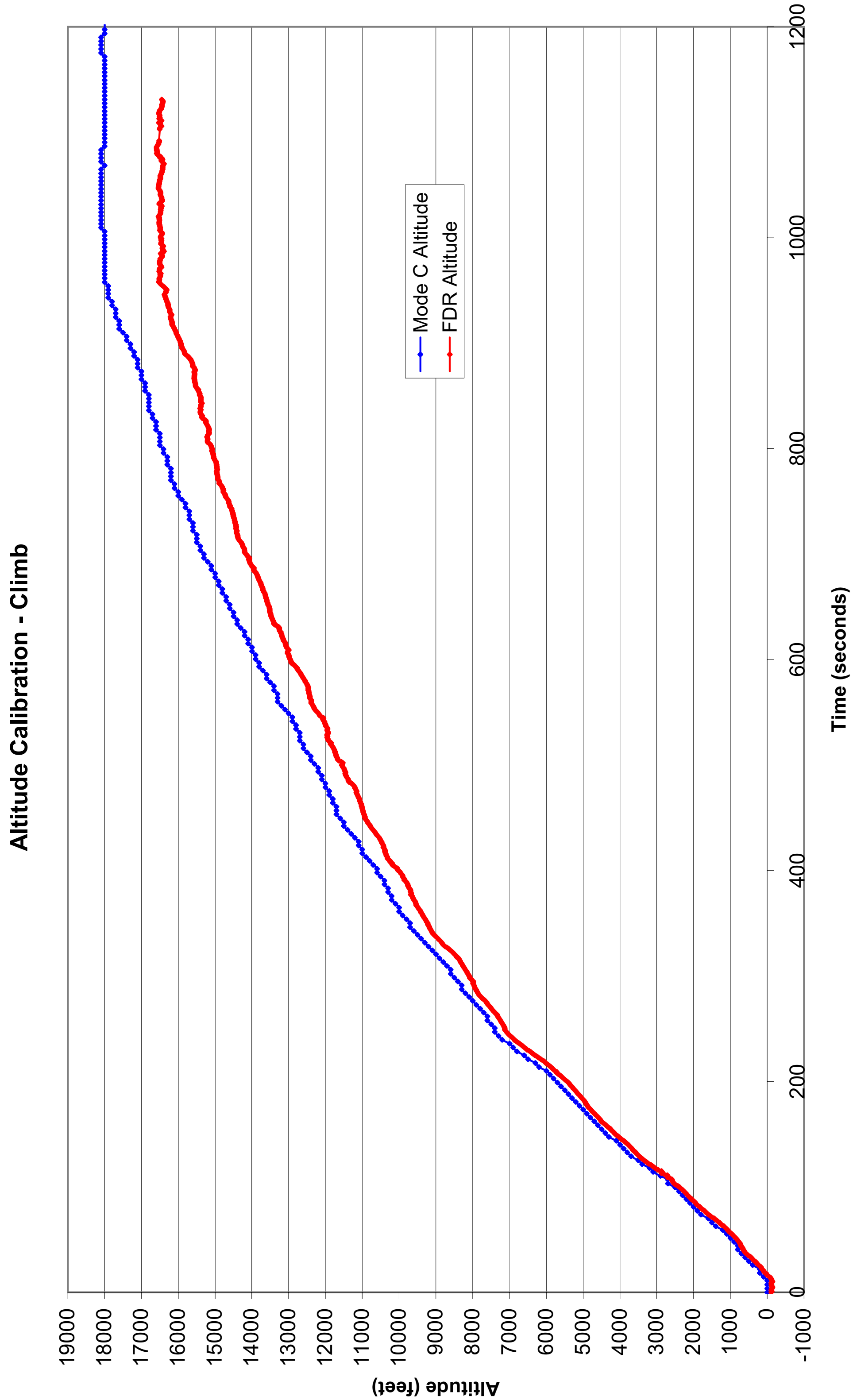
i.e. Corrected altitude = $value^3 * 7.0E\text{-}11 + value^2 * 4.0E\text{-}6 + value * 0.9958 + 152.82$

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

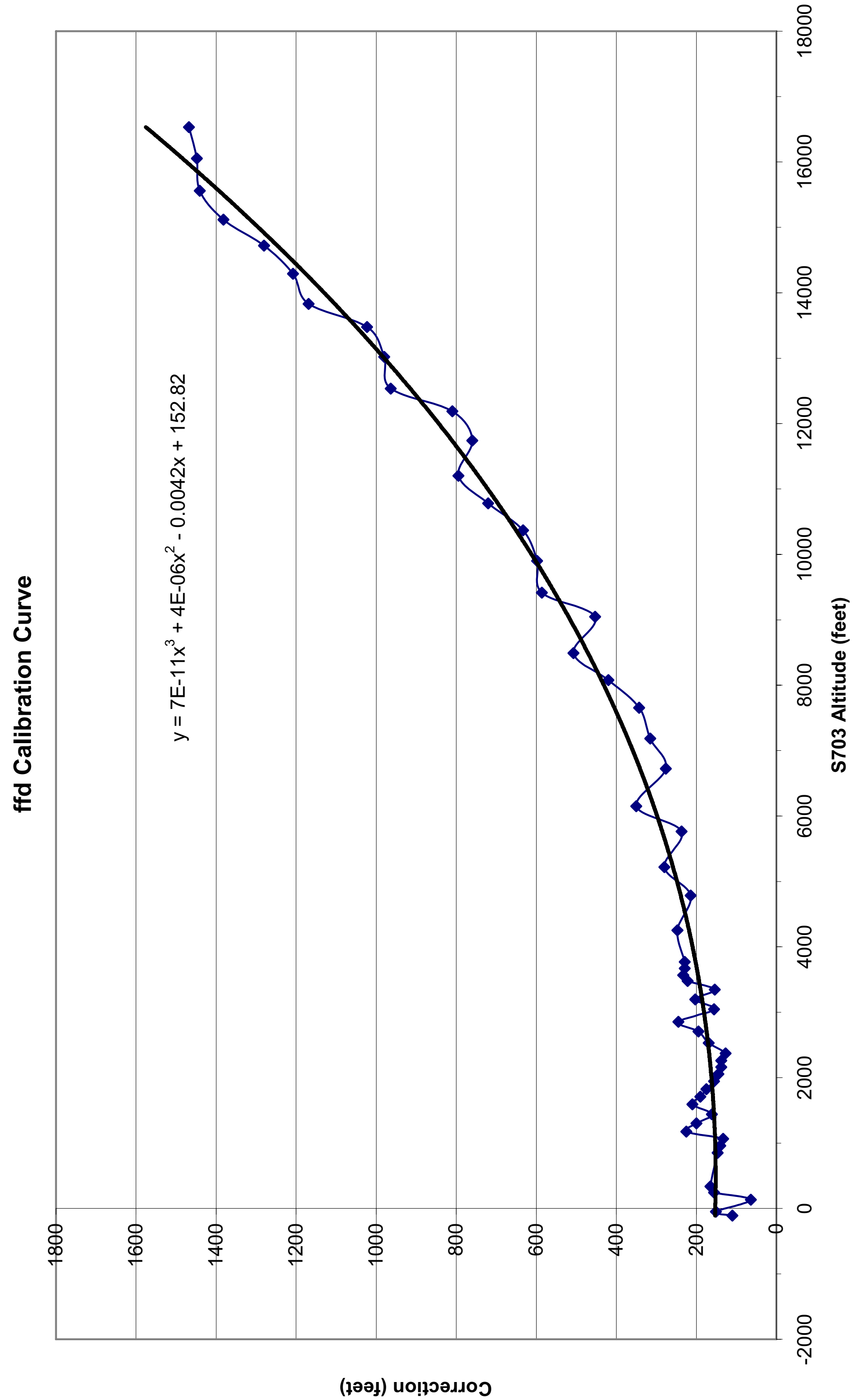
12 'Procedure for Crash Data Recovery for Flight Data Recorder Fairchild Model F1000 with Solid-State Memory'. Document FAR 0389 Revision 4, figure 7-1, Page 2.

Figure A-18:



Altitude Calibration - Climb
Altitude (feet)
Time (seconds)
Mode C Altitude
FDR Altitude
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
0
200
400
600
800
1000
1200

Figure A-19:



ffd Calibration Curve
y = 7E-11x3 + 4E-06x2 - 0.0042x + 152.82
S703 Altitude (feet)
Correction (feet)
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0
200
400
600
800
1000
1200
1400
1600
1800

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).

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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.

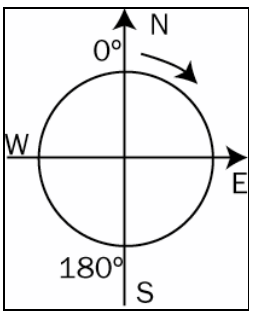
15 'Procedure for Crash Data Recovery for Flight Data Recorder Fairchild Model F1000 with Solid-State Memory'. Document FAR 0389, revision 4, figure 7-1, page 2.

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.

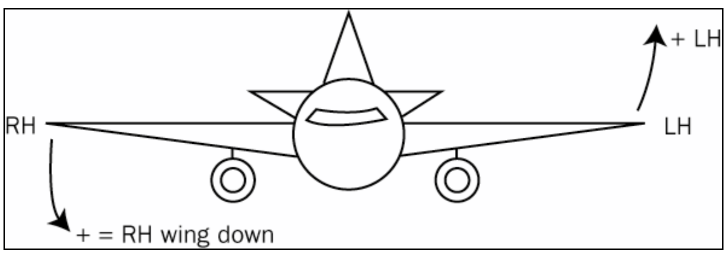
17 ATSB Recommendation 20060005 was issued on 10 February 2006 to address FDR and CVR system serviceability problems.

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:

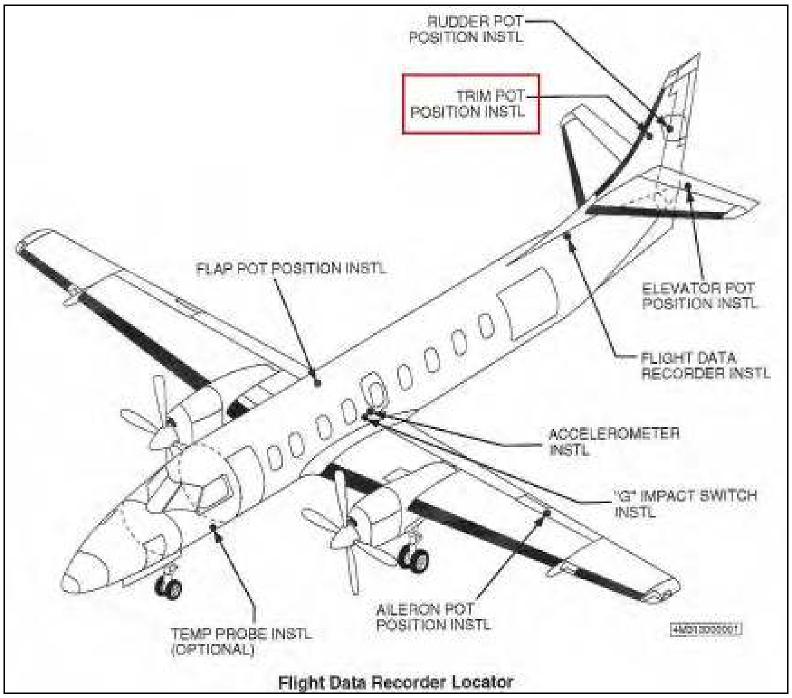
Figure A-22: Sign convention



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



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.

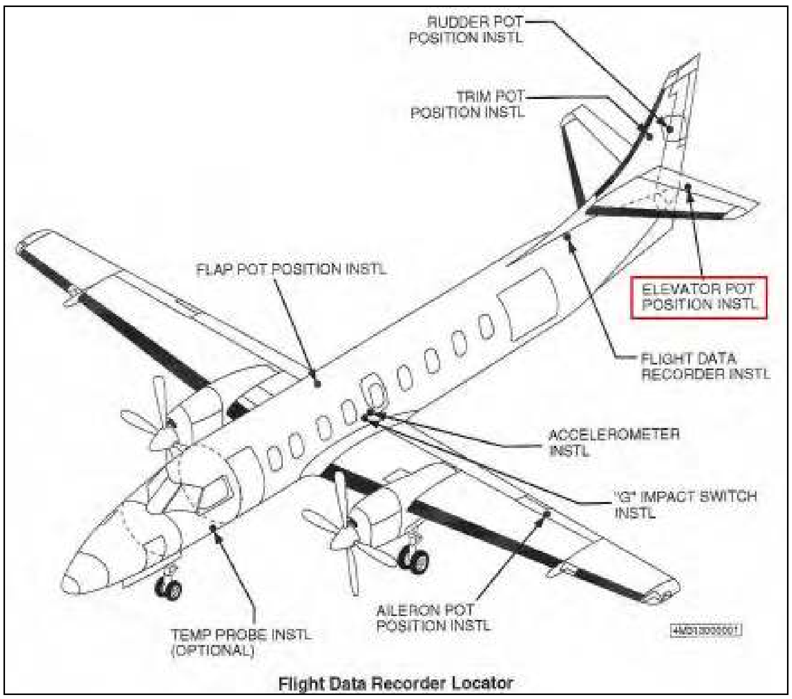
Examination of the raw horizontal stabiliser position data from VH-TFU showed that it behaved in a similar way to other Metro 23 aircraft. Data from VH-TFU and other Metro 23 aircraft were examined to determine the relationship between the raw decimal counts and horizontal stabiliser position.

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



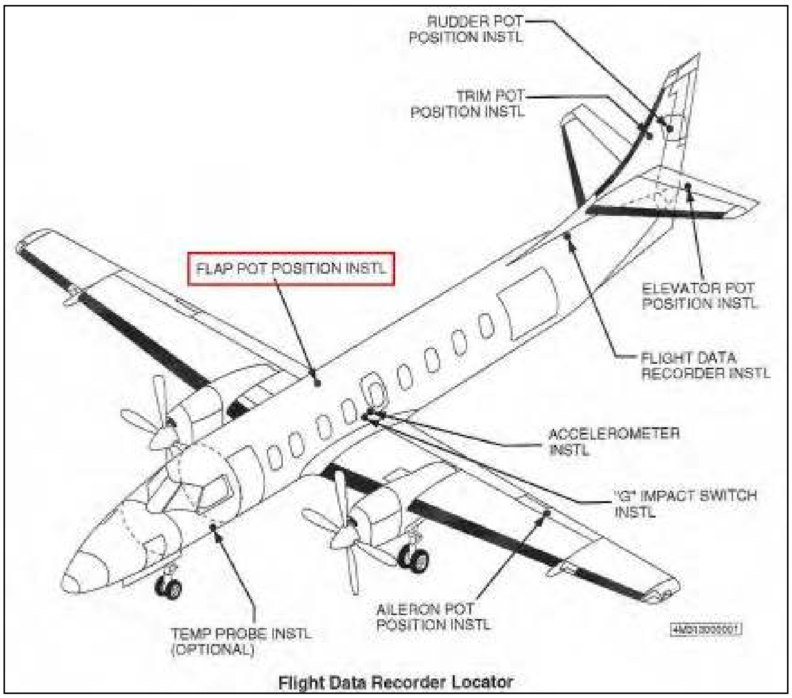
Elevator scaling was derived using Fairchild Aircraft drawing 27K82090 and figure 1-25 (page 40) from the L3 Communications component maintenance manual.

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



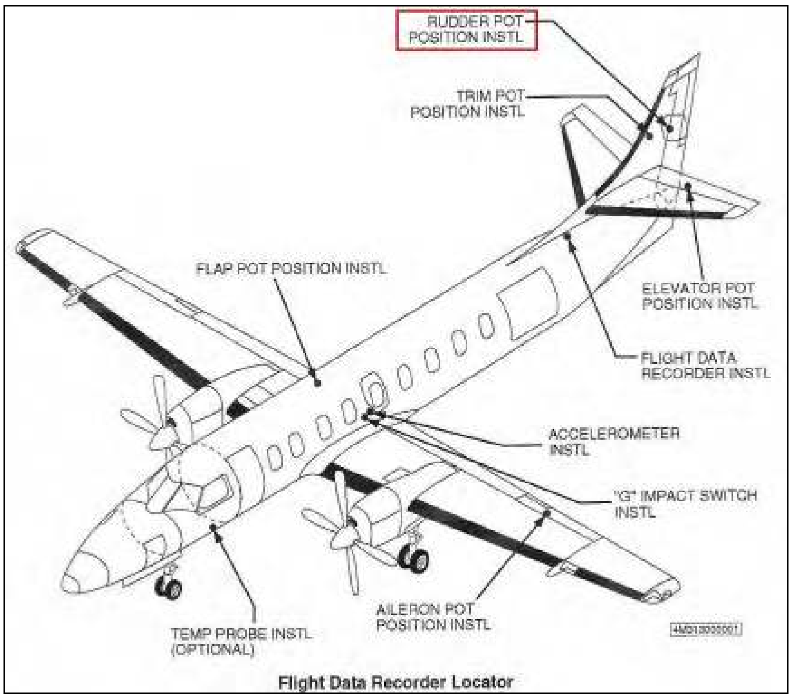
It was observed that the use of the standard scaling for flap position resulted in unrealistic values. The raw data was examined to determine the relationship between the raw decimal counts and flap position.

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



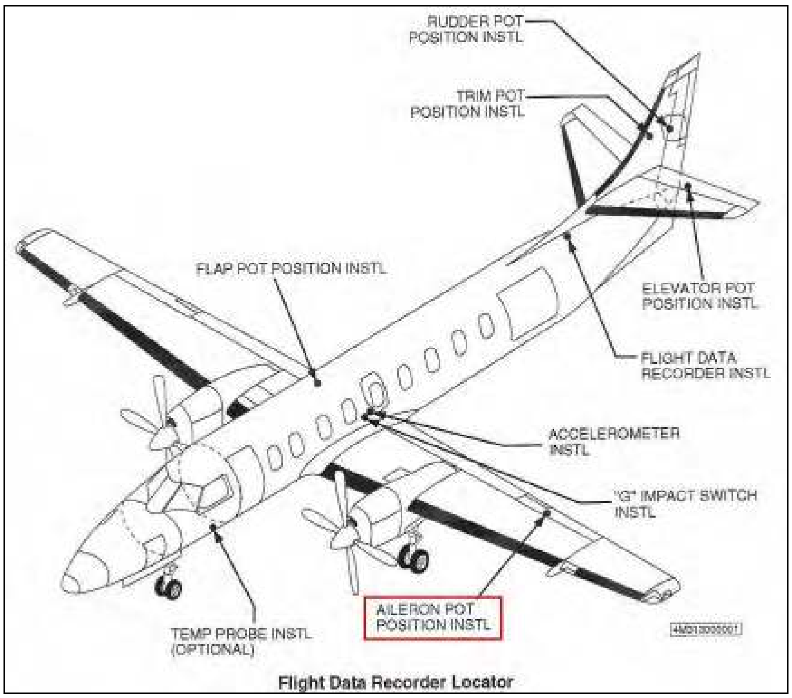
Rudder position scaling was derived using Fairchild Aircraft drawing 27K82090 and figure 1-25 (page 40) from the L3 Communications component maintenance manual.

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

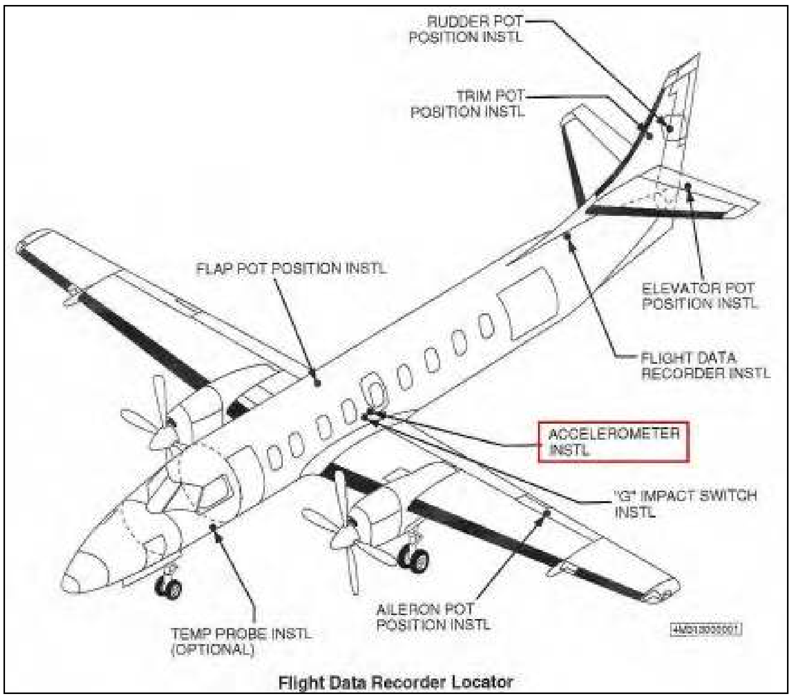
Signal Source:	Torque transducer (strain-gauge)
Signal Type:	DC voltage
Bits Used:	12
Word Location:	32
Resolution:	0.04%
Sampling Interval:	1 second

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

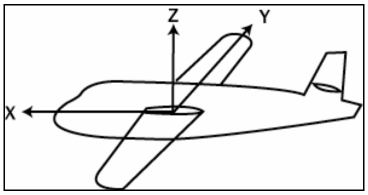
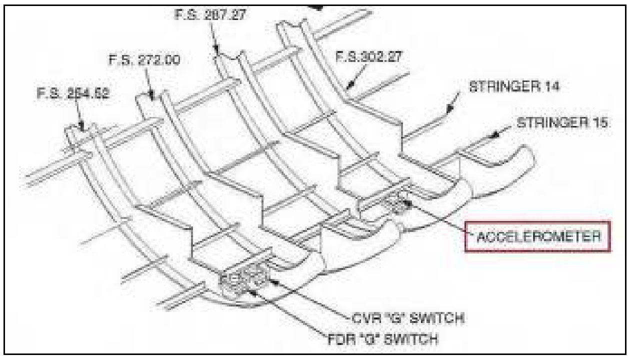


Figure A-30: Accelerometer detailed location



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

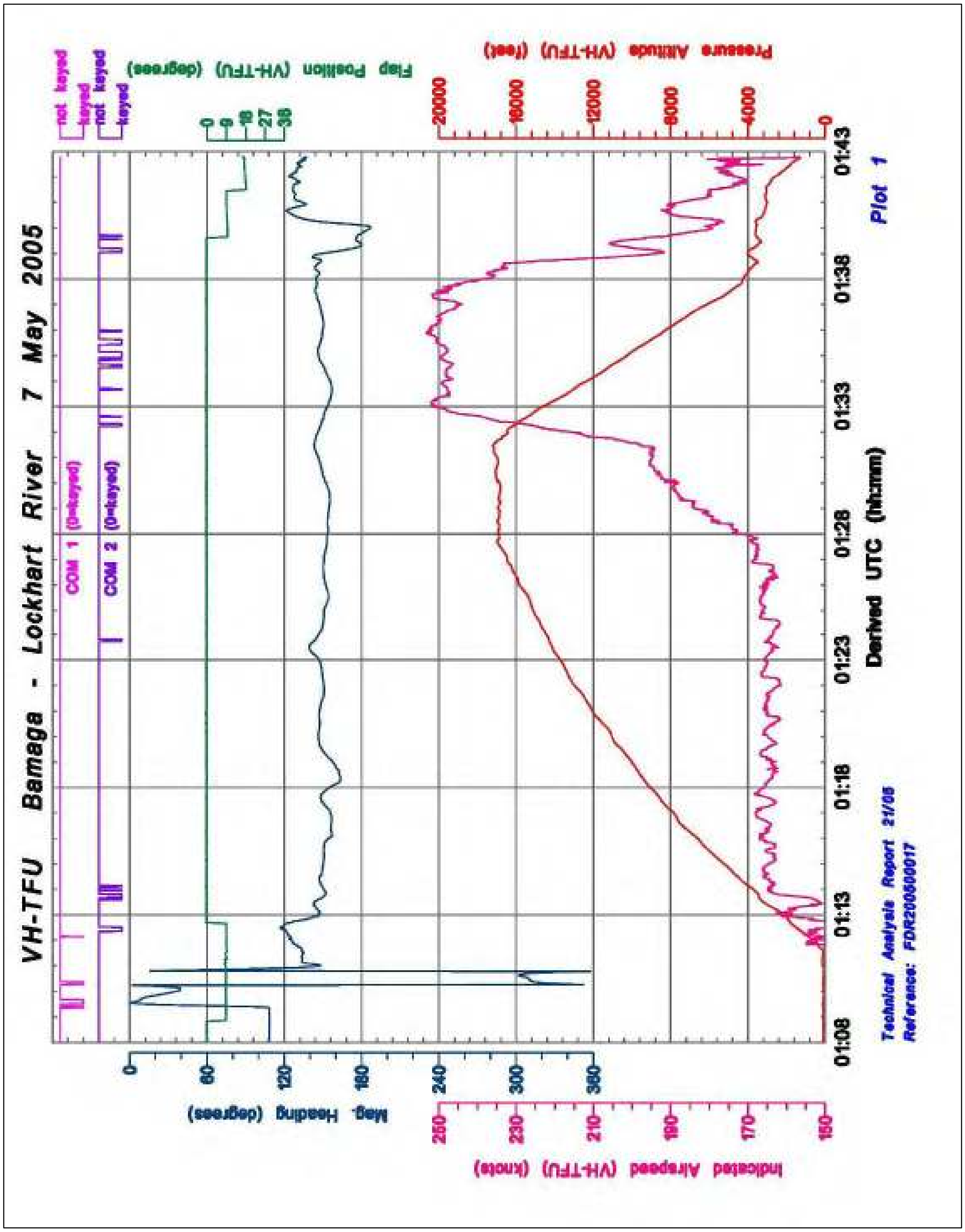


Figure A-33: Plot of engine parameters

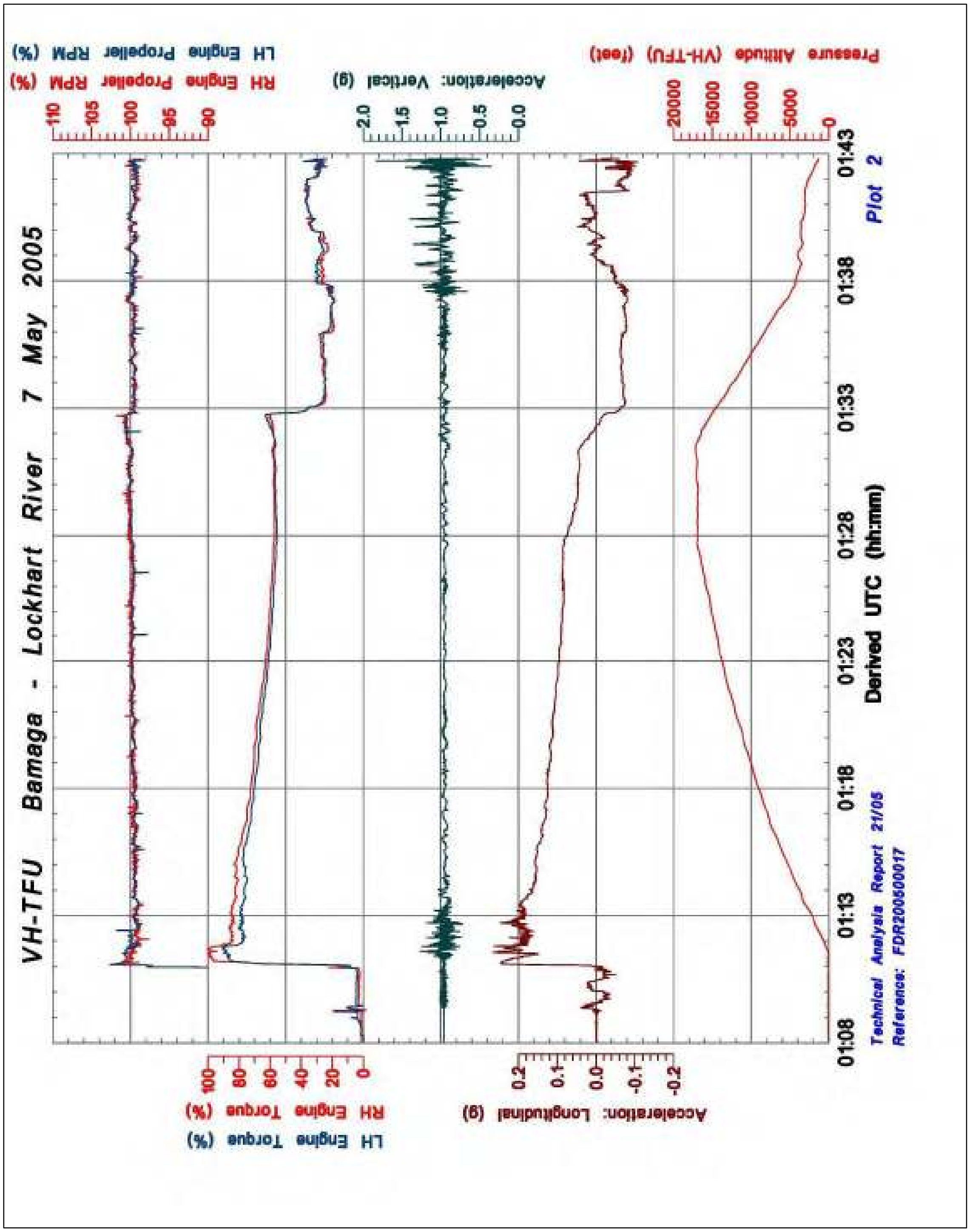


Figure A-34: Plot of control parameters

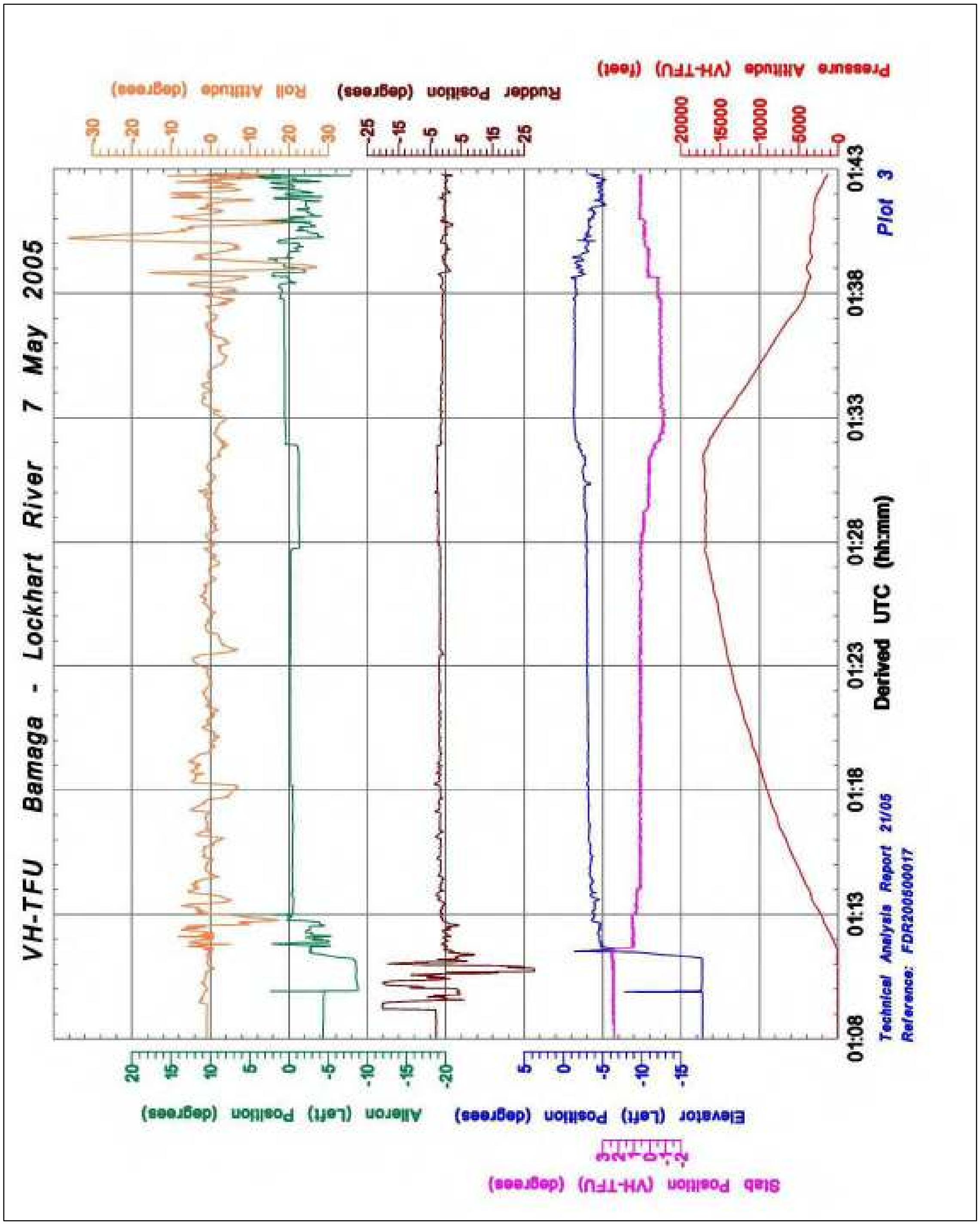


Figure A-35: Plot of flight parameters (last 5 minutes)

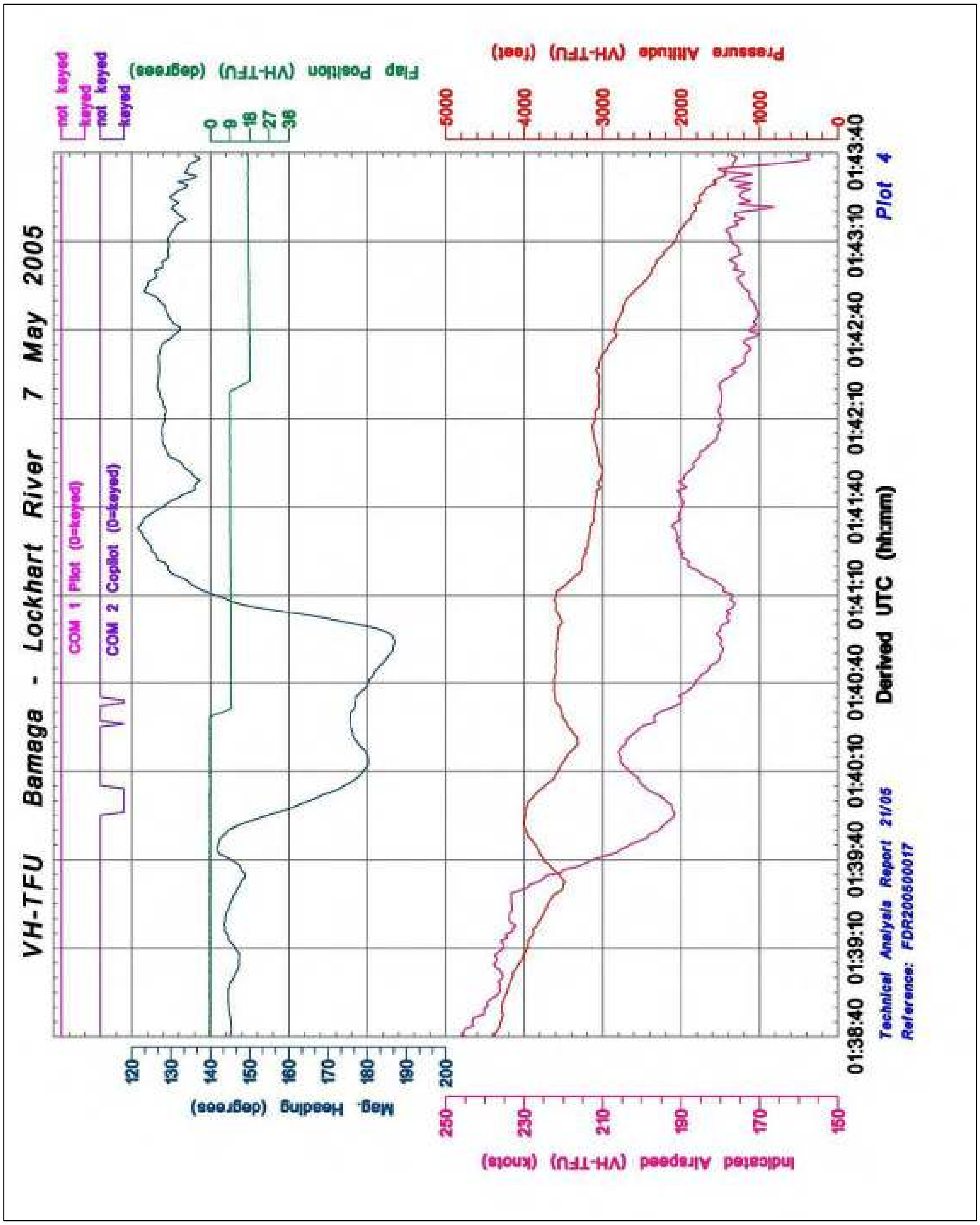


Figure A-36: Plot of engine parameters (last 5 minutes)

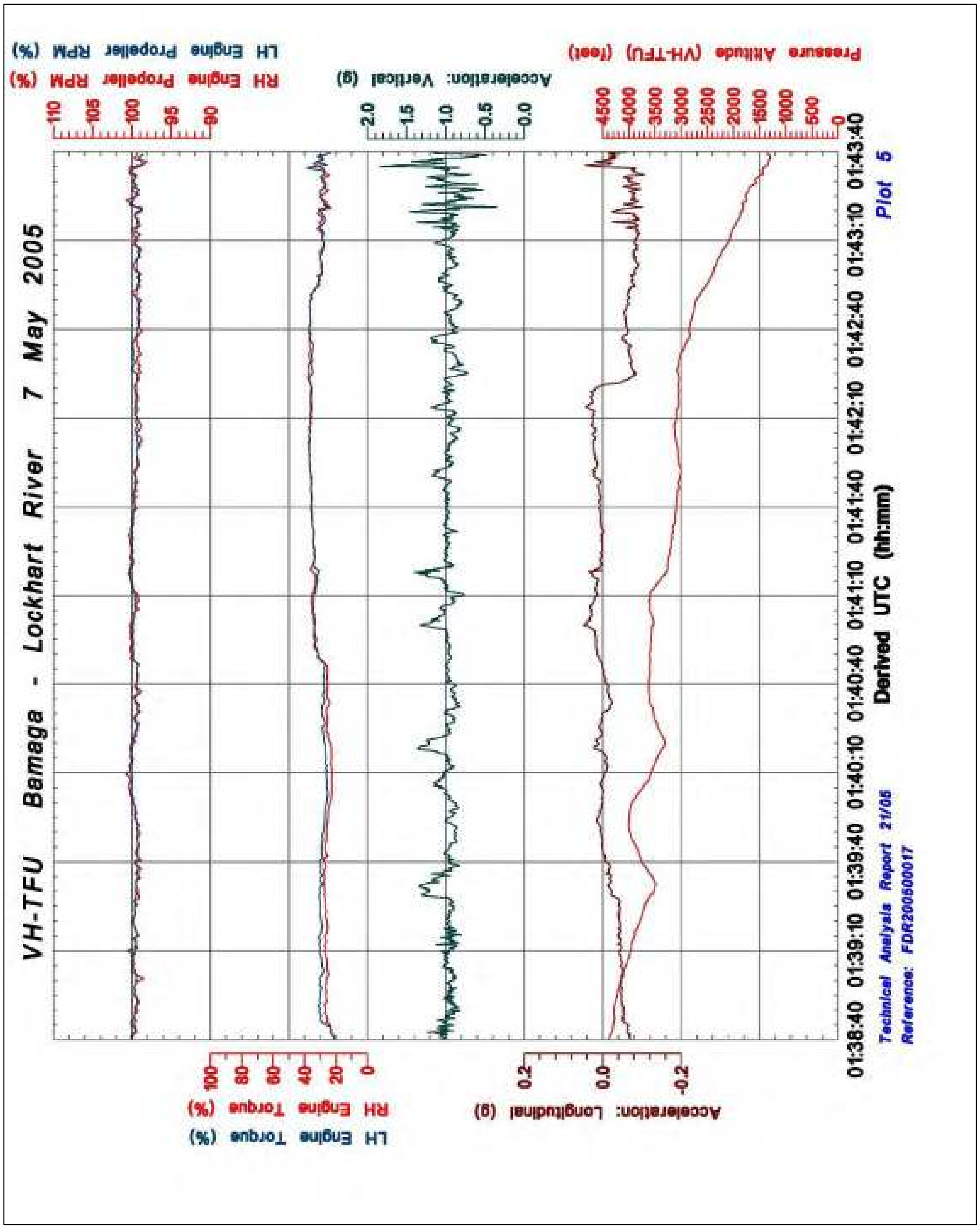
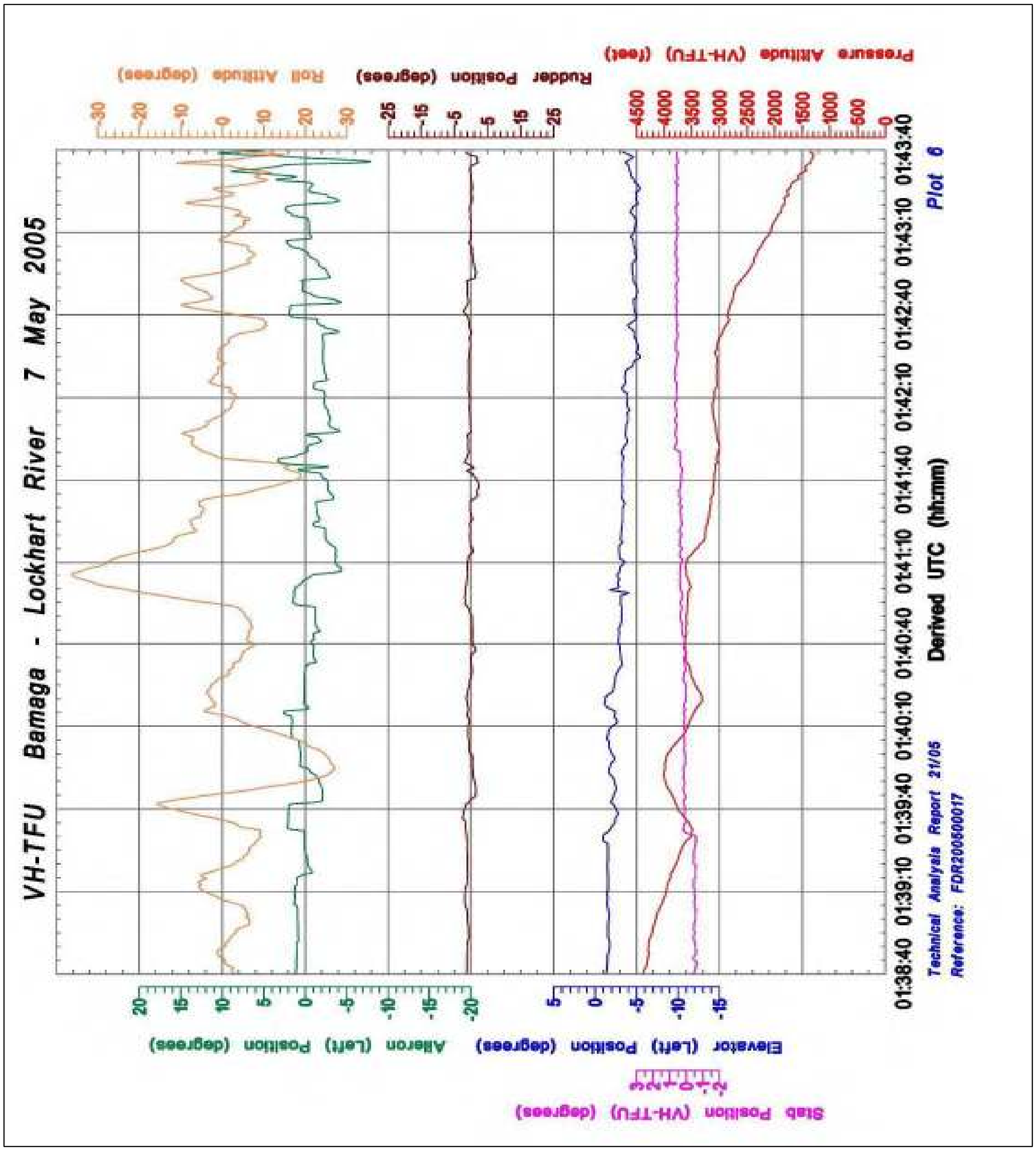


Figure A-37: Plot of control parameters (last 5 minutes)



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

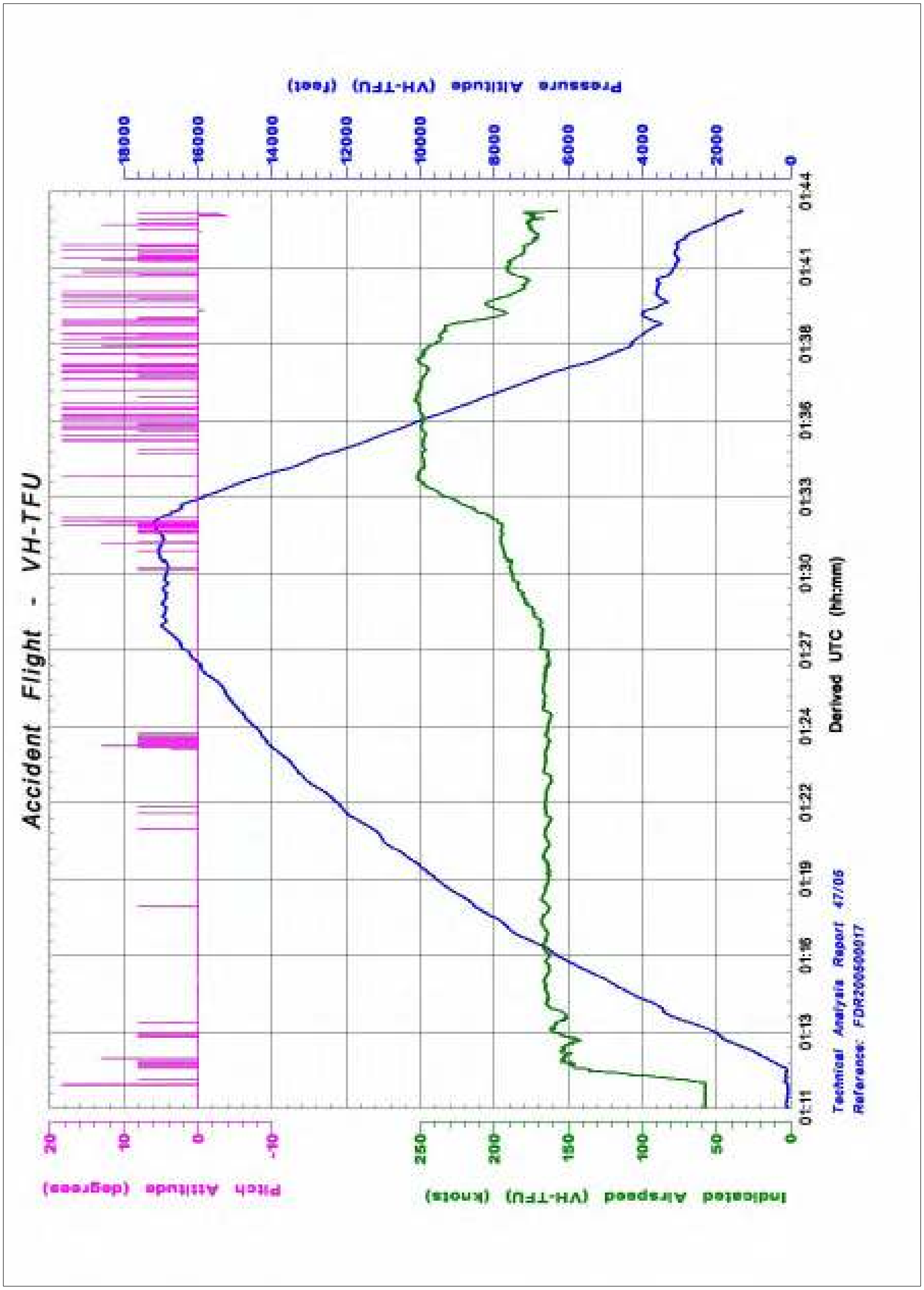
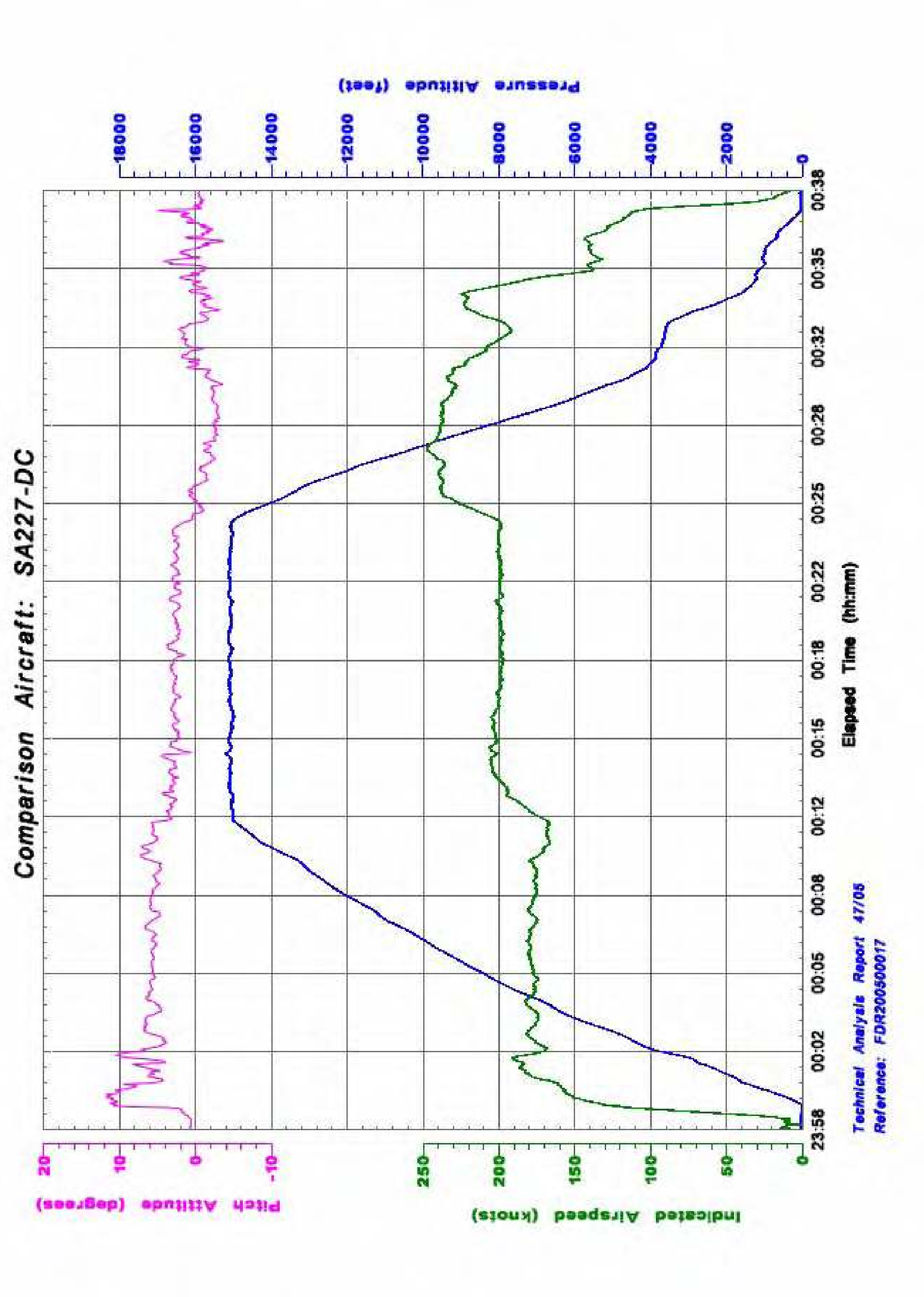


Figure A-39: Comparison pitch attitude data



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.

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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	

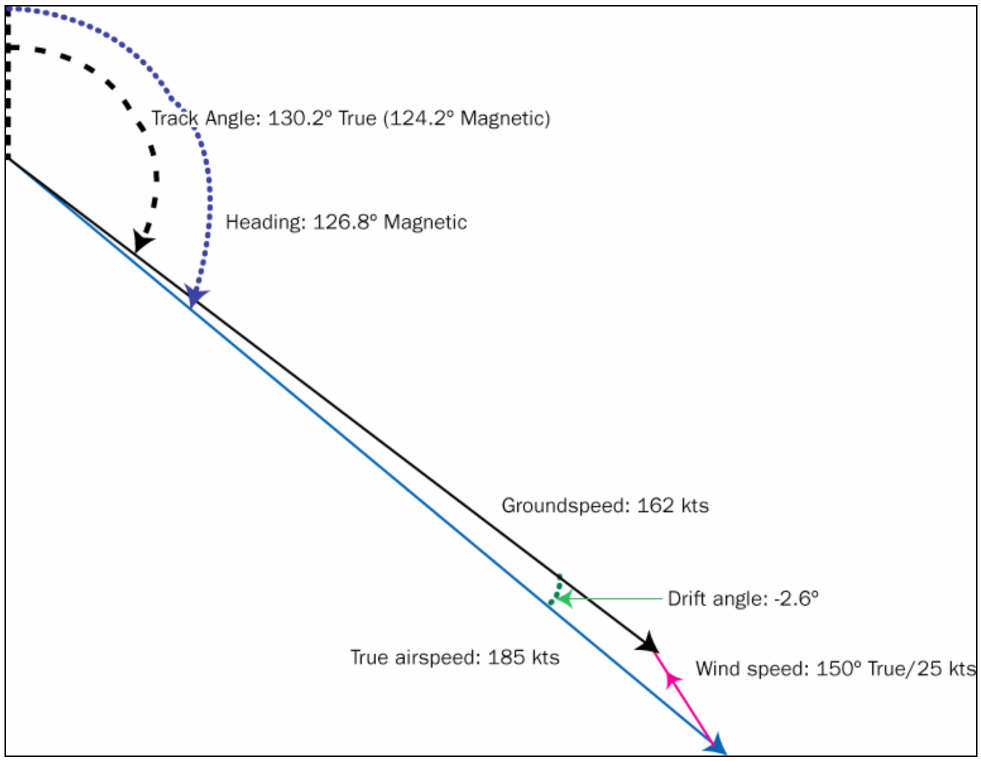
Table A-3: Determination of groundspeed from TAS

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.

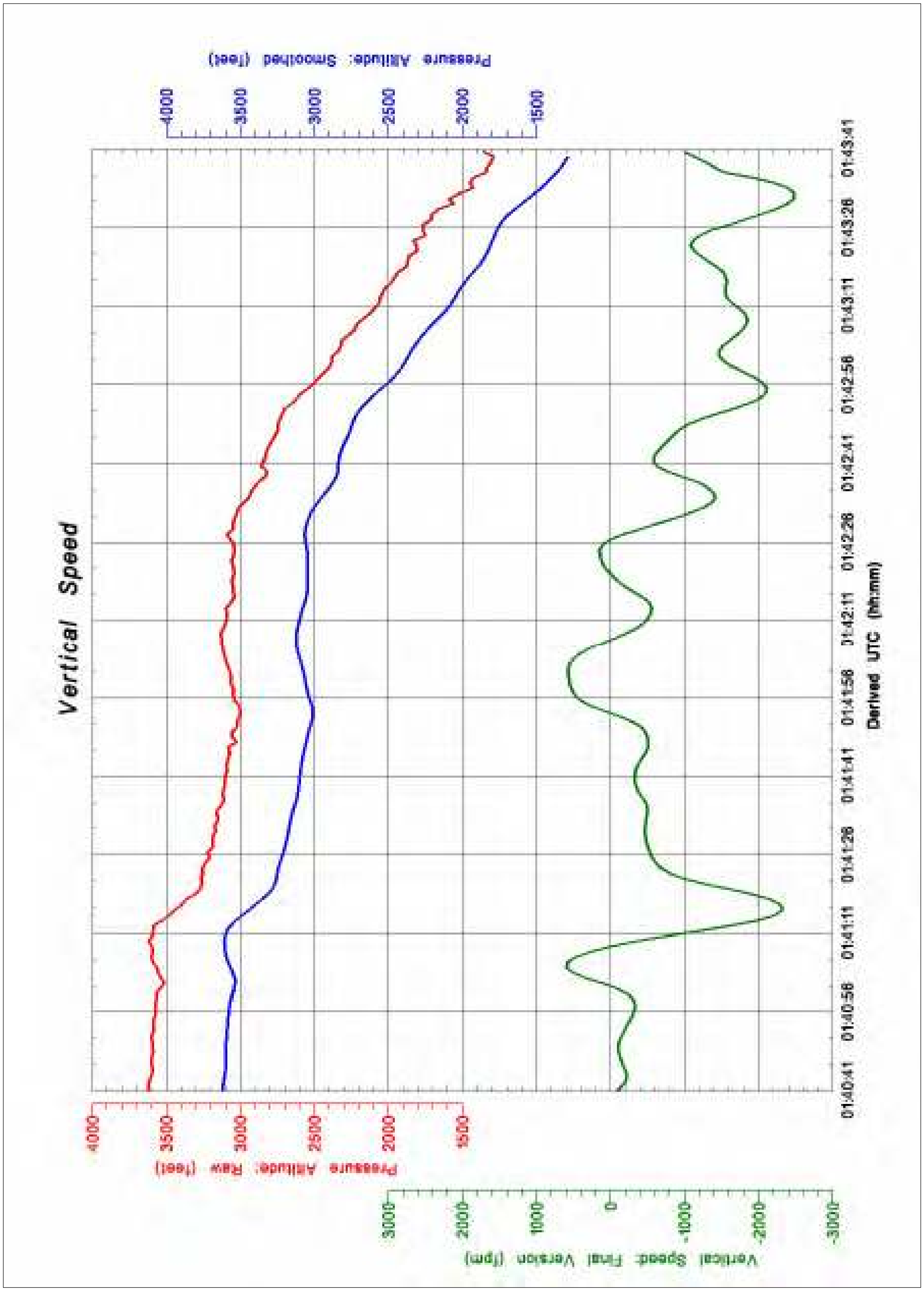
Determination of vertical speed

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:

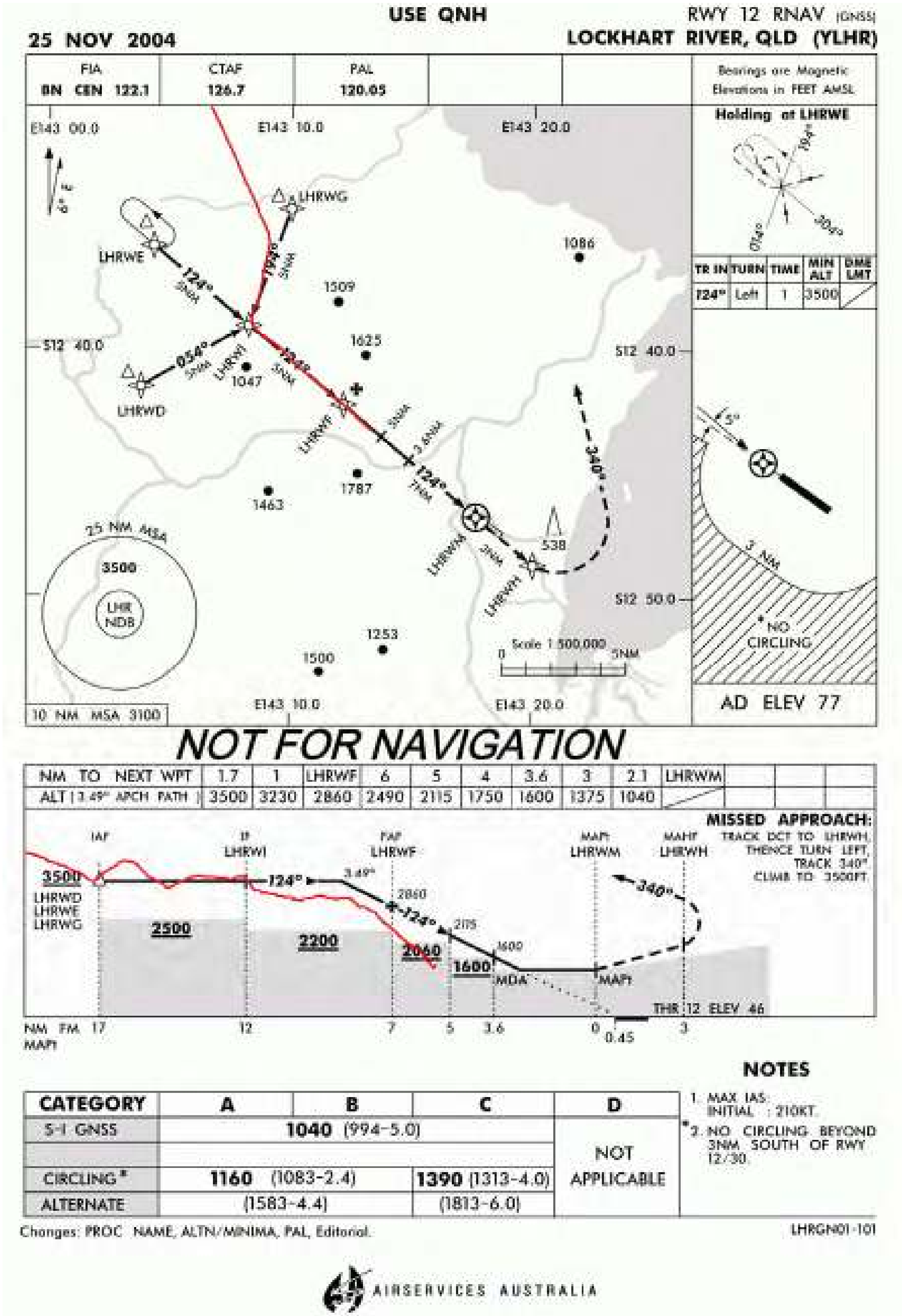
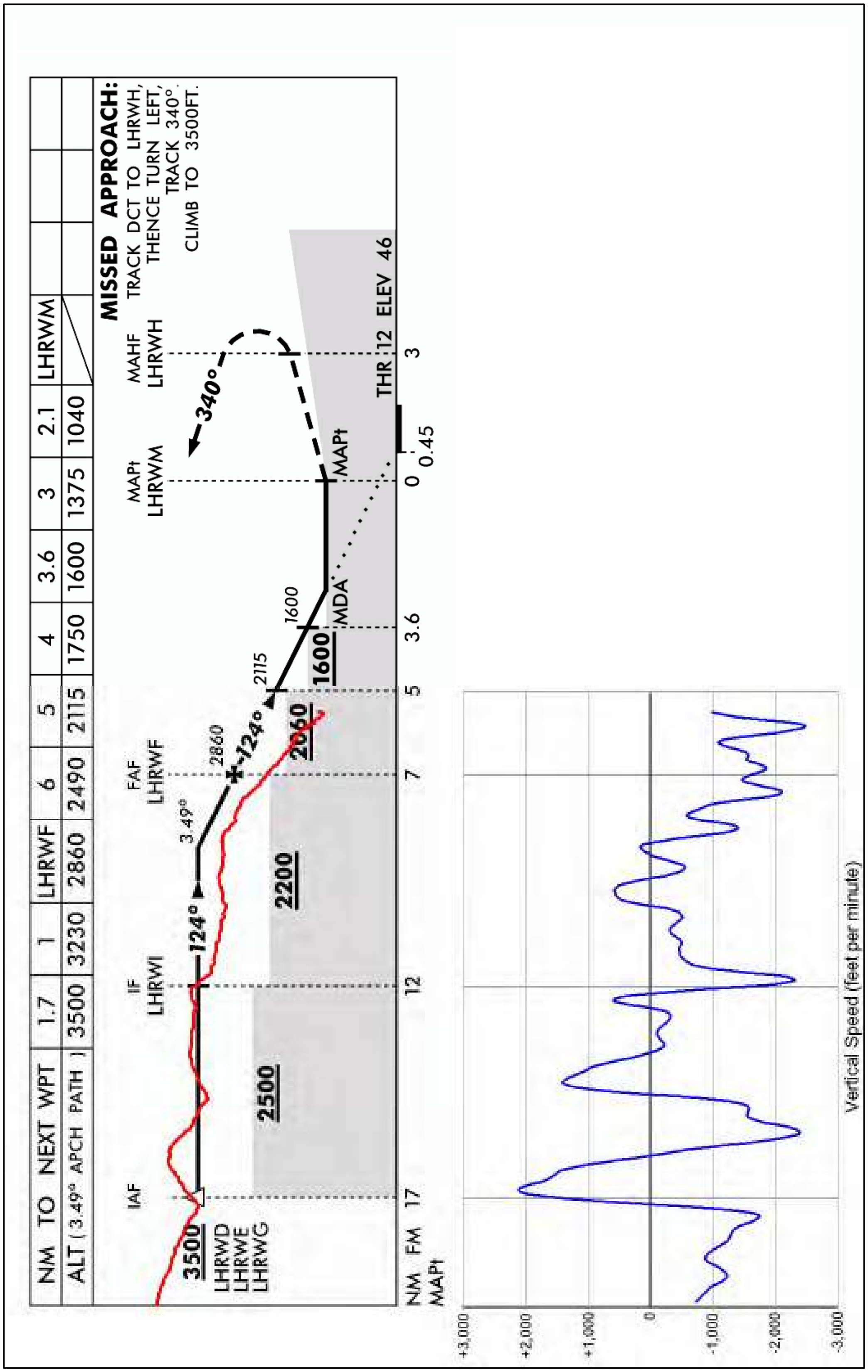

USE QNH
RWY 12 RNAV (GNSS)
25 NOV 2004
LOCKHART RIVER, QLD (YLHR)
FIA BN CEN 122.1
CTAF 126.7
PAL 120.05
Bearings are Magnetic
Elevations in FEET AMSL
Holding at LHRWE
TR IN | TURN | TIME | MIN ALT | DME LMT
124° | Left | 1 | 3500
E143 00.0
E143 10.0
E143 20.0
S12 40.0
S12 50.0
LHRWG
LHRWE
LHRWD
LHRWI
LHRWF
LHRWM
LHRWH
1086
1509
1625
1047
1787
1463
538
1253
1500
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.
IAF
IF LHRWI
FAF LHRWF
MAPt LHRWM
MAHF LHRWH
3500
LHRWD LHRWE LHRWG
2500
2200
2060
1600
MDA
MAPt
THR 12 ELEV 46
NM FM MAPt 17 12 7 5 3.6 0 0.45 3
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 A-43:



NM TO NEXT WPT
ALT (3.49° APCH PATH)
17
1.7
3500
1
3230
LHRWF
2860
6
2490
5
2115
4
1750
3.6
1600
3
1375
2.1
1040
LHRWM
LHRWH
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
124°
2115
1600
MDA
MAPt
340°
2500
2200
2060
1600
THR 12 ELEV 46
NM FM
MAPt
12
7
5
3.6
0
0.45
3
+3,000
+2,000
+1,000
0
-1,000
-2,000
-3,000
Vertical Speed (feet per minute)

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

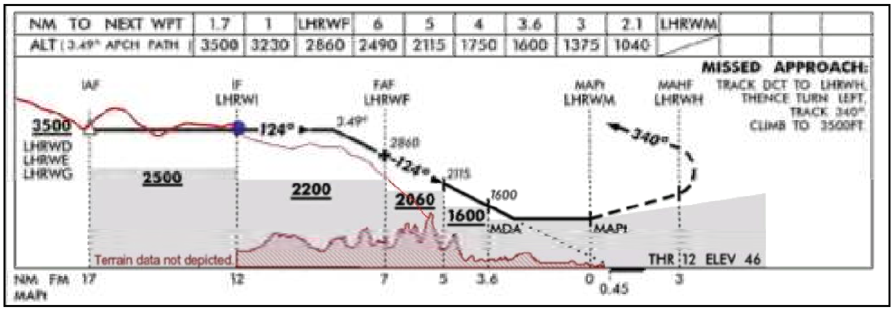
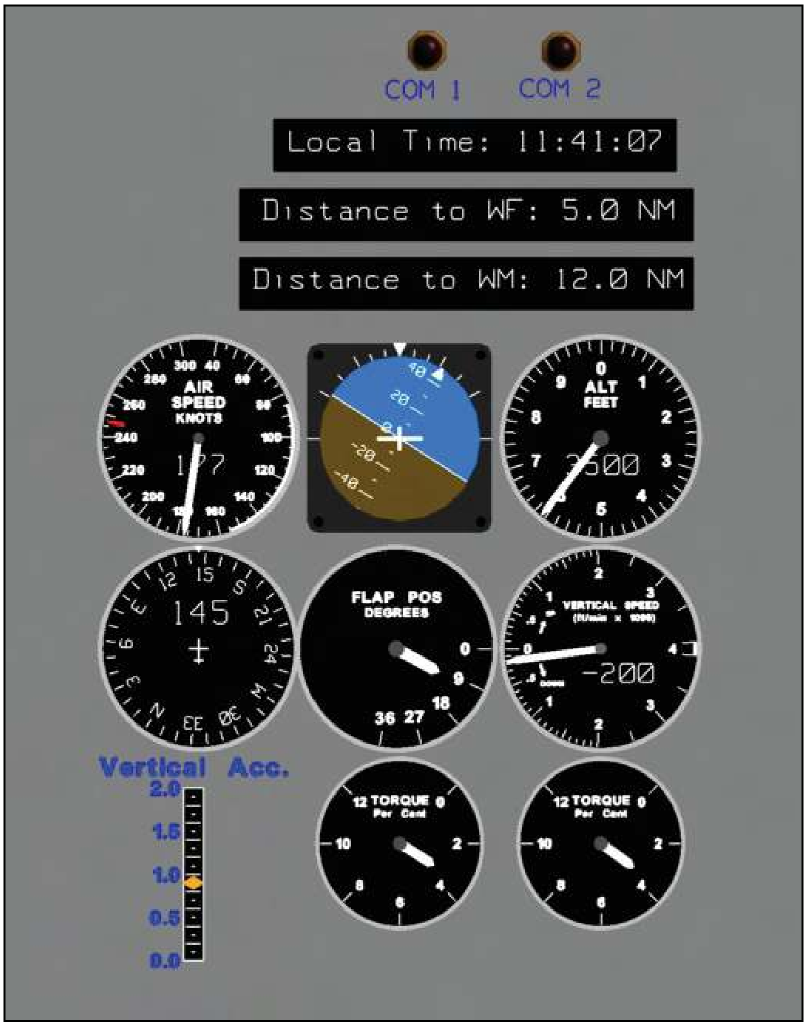


Figure A-46: Animation instrument panel



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)

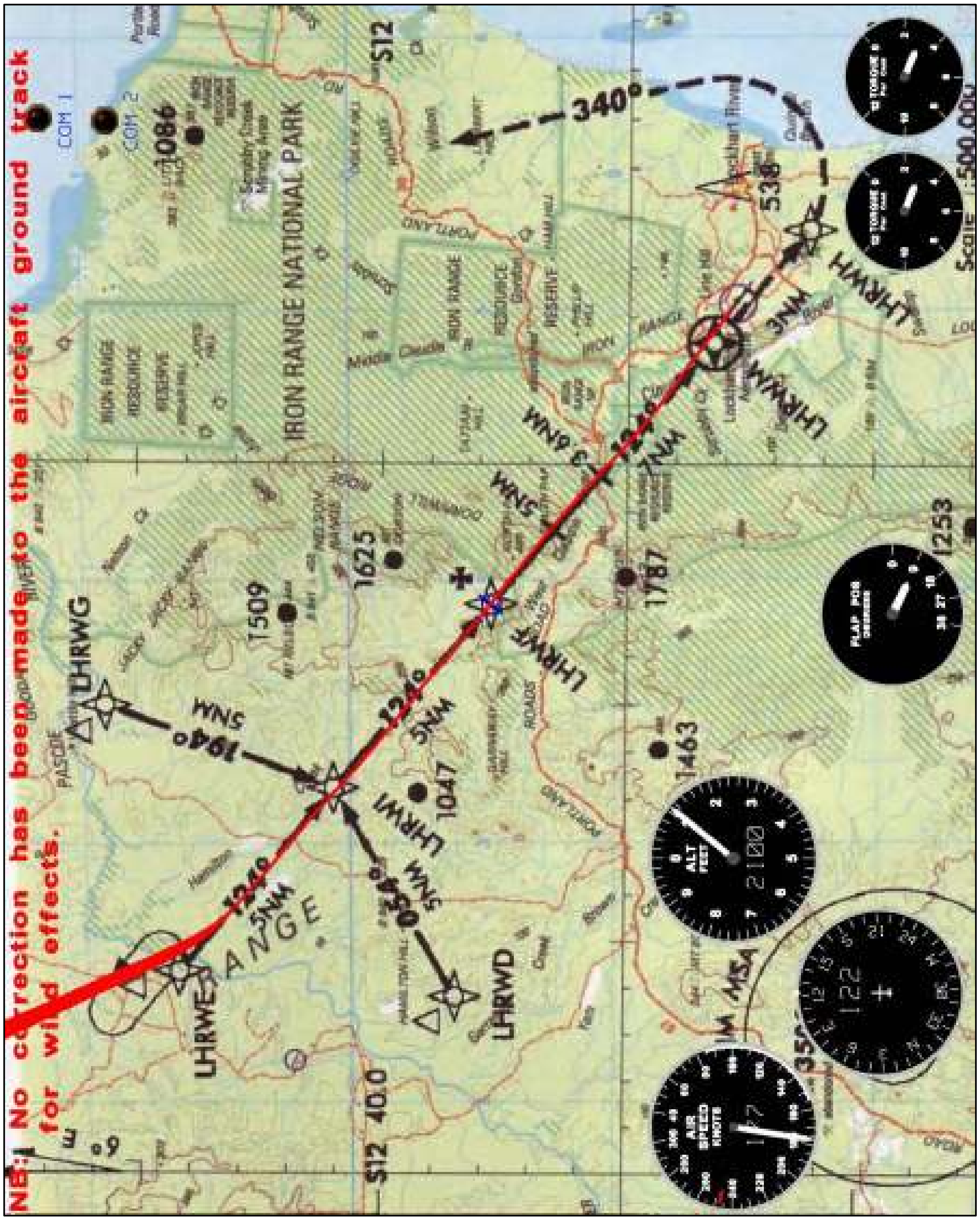
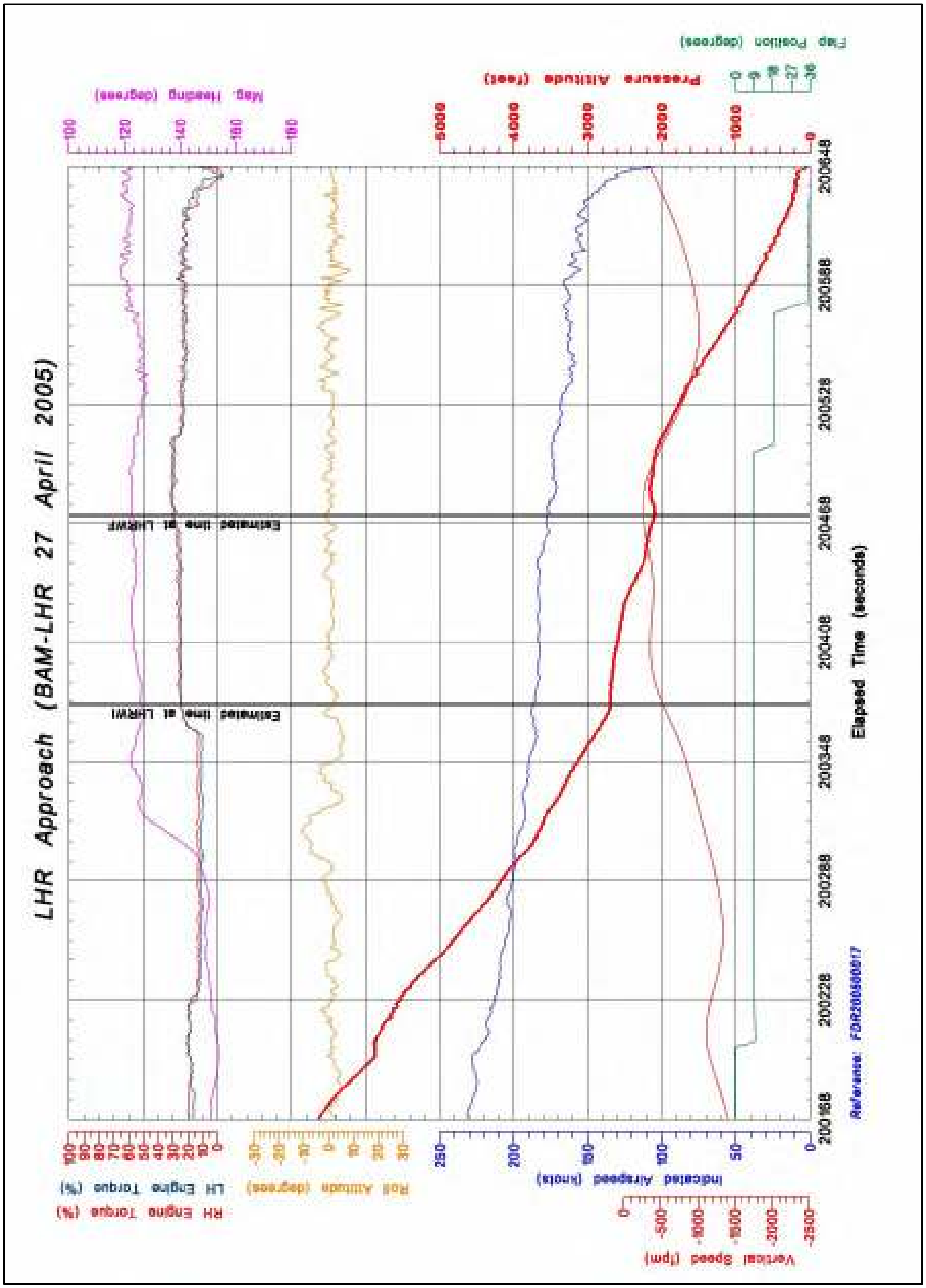


Figure A-48:



LHR Approach (BAM-LHR 27 April 2005)
Estimated time at LHRWI
Estimated time at LHRWF
Elapsed Time (seconds)
RH Engine Torque (%)
LH Engine Torque (%)
Roll Attitude (degrees)
Indicated Airspeed (knots)
Vertical Speed (fpm)
Mag. Heading (degrees)
Pressure Altitude (feet)
Flap Position (degrees)

Figure A-49: Animation elevation view (CNS-LHR 7 May 2005)

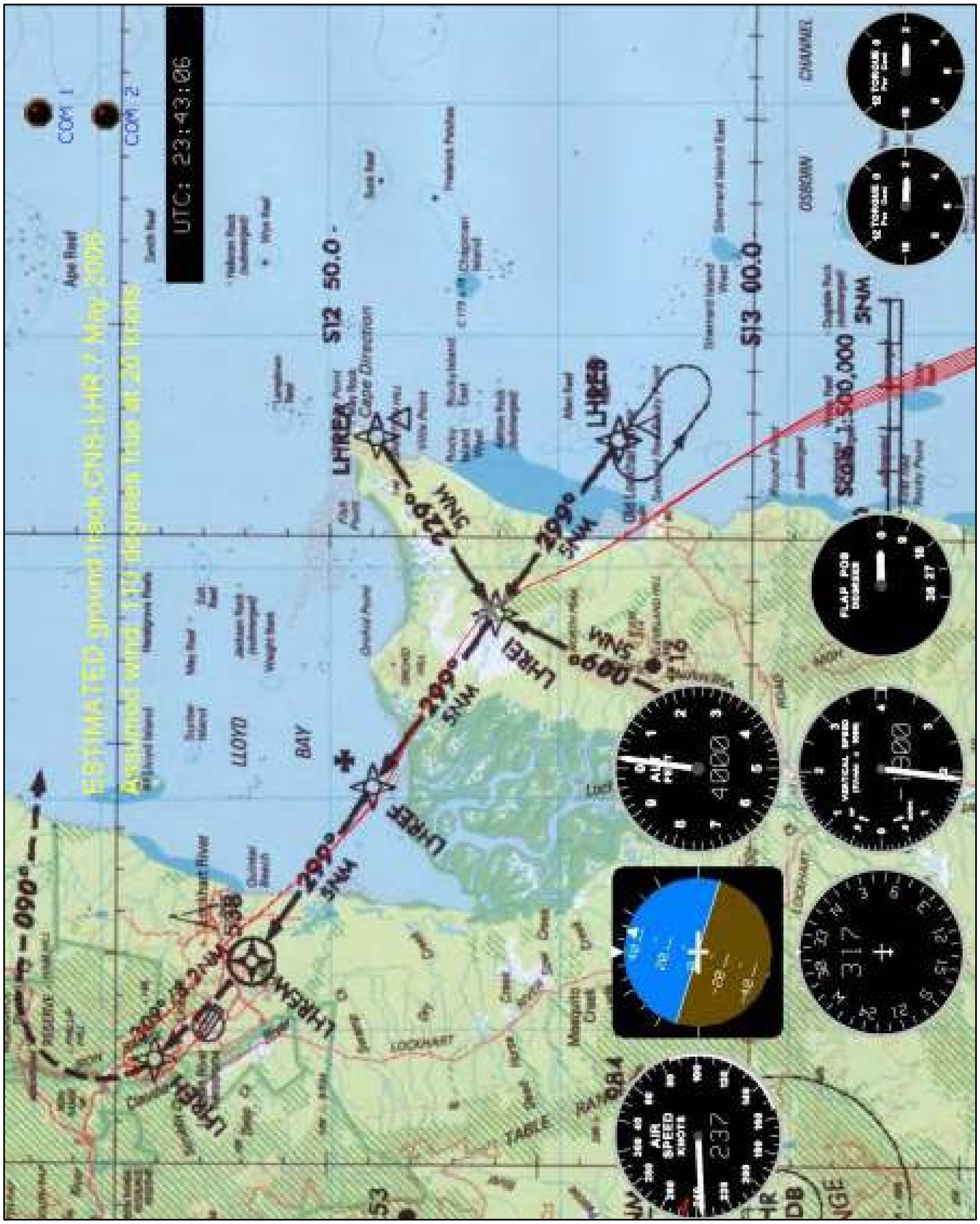


Figure A-50:

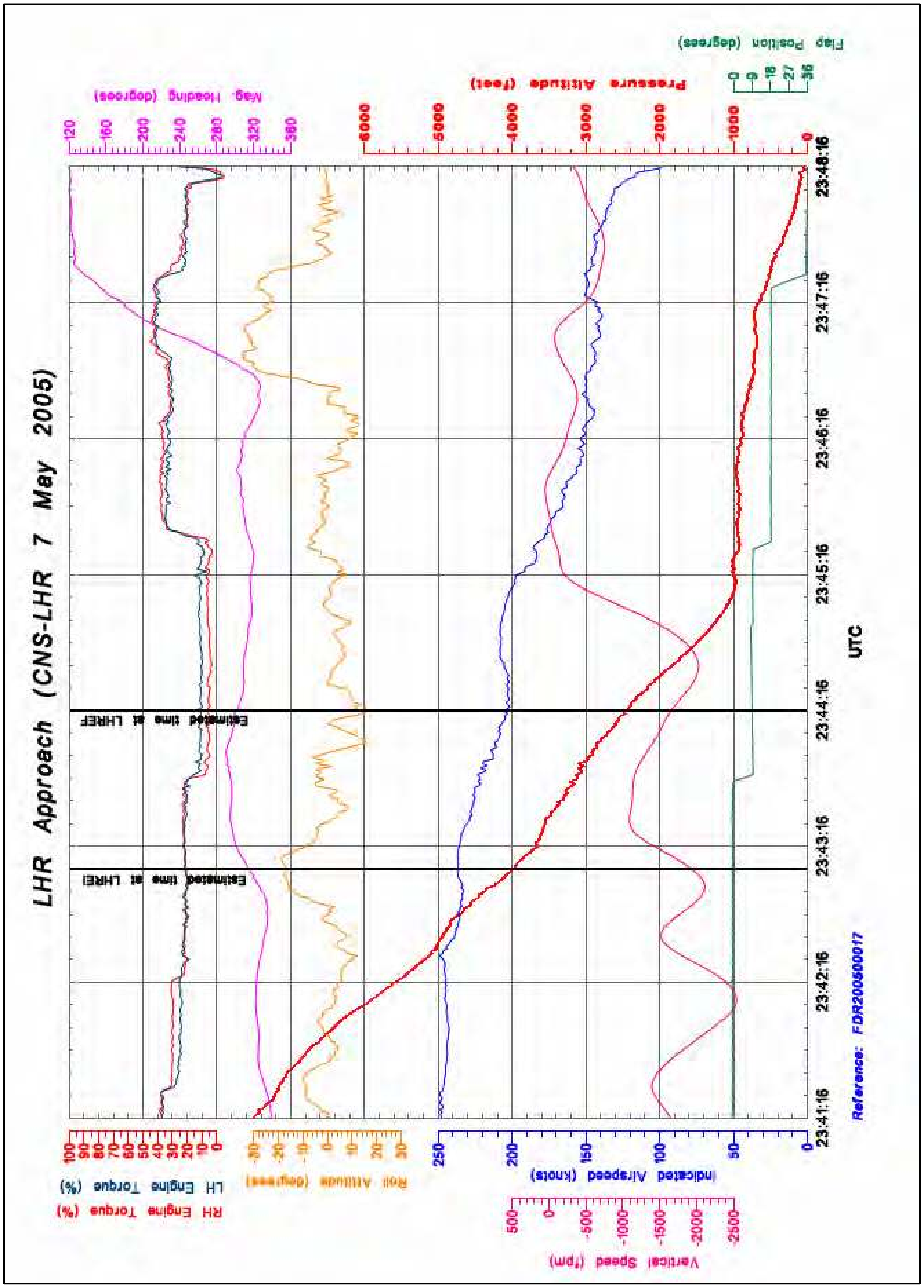
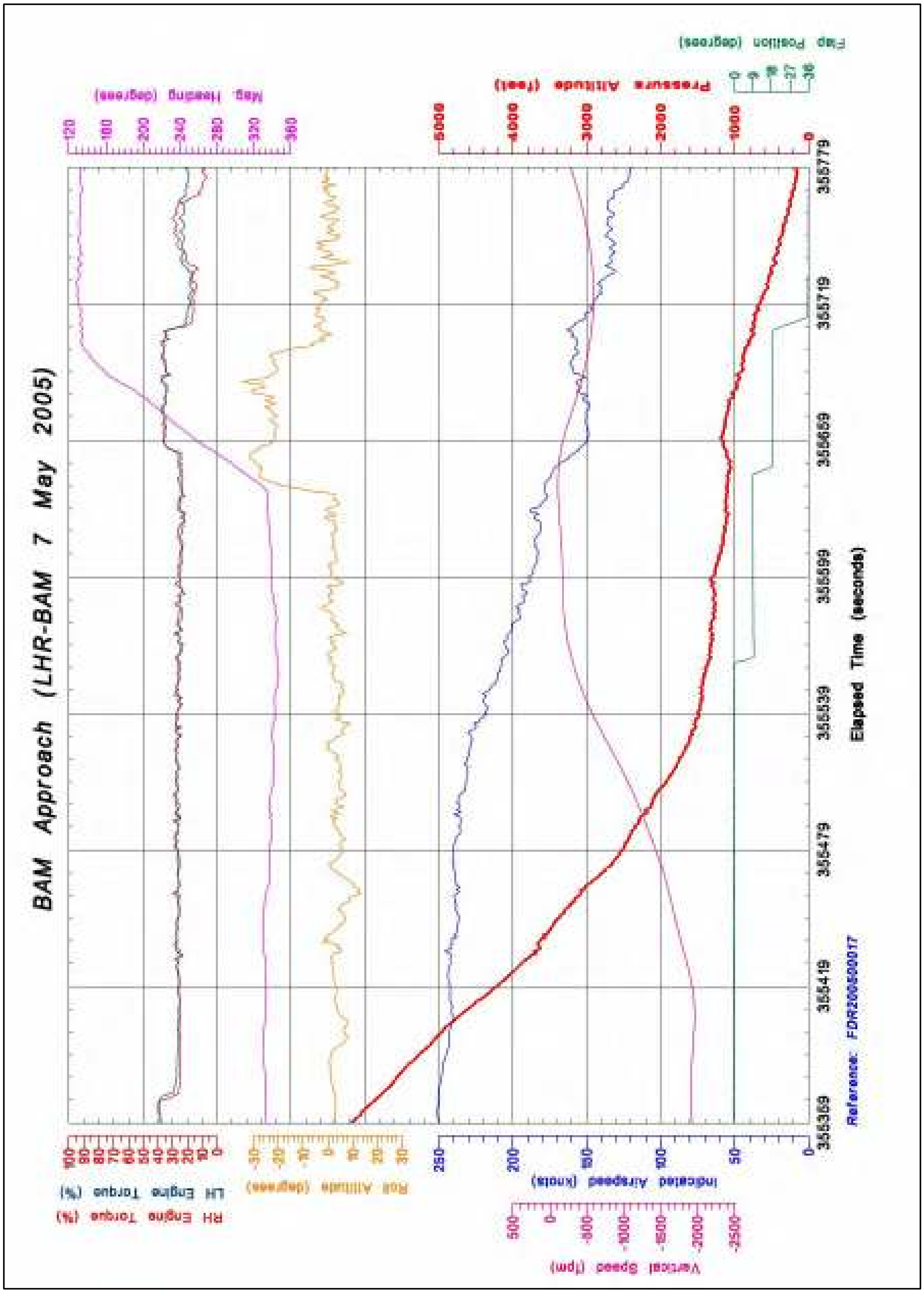

LHR Approach (CNS-LHR 7 May 2005)
RH Engine Torque (%)
LH Engine Torque (%)
Roll Attitude (degrees)
Indicated Airspeed (knots)
Vertical Speed (fpm)
Mag. Heading (degrees)
Pressure Altitude (feet)
Flap Position (degrees)
Estimated time at LHREI
Estimated time at LHREF
23:41:16
23:42:16
23:43:16
23:44:16
23:45:16
23:46:16
23:47:16
23:48:16
UTC
Reference: FDR200500017

Figure A-51:



BAM Approach (LHR-BAM 7 May 2005)
Elapsed Time (seconds)
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:

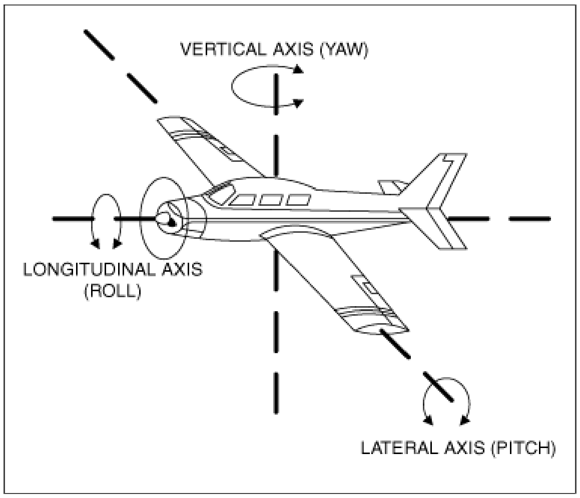
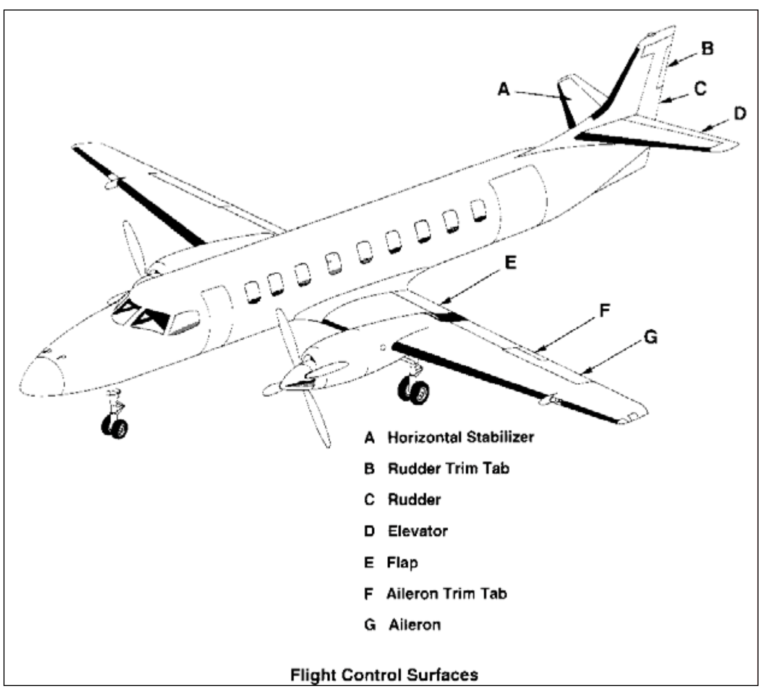


Figure A-53: Flight control surfaces of a Metro 23 aircraft



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.

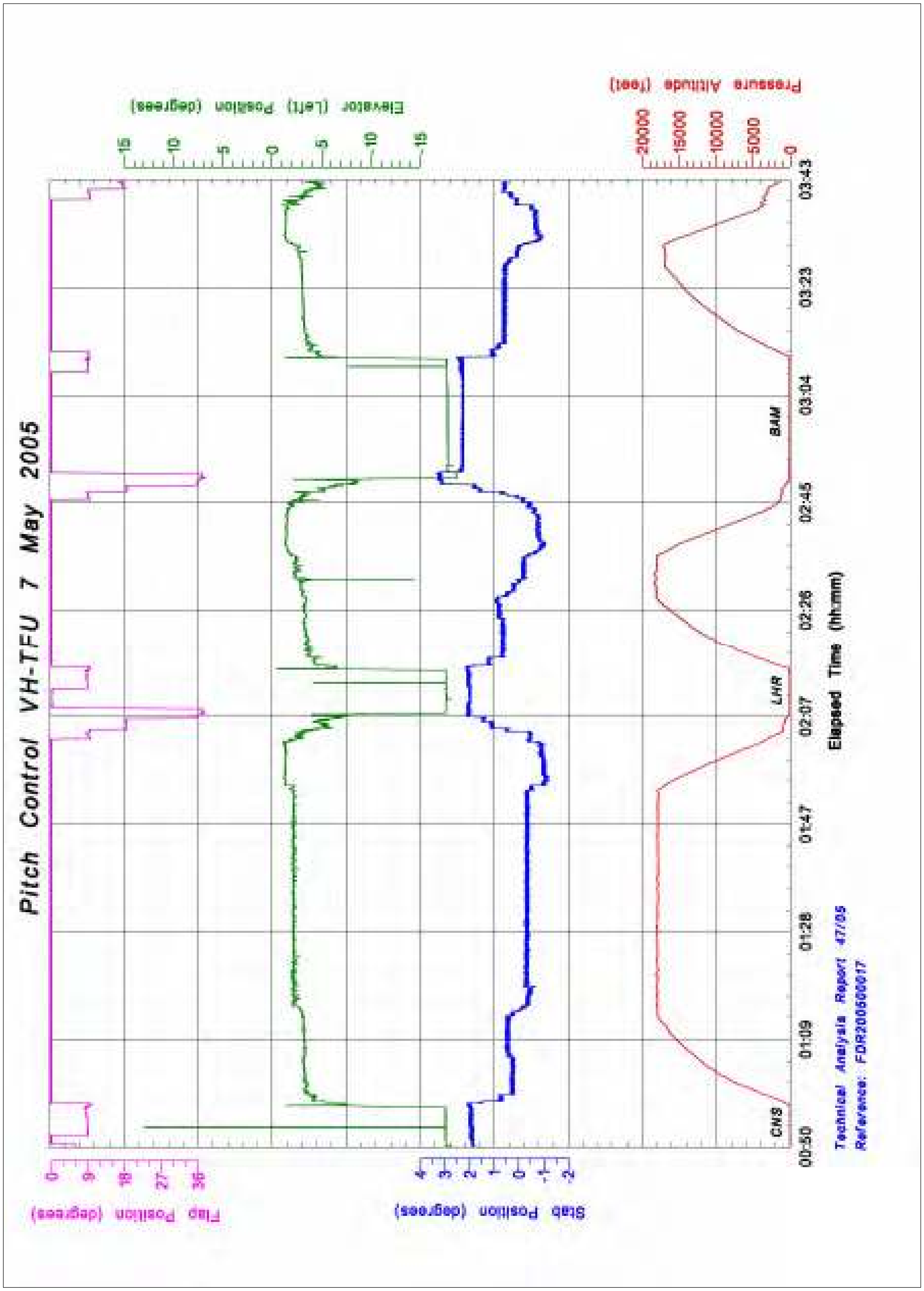
No anomalies were observed in recorded rudder position during the accident flight or the two previous flights recorded on 7 May 2005.

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.

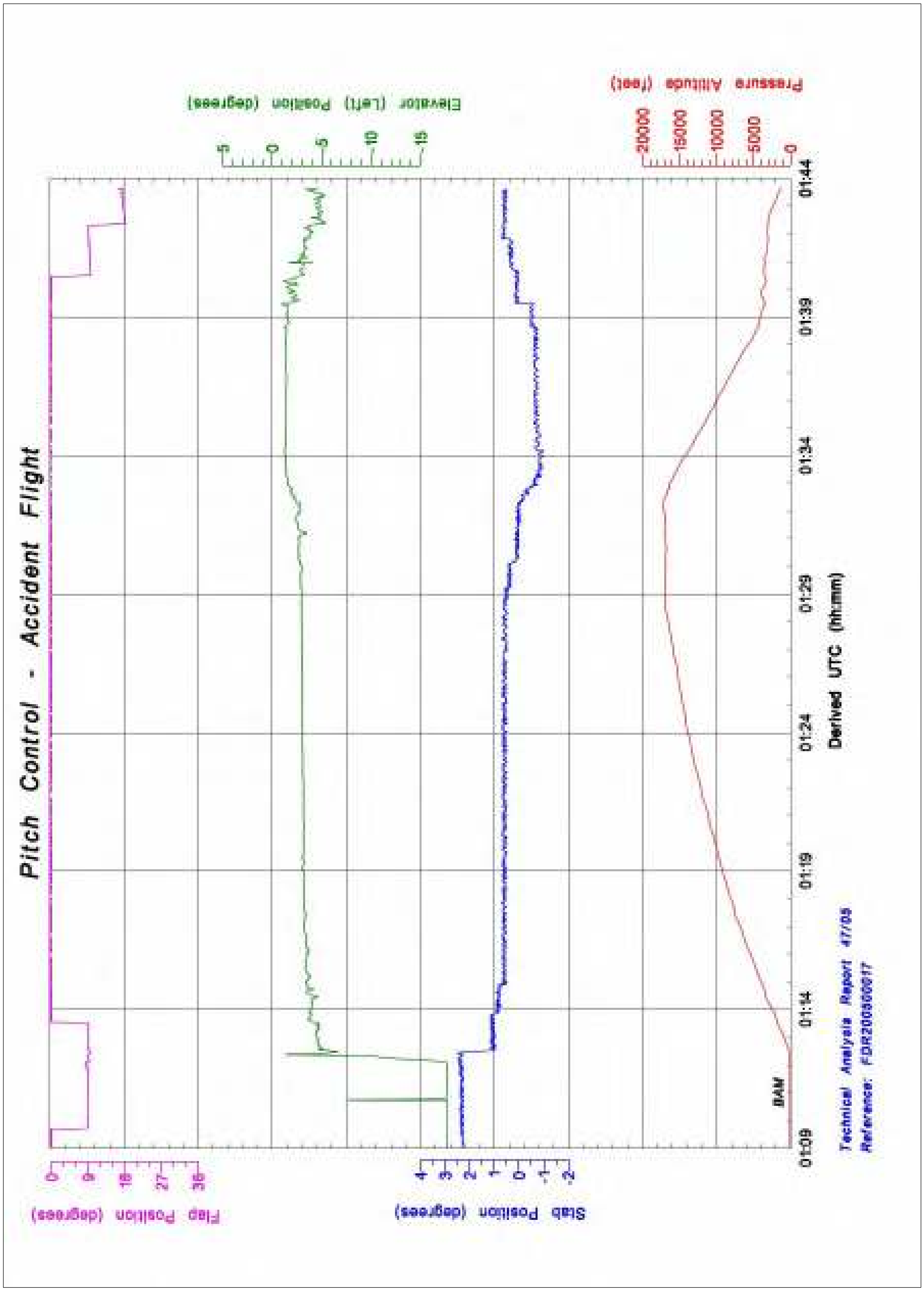
A GPWS escape manoeuvre requires that the pilot make a large nose-up pitch control input and apply maximum power. Recorded elevator position and engine torque parameters showed no evidence of such commands.

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)
00:50
01:09
01:28
01:47
02:07
02:26
02:45
03:04
03:23
03:43
CNS
LHR
BAM
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-55:



Pitch Control - Accident Flight
Flap Position (degrees)
Stab Position (degrees)
Elevator (Left) Position (degrees)
Pressure Altitude (feet)
Derived UTC (hh:mm)
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-56:

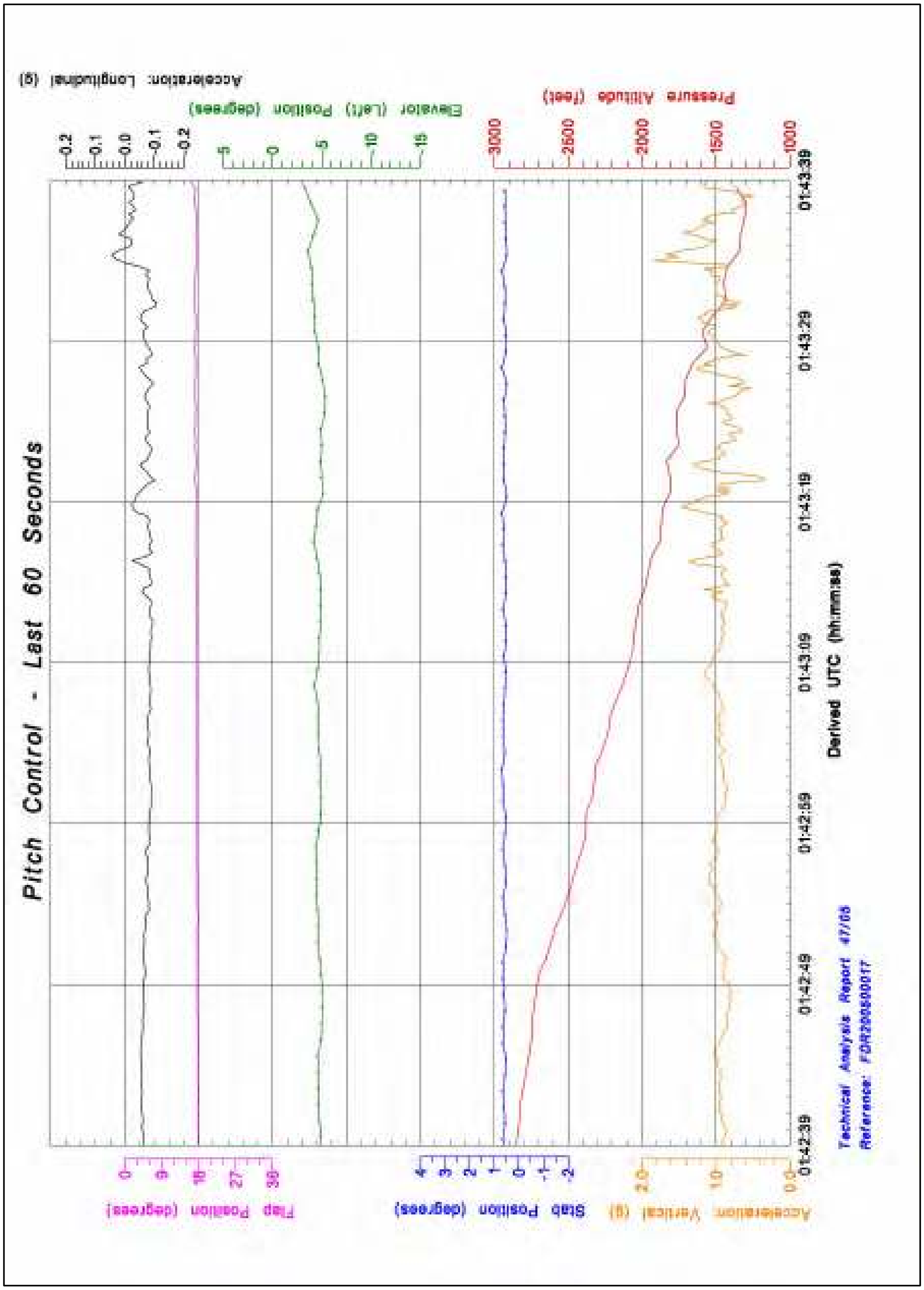
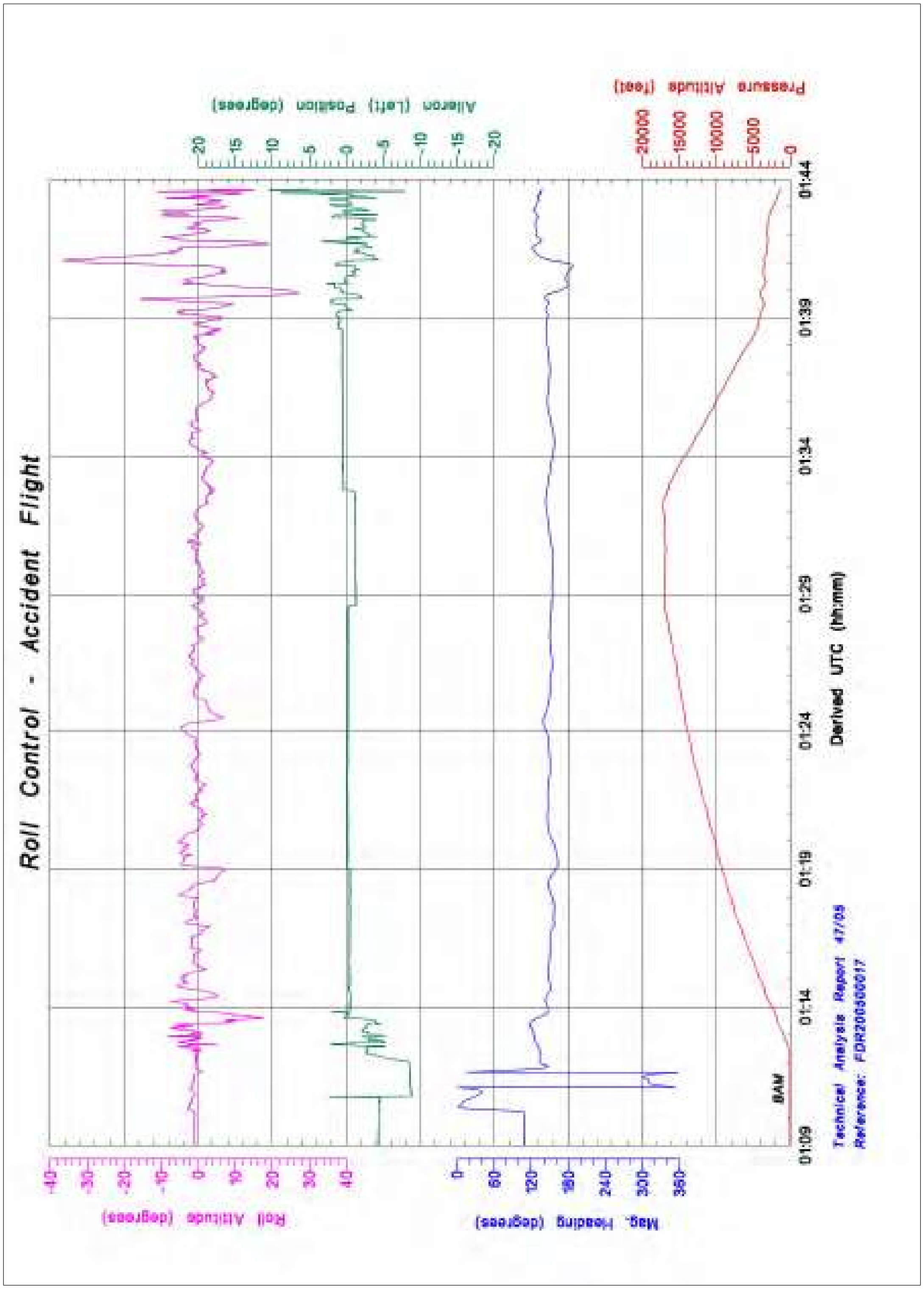
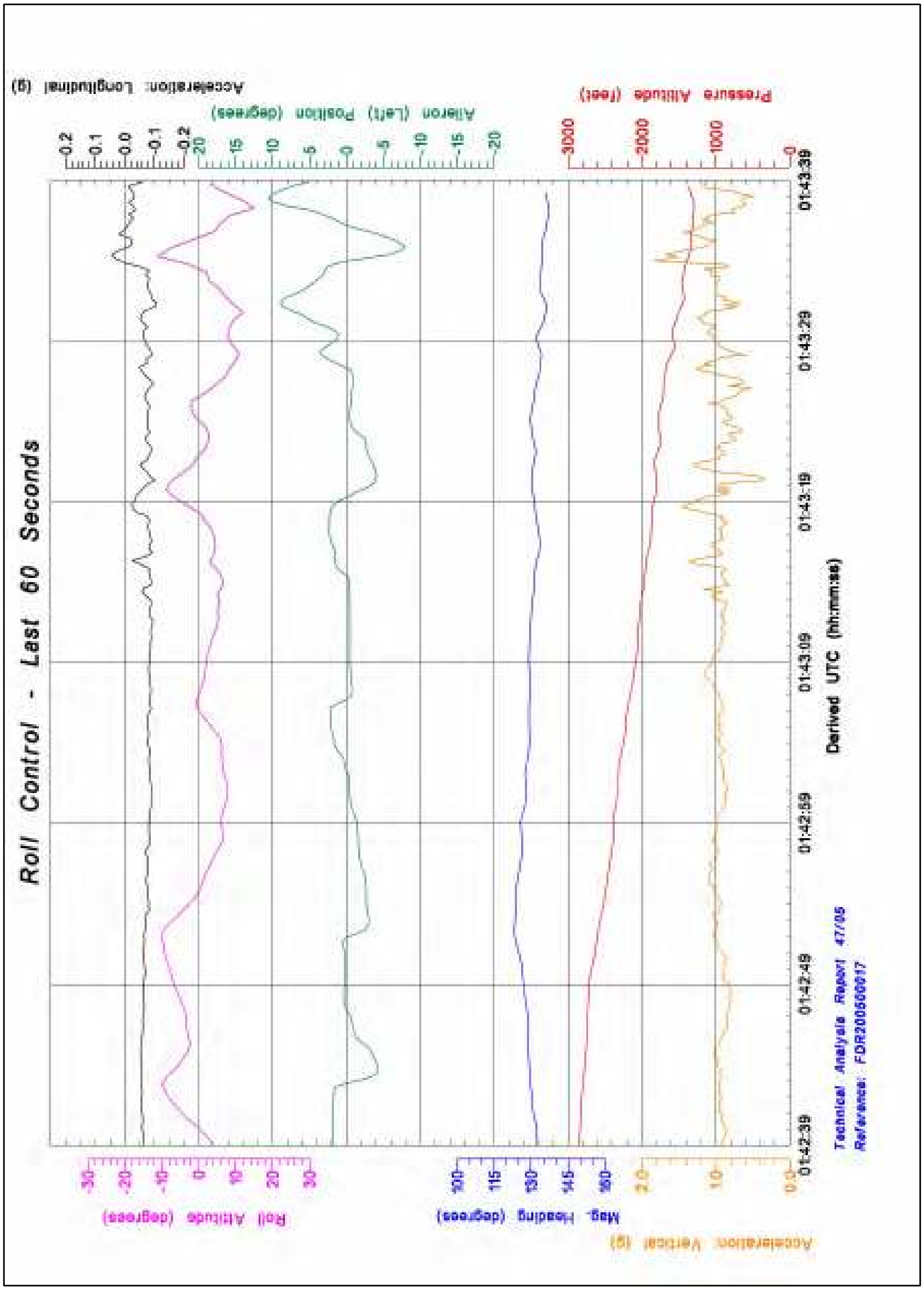

Pitch Control - Last 60 Seconds
Acceleration: Longitudinal (g)
Elevator (Left) Position (degrees)
Pressure Altitude (feet)
Flap Position (degrees)
Stab Position (degrees)
Acceleration: Vertical (g)
Derived UTC (hh:mm:ss)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-57:



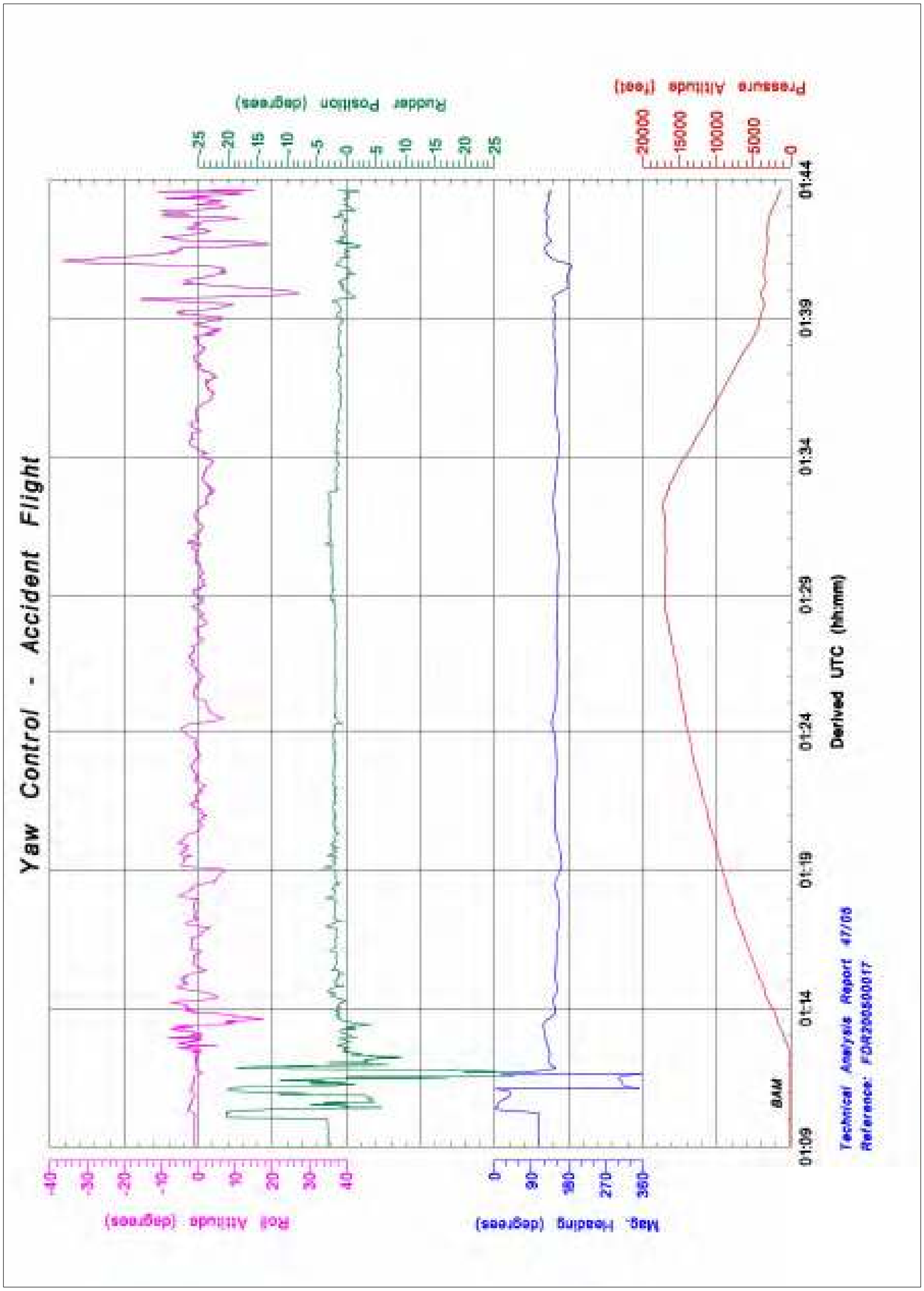
Roll Control - Accident Flight
Roll Attitude (degrees)
Aileron (Left) Position (degrees)
Mag. Heading (degrees)
Pressure Altitude (feet)
Derived UTC (hh:mm)
BAM
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-58:



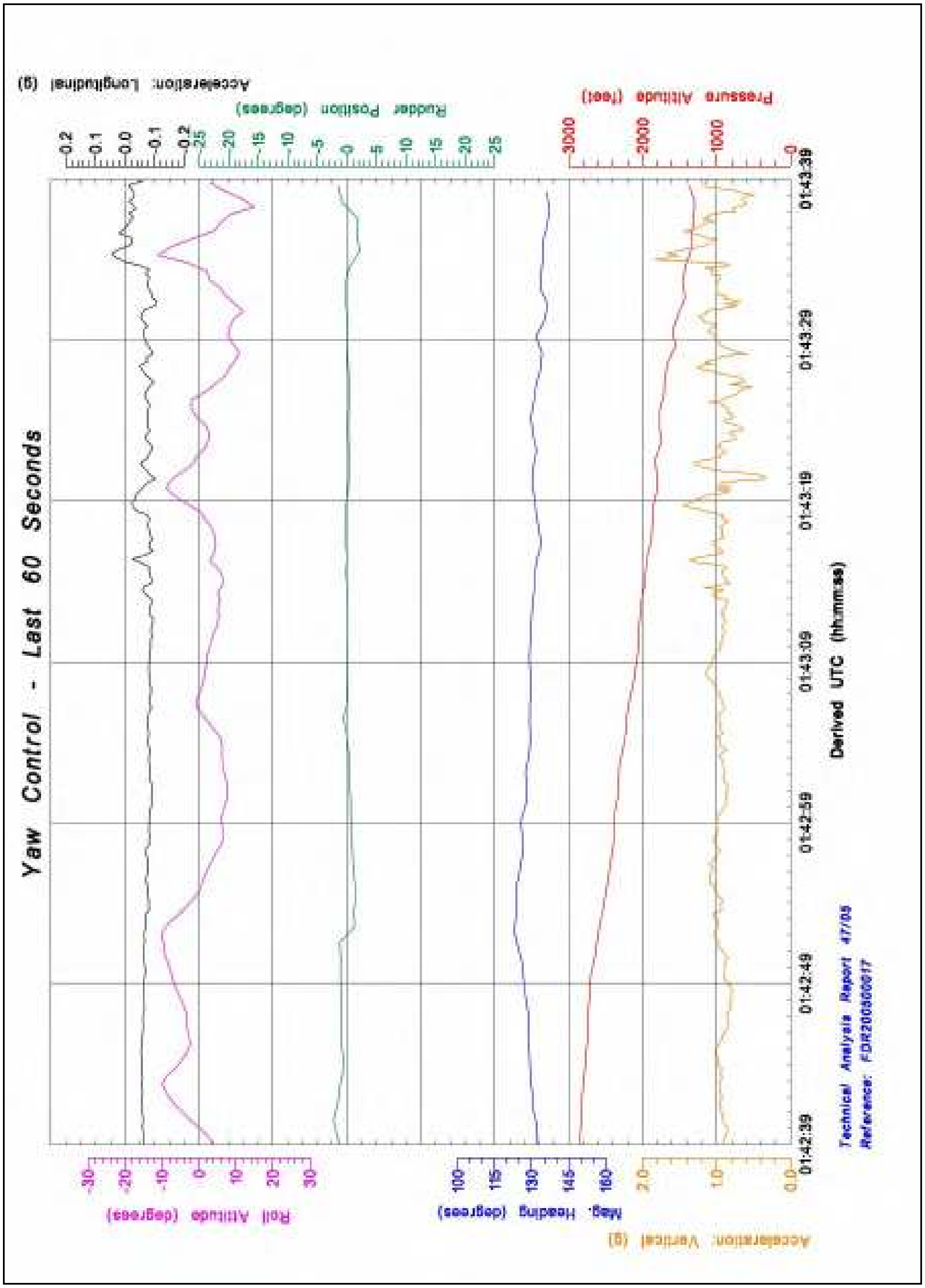
Roll Control - Last 60 Seconds
Acceleration: Longitudinal (g)
Aileron (Left) Position (degrees)
Pressure Altitude (feet)
Roll Attitude (degrees)
Mag. Heading (degrees)
Acceleration: Vertical (g)
Derived UTC (hh:mm:ss)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Technical Analysis Report 47/05
Reference: FDR200500017

Figure A-59:



Yaw Control - Accident Flight
Roll Attitude (degrees)
Rudder Position (degrees)
Mag. Heading (degrees)
Pressure Altitude (feet)
Derived UTC (hh:mm)
Technical Analysis Report 47/05

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)
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Derived UTC (hh:mm:ss)
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.

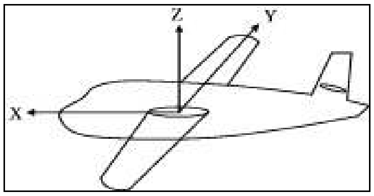
Engines and propellers

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.

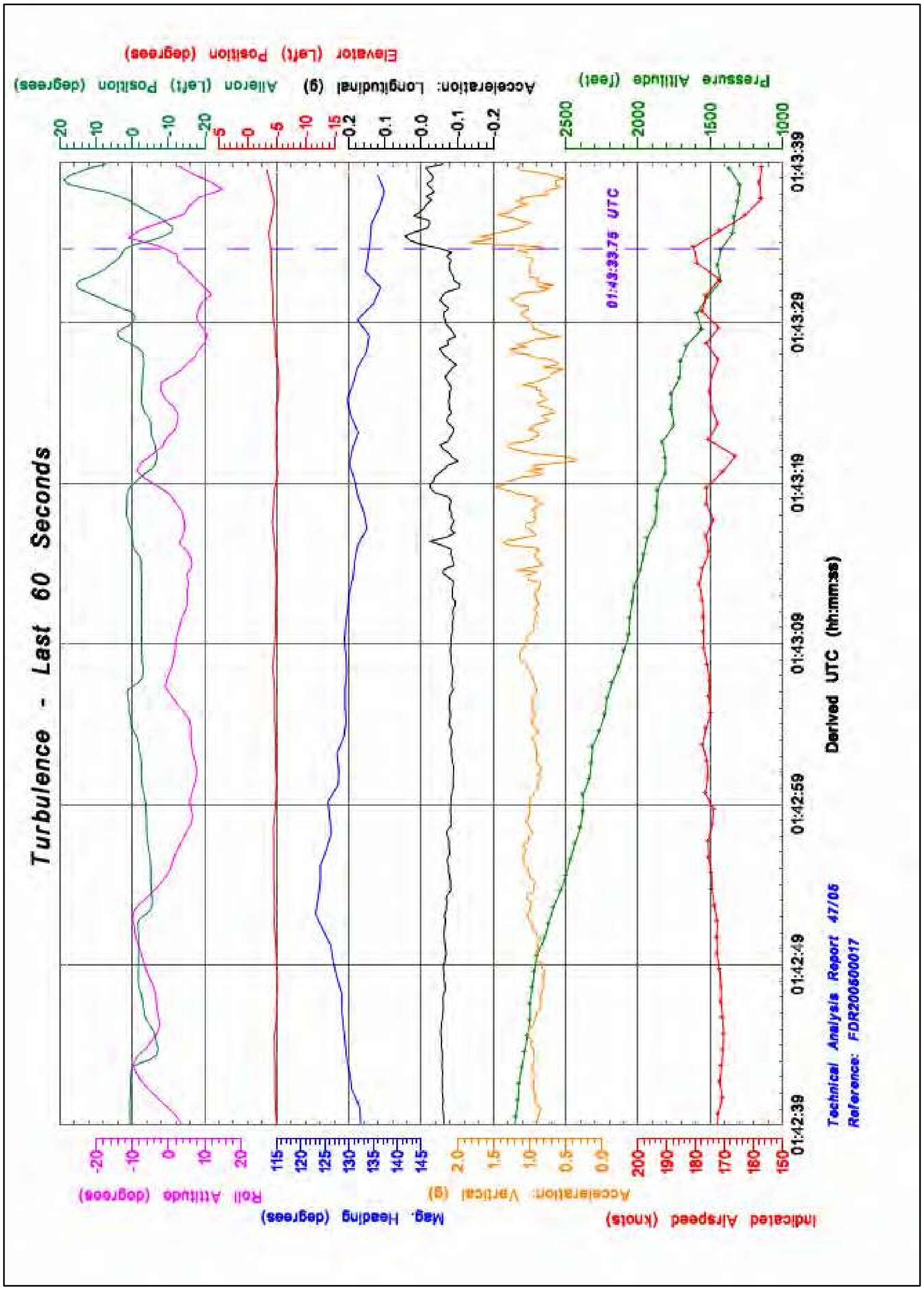
A spike in the vertical acceleration trace was evident at 01:43:33.75 UTC, approximately five seconds before the end of recorded data, refer to figure A-62. The rapid increase in vertical acceleration and the lack of nose-up elevator movements make it likely that the spike was due to turbulence and not 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
Roll Attitude (degrees)
Mag. Heading (degrees)
Acceleration: Vertical (g)
Indicated Airspeed (knots)
Aileron (Left) Position (degrees)
Elevator (Left) Position (degrees)
Acceleration: Longitudinal (g)
Pressure Altitude (feet)
01:43:33.75 UTC
01:42:39
01:42:49
01:42:59
01:43:09
01:43:19
01:43:29
01:43:39
Derived UTC (hh:mm:ss)
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.

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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.

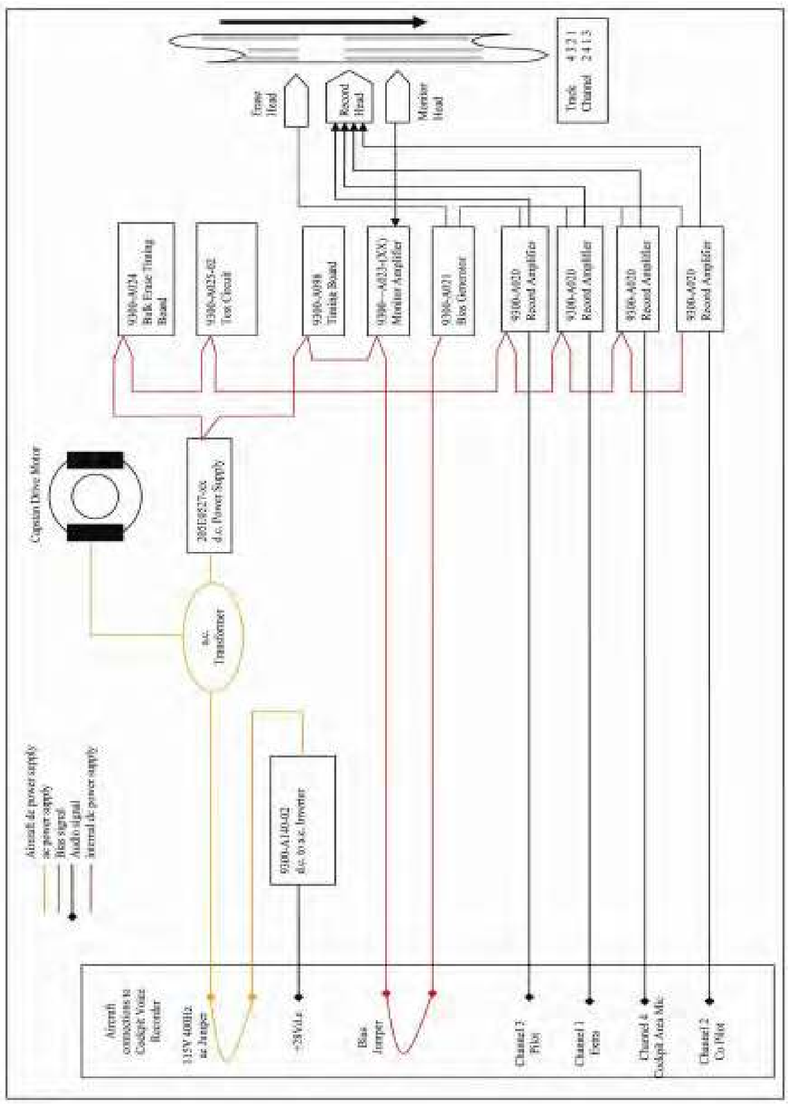
30 Civil Aviation Order 20.18 section 6 paragraph 6.4

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.



31 M7 Aerospace was the holder of the type certificate for the Fairchild Metro series aircraft and source for parts and technical support.

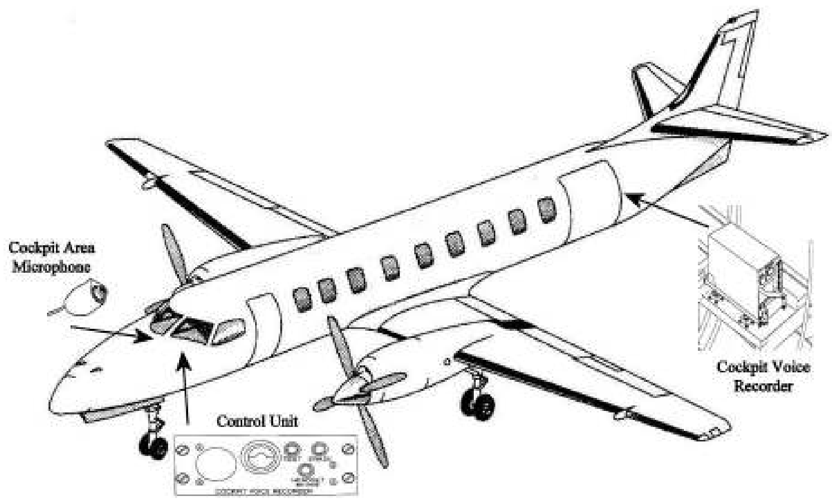
Physical Location of CVR and Control Unit

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.

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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

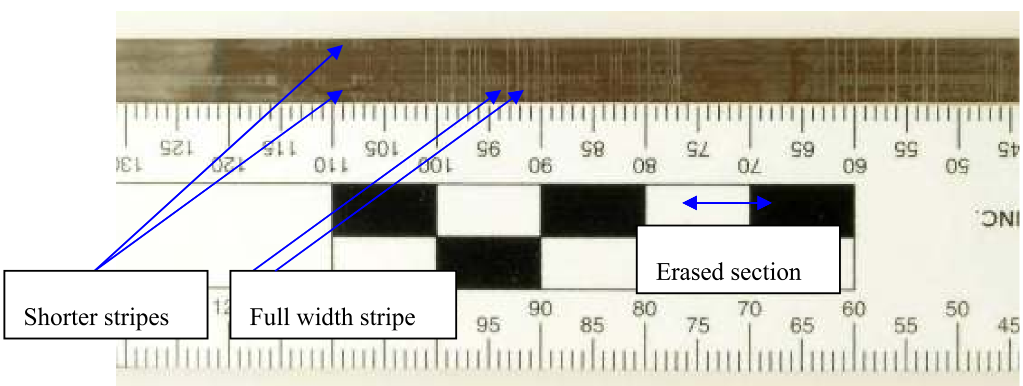


Figure B-10: The newest information recorded on the CVR tape, showing stripes indicating 'spikes' that are present for individual tracks and full width of the tape. Also illustrated is part of the erased section of tape.

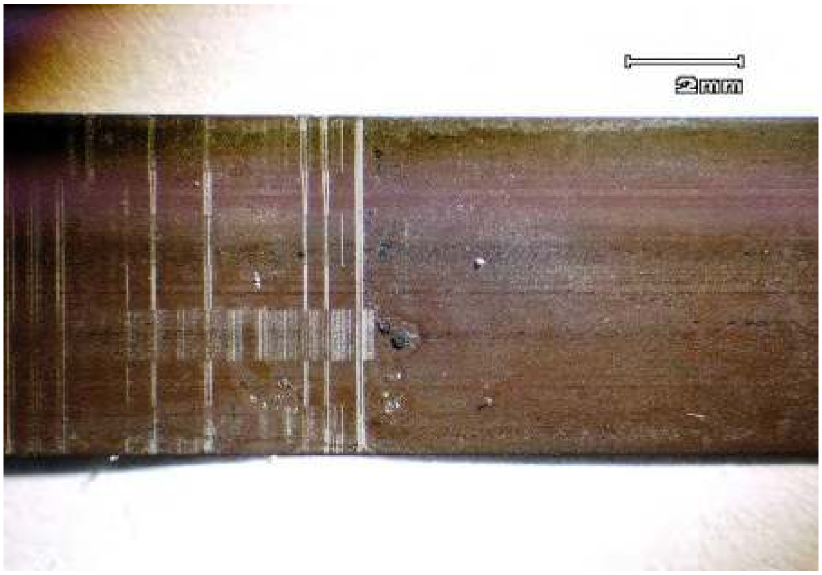


Figure B-11: Recovered tape with Magnasee applied, magnified to oldest information recorded.

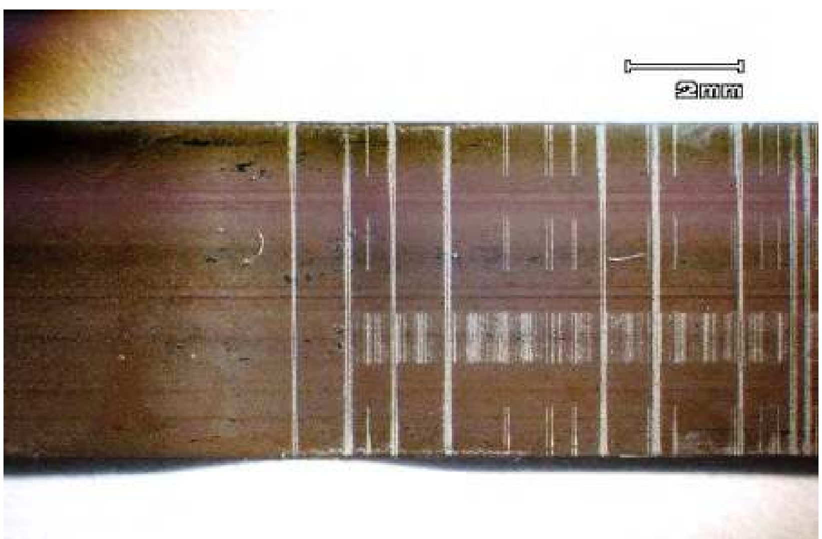
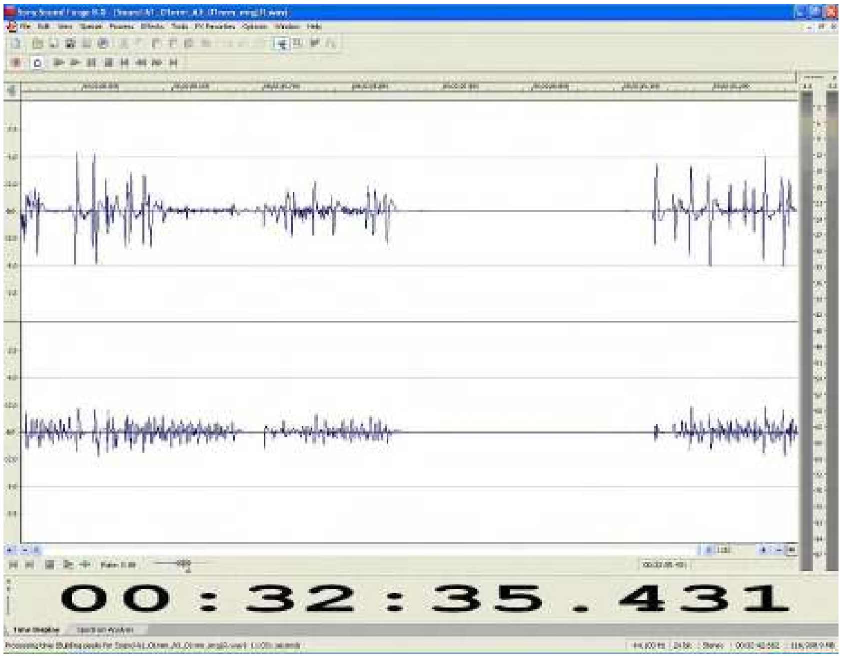


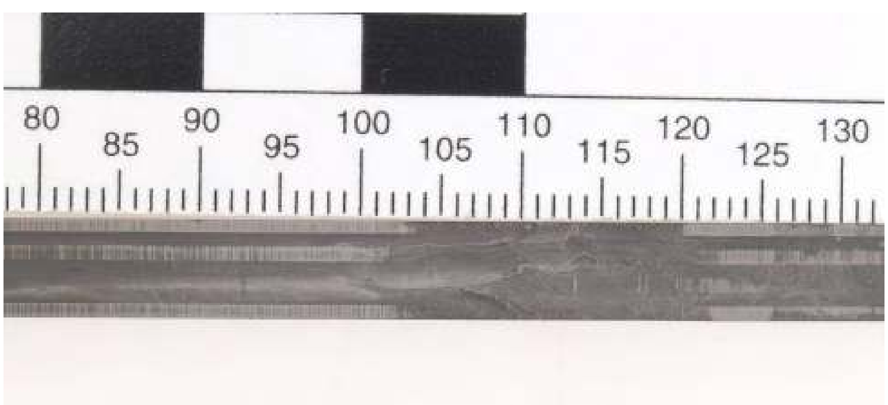
Figure B-12 is a time domain or oscillograph presentation of the spikes. The top trace relates to a recording made of a crew position and the bottom trace relates to audio recorded from the CAM. The spacing, duration and amplitude exhibited by the spikes contained in the CVR recording were examined. 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.

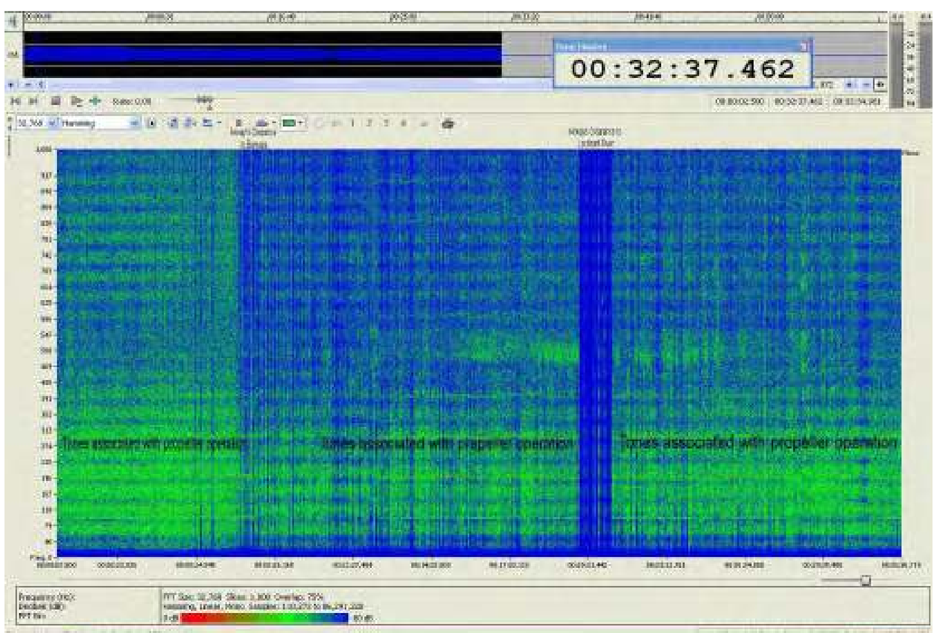
Audio2_01.wav recording contains several fragments of conversation. These fragments correlate with what appears to be public address announcements from the operating crew to the passengers that were also recorded in file Audio1_01.wav.

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.

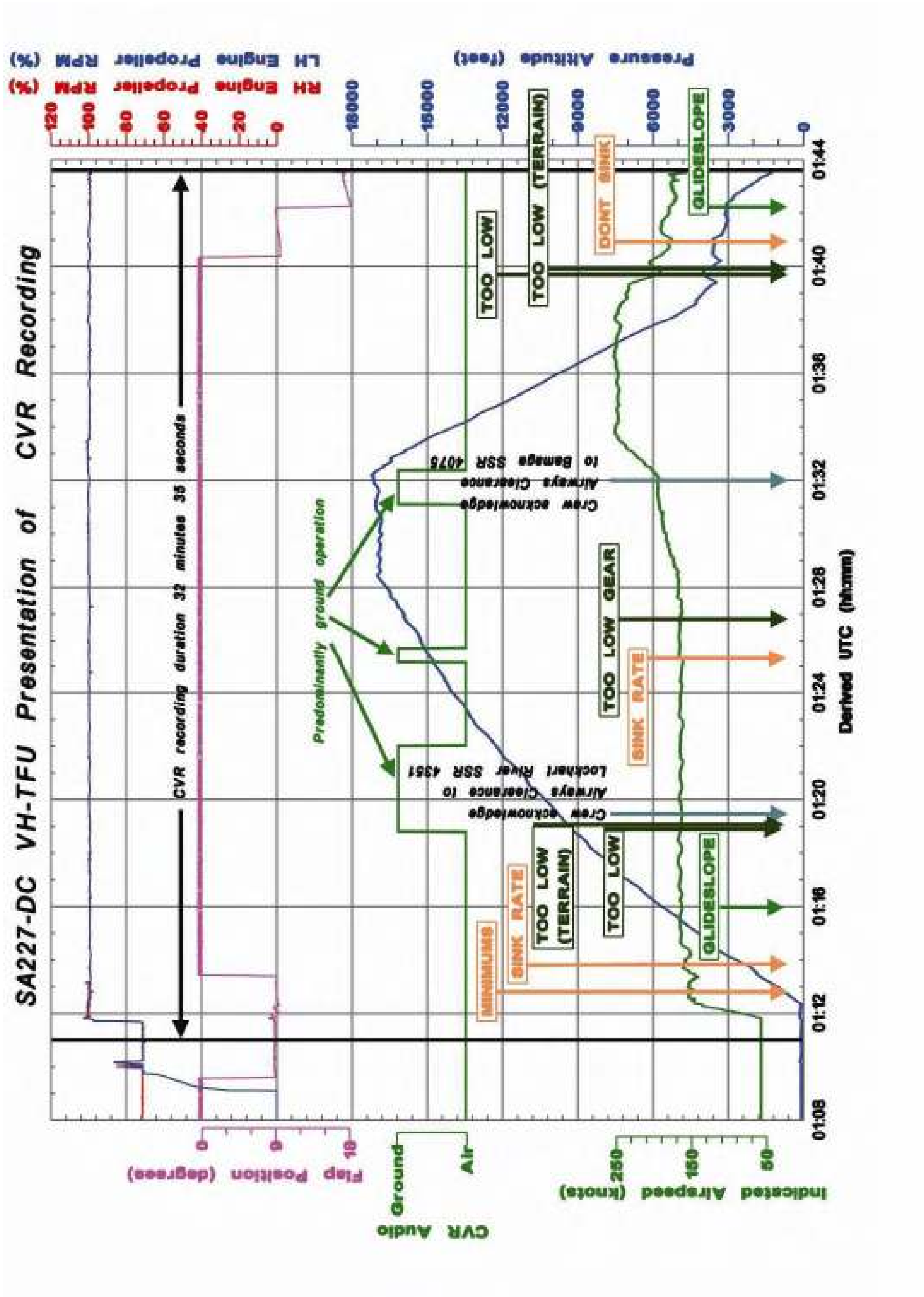
Table B-3: GPWS alerts recorded on the CVR correlated with the FDR data (the timebase was synchronised by aligning the data when the CVR and FDR ceased recording)

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.

.

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.

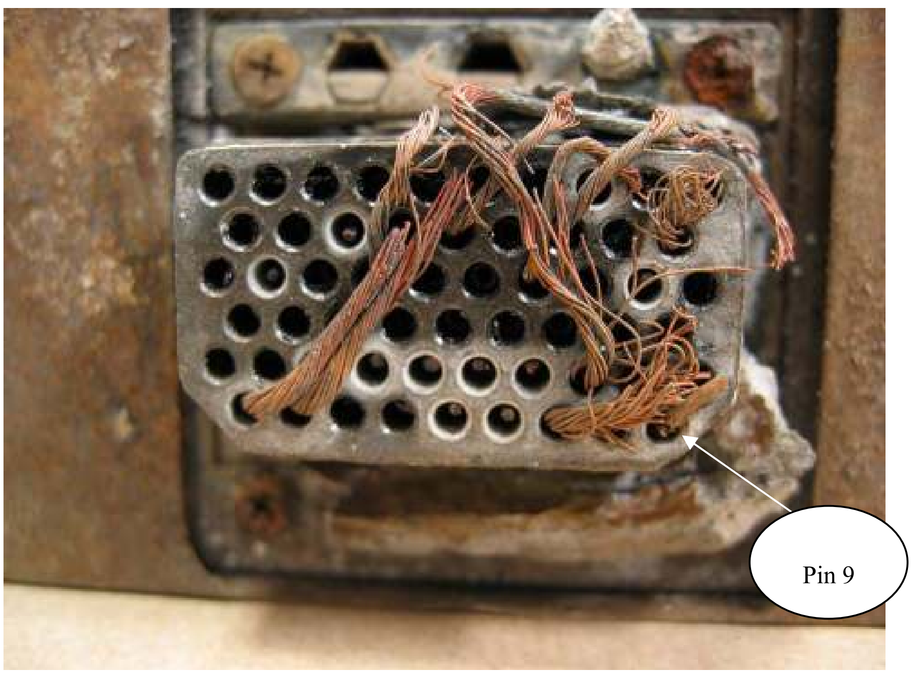
Physical examination of CVR

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.

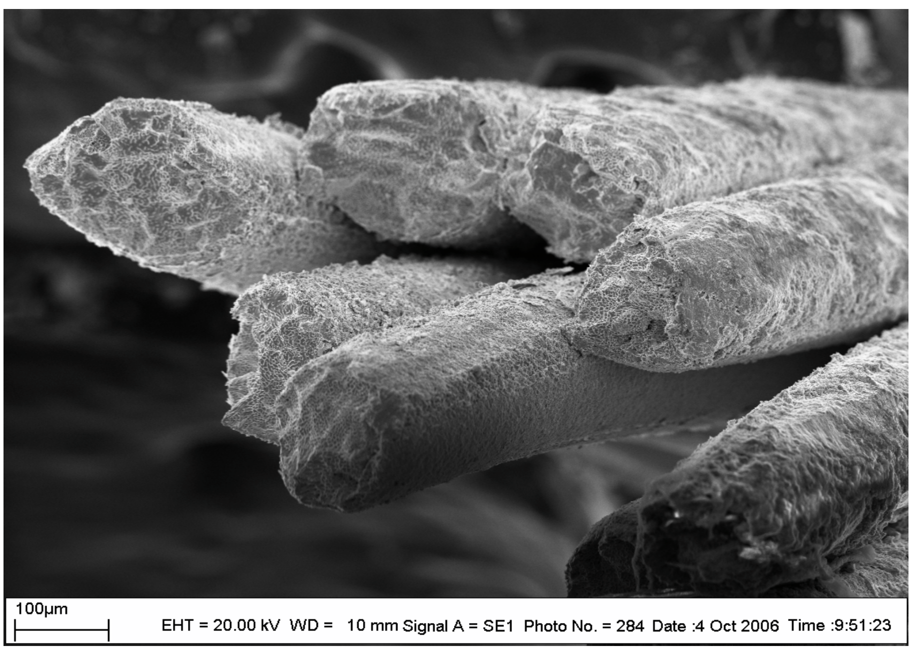
Figure B-16: Photograph of VH-TFU CVR unit aircraft interface connector



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

Description of Assembly	Part Number	Fitted to CVR from VH-TFU
(as prescribed by L-3 Aviation Recorders CMM)	(as prescribed by L-3 Aviation Recorders CMM)	
Record Amplifier	9300A020	No part number or serial number was found due to heat damage. Assembly identified by shape and position of components
Record Amplifier	9300A020	
Record Amplifier	9300A020	
Record Amplifier	9300A020	
Bias Generator	9300A021	
Power Supply	205E0527-xx	
Bulk Erase Timing	9300A024	
Monitor Amplifier	9300A023	
Test Circuit	9300A025-02	
Timer	9300A098	
Inverter	9300A140-02	9300A140-02 serial number 05044 (punched into plate fixed to inverter)

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

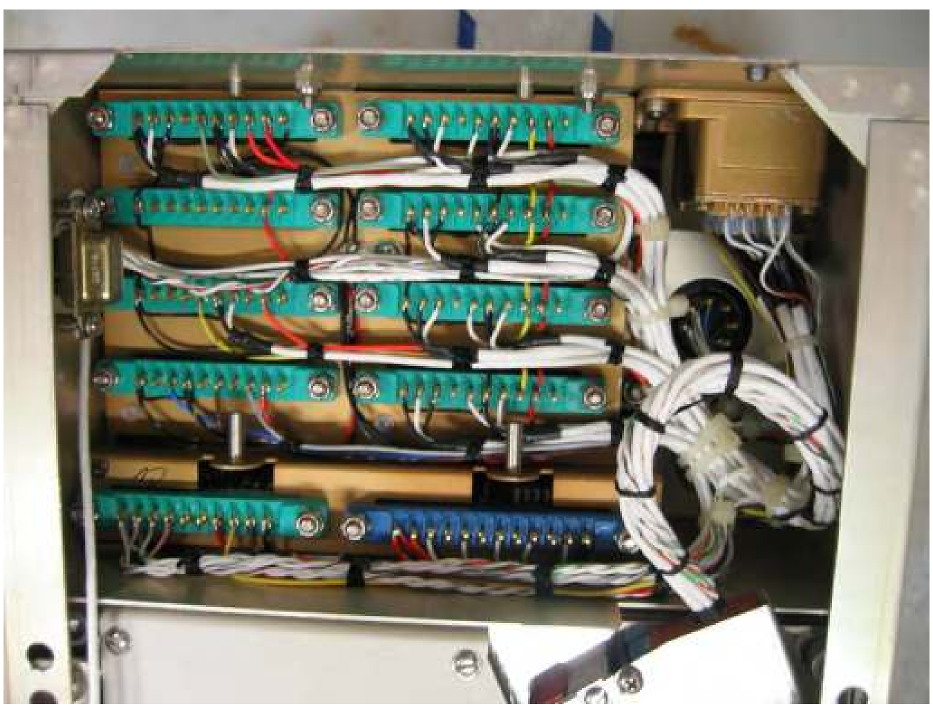


Figure B-23: VH-TFU power supply assembly

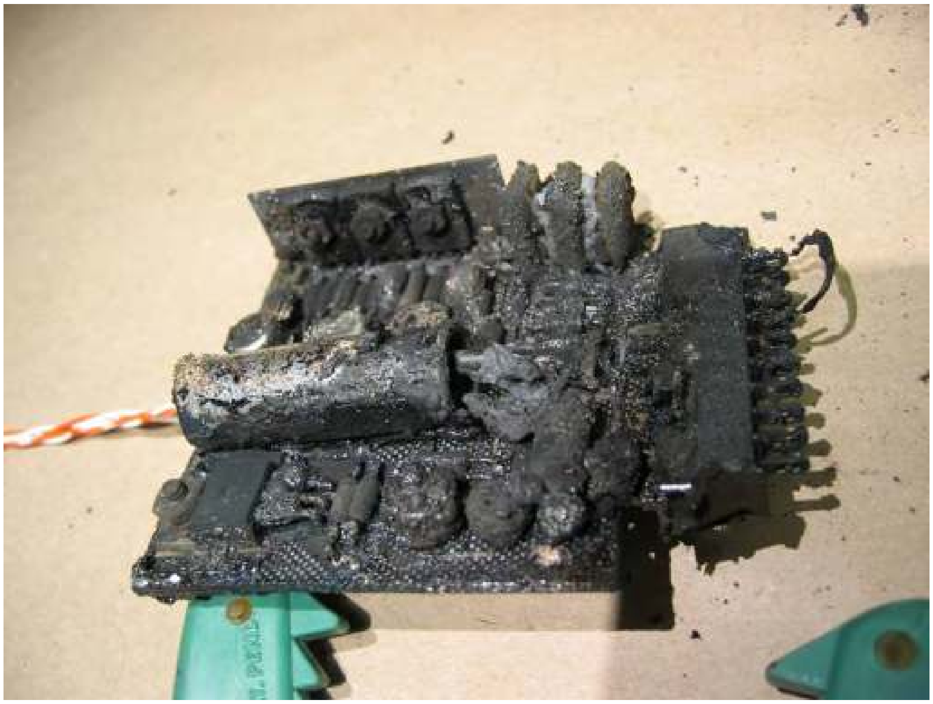


Figure B-24: Serviceable power supply card

Figure B-25: VH-TFU bias oscillator assembly

Figure B-26: Serviceable bias oscillator assembly

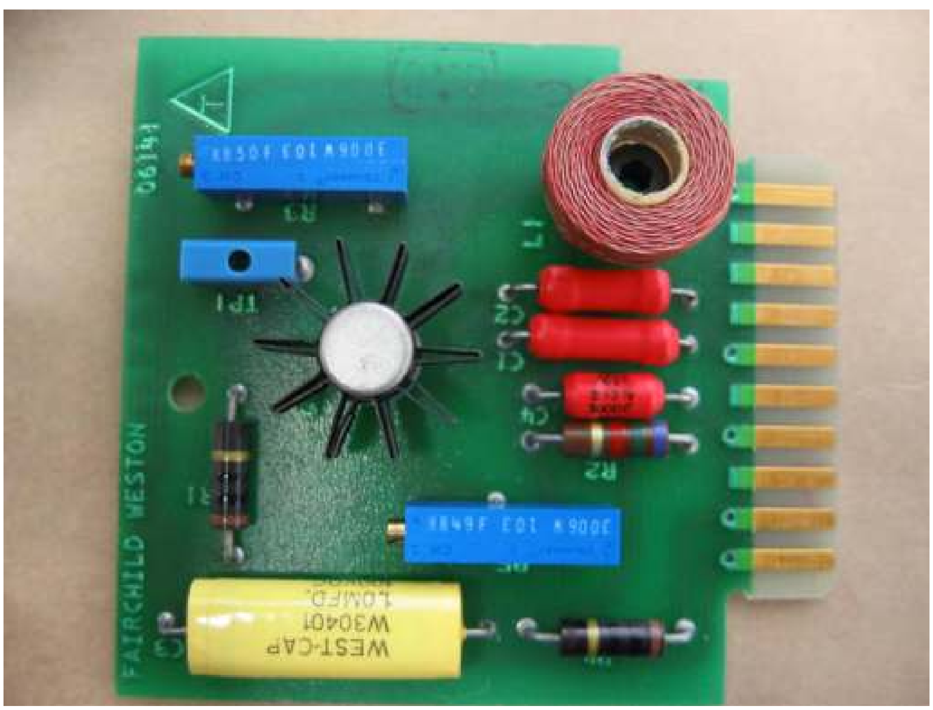


Figure B-27: VH-TFU CVR inverter assembly

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.

---

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.

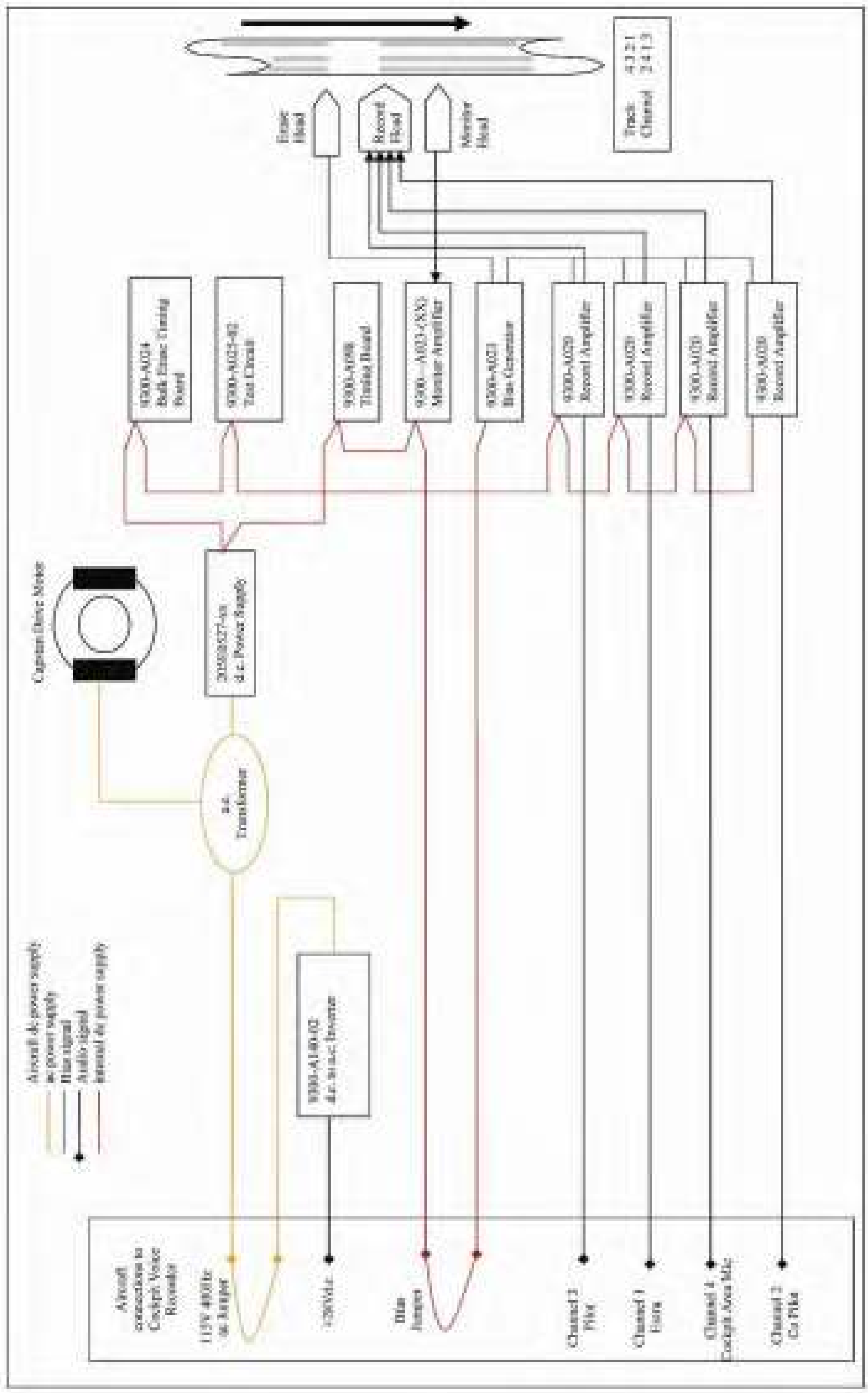
Possible CVR failure mode

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.

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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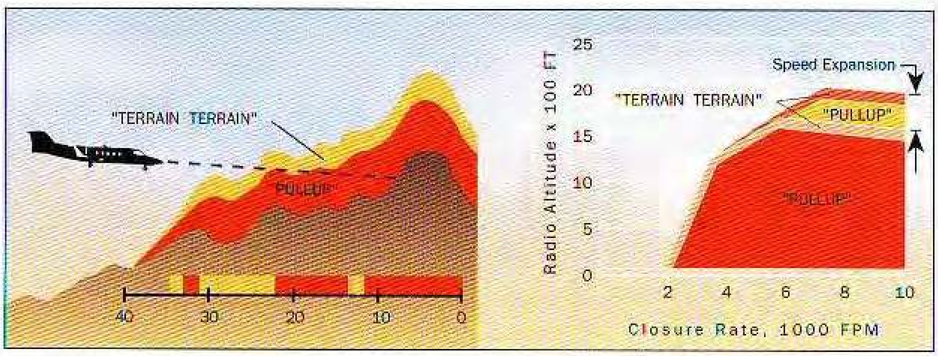
APPENDIX C: EXTRACT FROM HONEYWELL GPWS MK VI WARNING SYSTEM PILOT'S GUIDE

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 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.

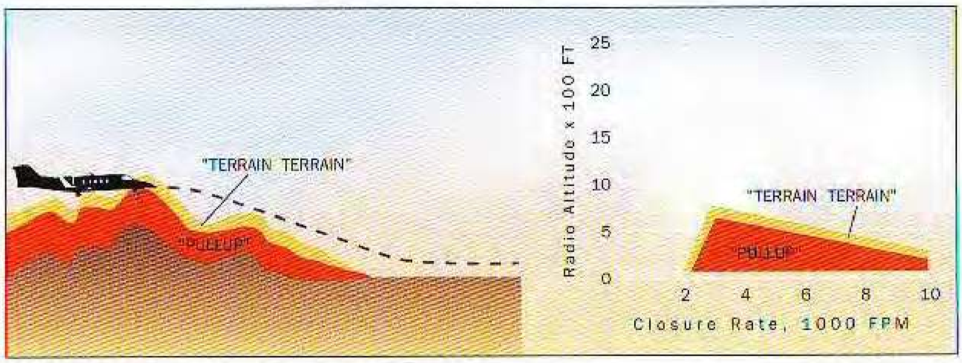
The Speed Expansion area at the top of the warning envelope is to provide additional warning time for aircraft flying at approximately 220 knots or faster.

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.

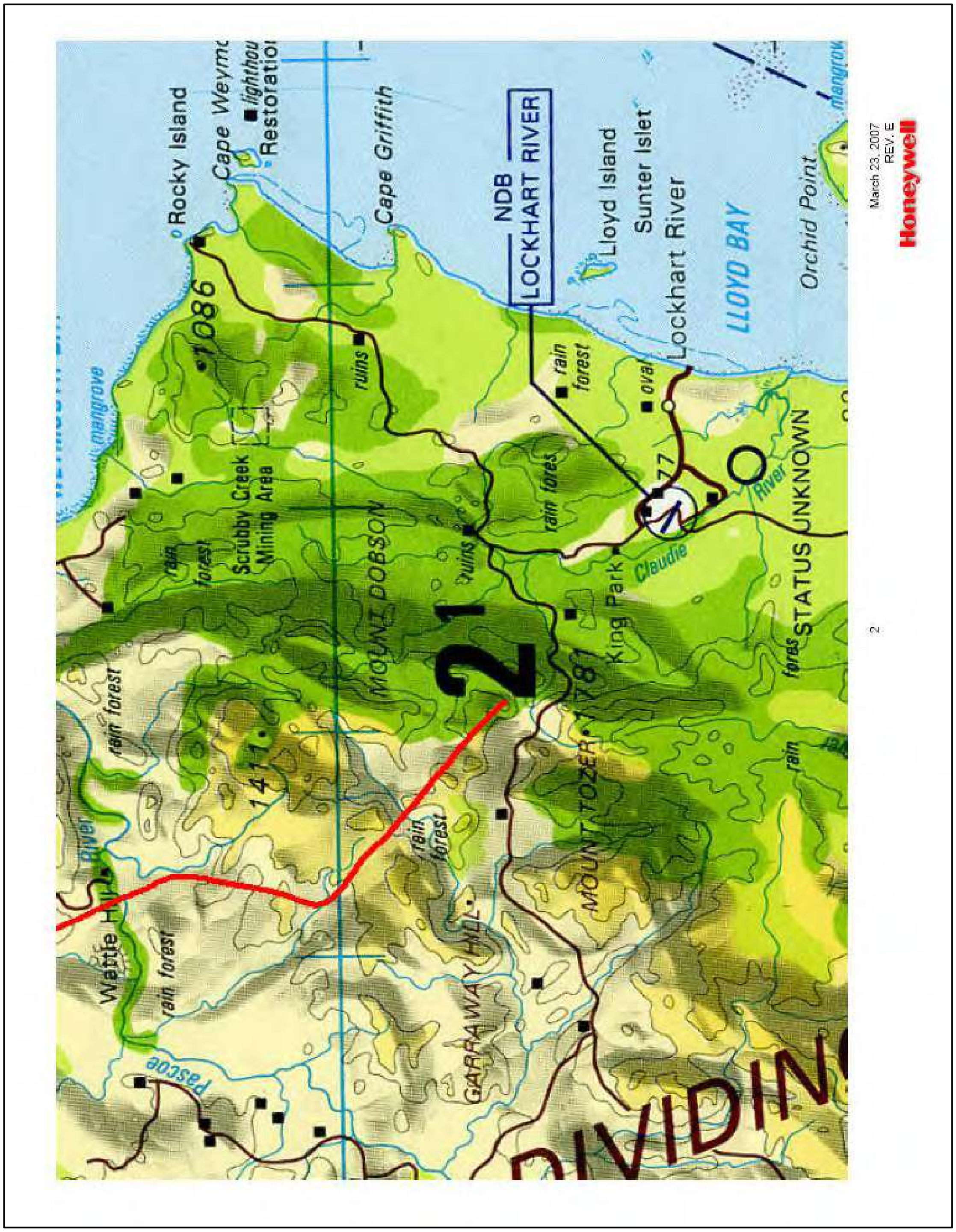
That information indicates that the engines were delivering power at the time of impact.

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

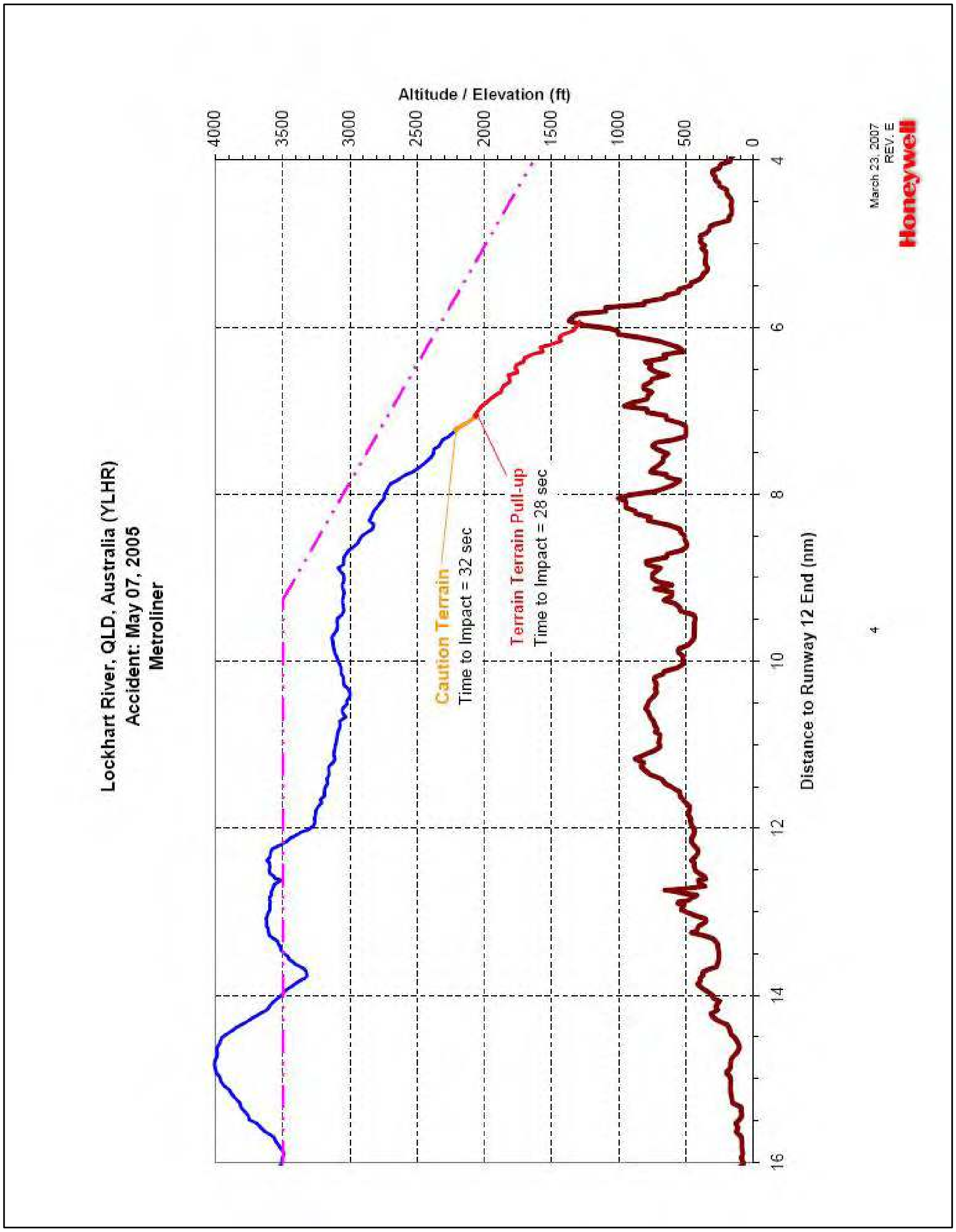
March 23, 2007
REV. E
Honeywell


Rocky Island
Cape Griffith
NDB
LOCKHART RIVER
Lloyd Island
Sunter Islet
Lockhart River
LLOYD BAY
Orchid Point
Scrubby Creek
Mining Area
MOUNT DOBSON
MOUNT TOZER
GARRAWAY HILL
King Park
Claudie
River
STATUS UNKNOWN
rain forest
ruins
oval
Wattle Hill
Pascoe
DIVIDIN
21
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
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Honeywell

March 23, 2007
REV. E
Honeywell

5

40 seconds before impact

March 23, 2007
REV. E
Honeywell

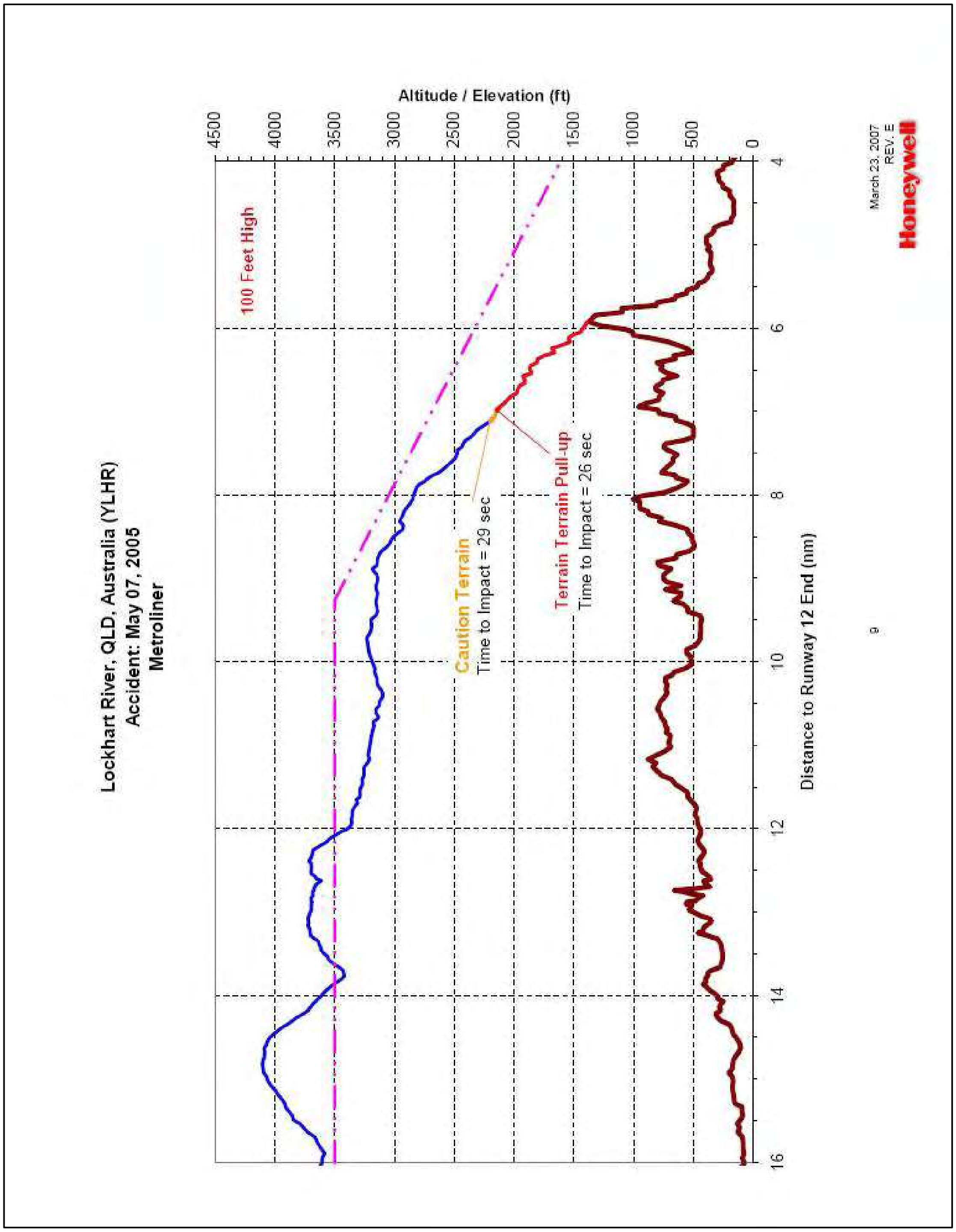
"Caution Terrain"

32 seconds before impact

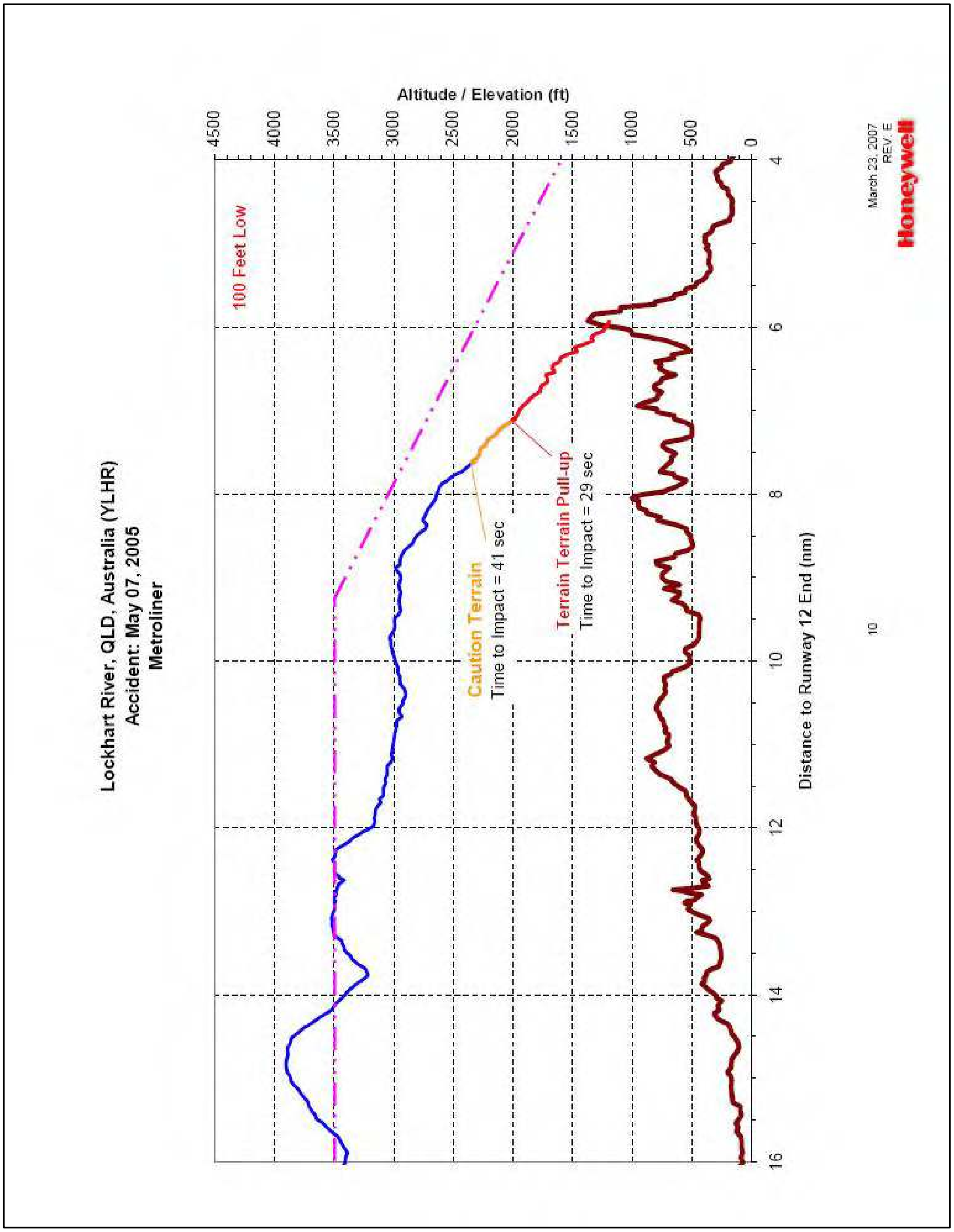
7

March 23, 2007
REV. E
Honeywell

"Terrain Terrain Pull-up"
28 seconds before impact



Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner
100 Feet High
Caution Terrain
Time to Impact = 29 sec
Terrain Terrain Pull-up
Time to Impact = 26 sec
Altitude / Elevation (ft)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4
6
8
10
12
14
16
Distance to Runway 12 End (nm)
9
March 23, 2007
REV. E
Honeywell



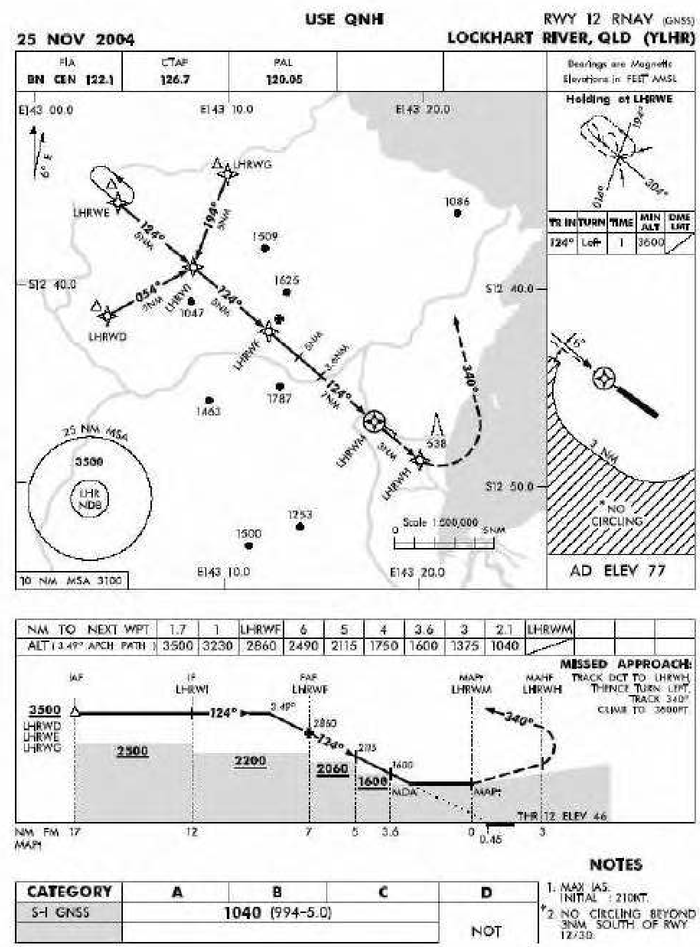
Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner
Altitude / Elevation (ft)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Distance to Runway 12 End (nm)
4
6
8
10
12
14
16
100 Feet Low
Caution Terrain
Time to Impact = 41 sec
Terrain Terrain Pull-up
Time to Impact = 29 sec
10
March 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



March 23, 2007
REV. E
Honeywell

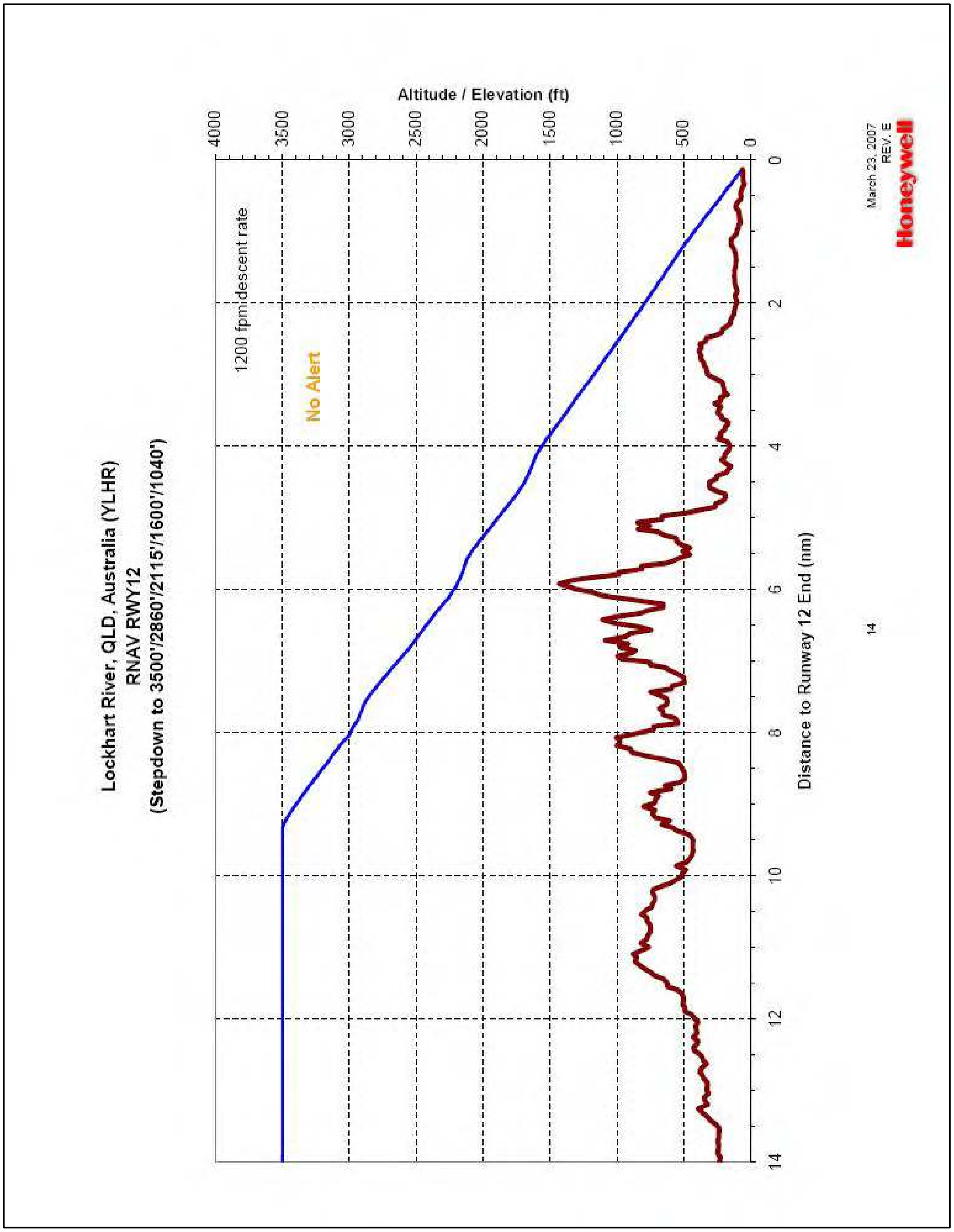
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, and the landing flaps were set soon after the landing gear was down.

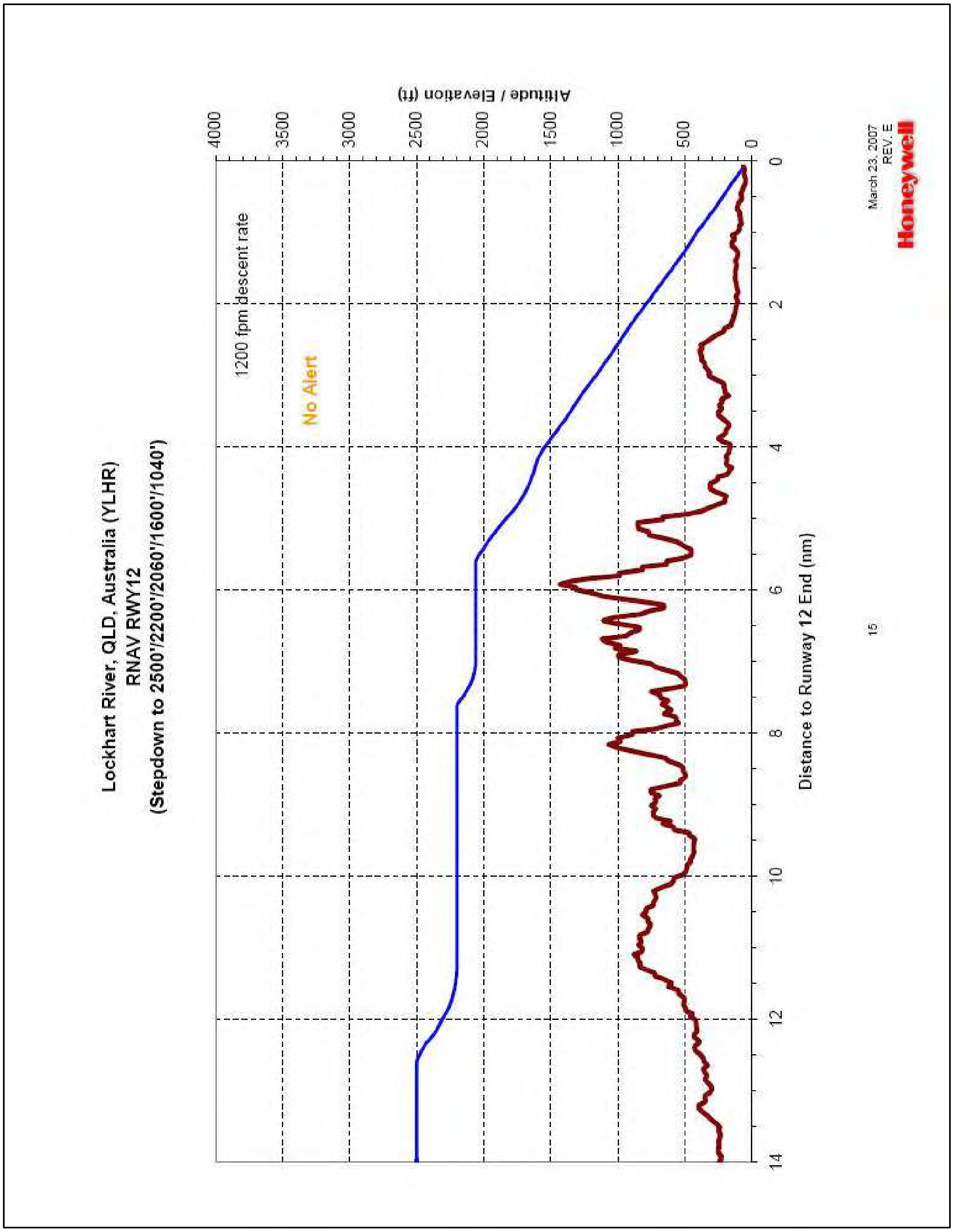
Case 1:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -960 fpm

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)
4000
3500
3000
2500
2000
1500
1000
500
0
Distance to Runway 12 End (nm)
0
2
4
6
8
10
12
14
March 23, 2007
REV. E
Honeywell
14



Lockhart River, QLD, Australia (YLHR)
RNAV RWY12
(Stepdown to 2500'/2200'/2060'/1600'/1040')
1200 fpm descent rate
No Alert
Altitude / Elevation (ft)
4000
3500
3000
2500
2000
1500
1000
500
0
Distance to Runway 12 End (nm)
14
12
10
8
6
4
2
0
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.

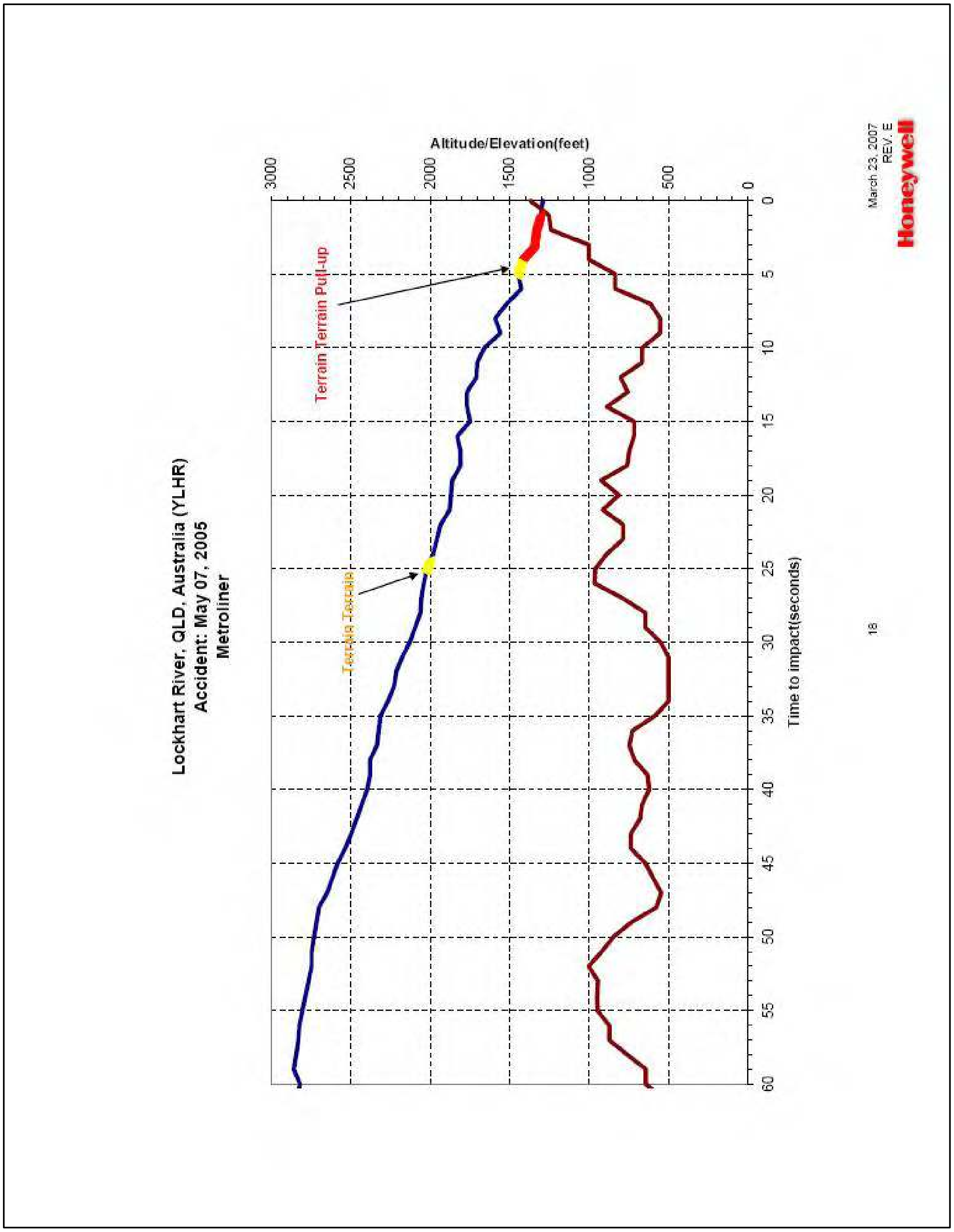
The simulation assumes that the flaps were not in landing configuration and that the landing gear was down. Also the simulation assumes that the cockpit GPWS DESENS or Flap Override switch was not activated.

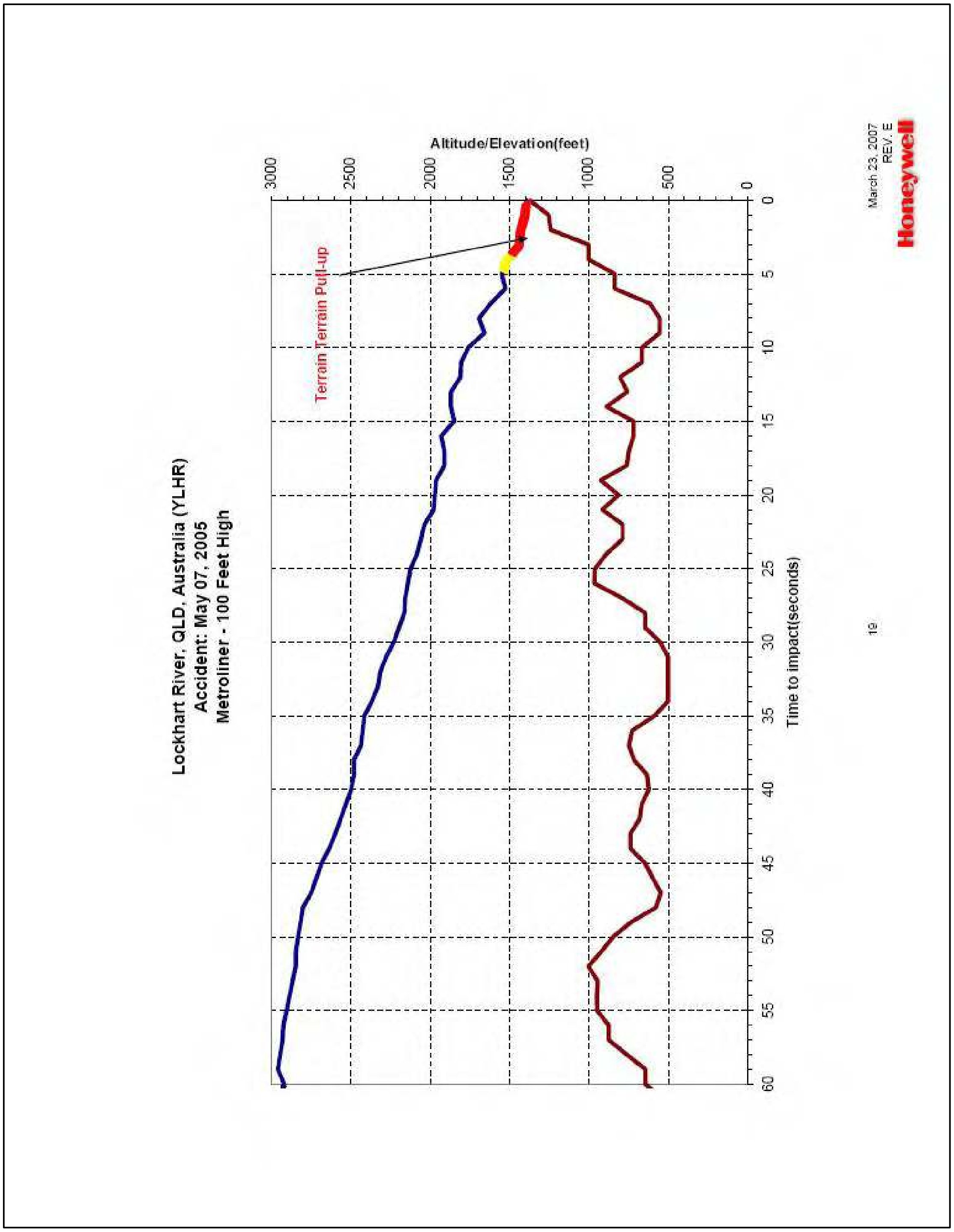
The following table shows the results of the GPWS simulation.

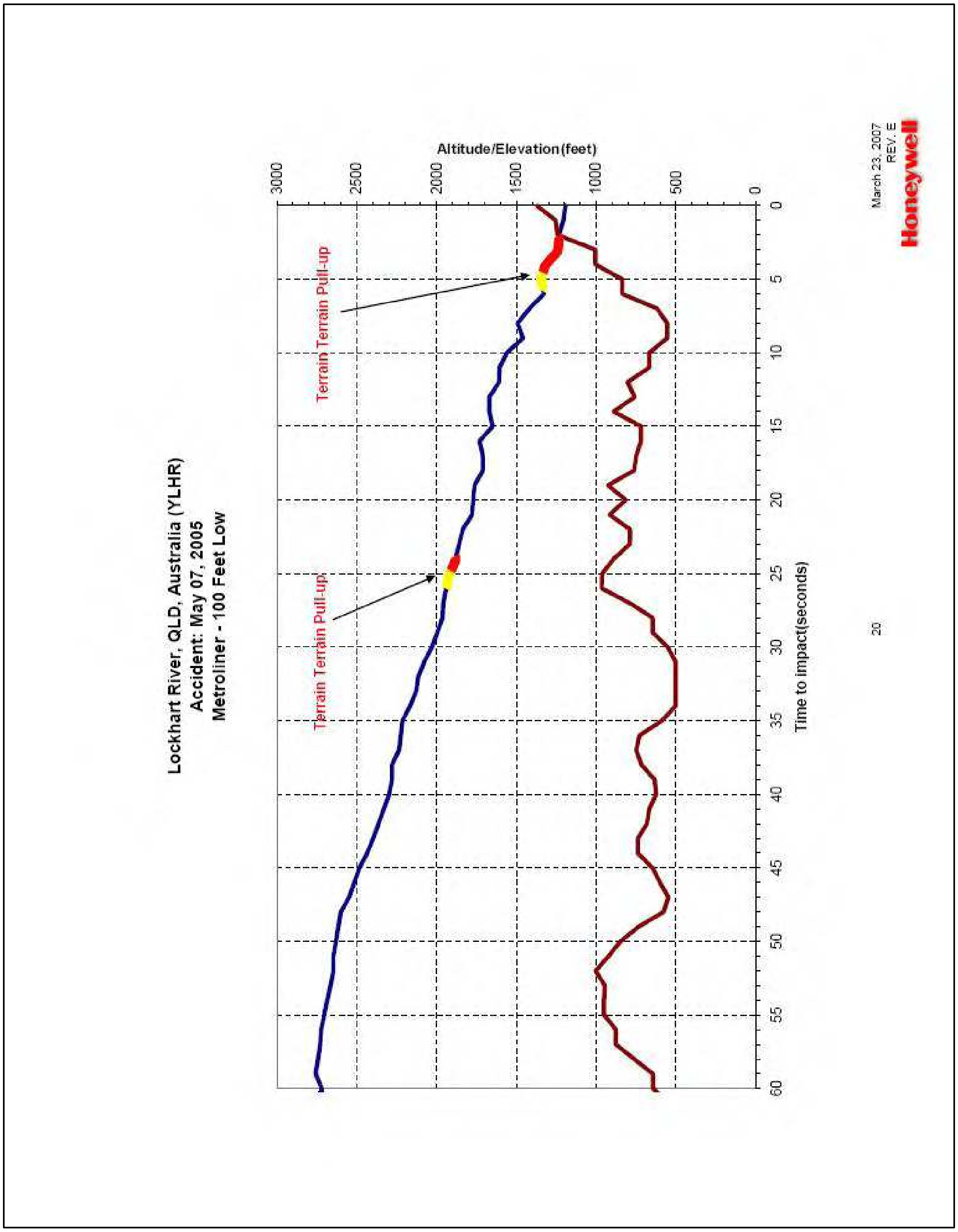
Time to impact	Voice message - event
25.15	"TERRAIN-TERRAIN"
24.4	Voice off.
5.1	"TERRAIN-TERRAIN PULL UP"

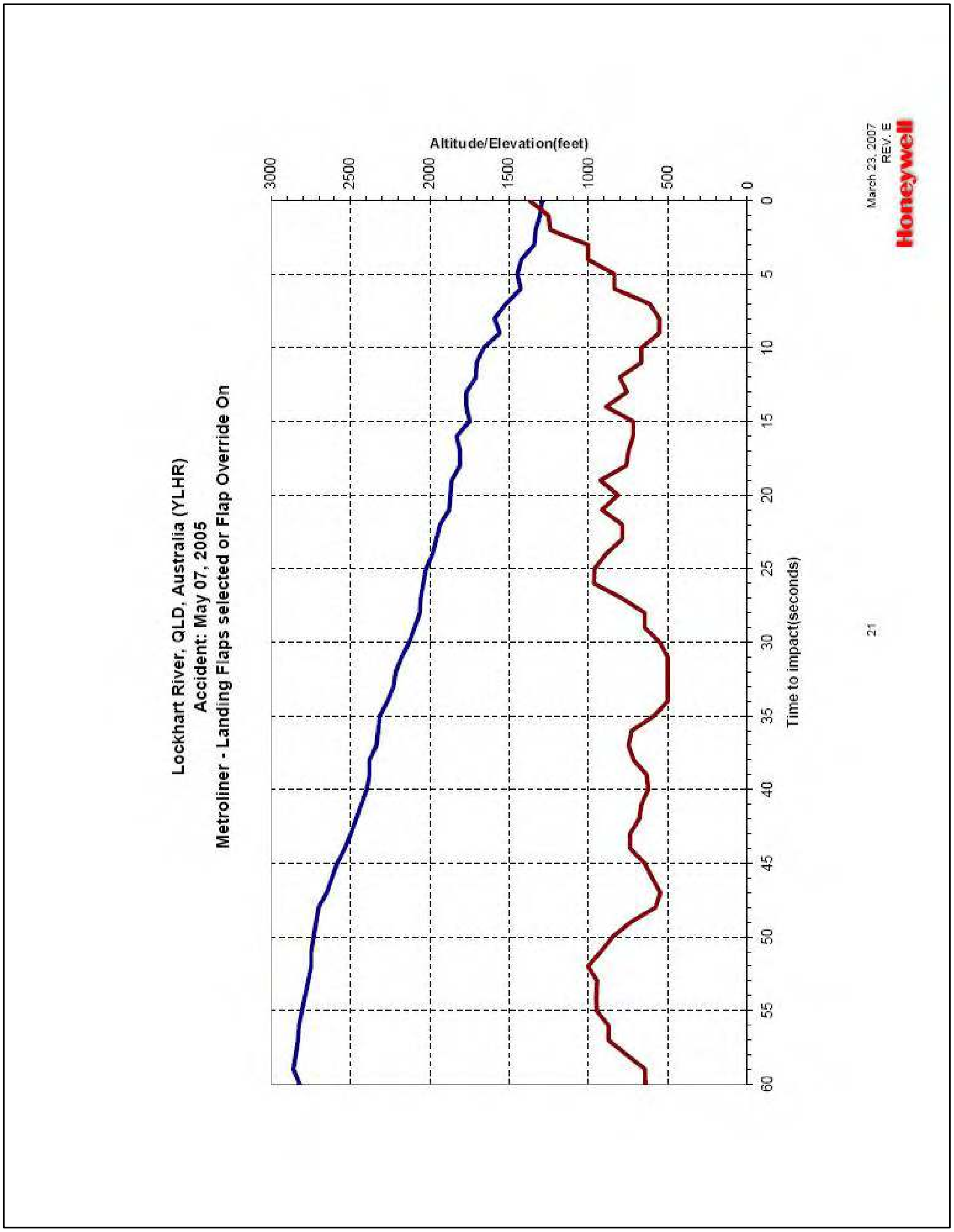
In addition two additional simulations where run in which the assumed aircraft altitude was modified by 100 feet. The first has the altitude increased by 100 feet the second decreased by 100 feet.

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
Time to impact(seconds)
0
5
10
15
20
25
30
35
40
45
50
55
60
Terrain Terrain Pull-up
Terrain Terrain
March 23, 2007
REV. E
18
Honeywell


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
0
5
10
15
20
25
30
35
40
45
50
55
60
Time to impact(seconds)
19
March 23, 2007
REV. E
Honeywell


Lockhart River, QLD, Australia (YLHR)
Accident: May 07, 2005
Metroliner - 100 Feet Low
Altitude/Elevation (feet)
Time to impact (seconds)
Terrain Terrain Pull-up
Terrain Terrain Pull-up
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
55
60
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
Time to impact(seconds)
0
5
10
15
20
25
30
35
40
45
50
55
60
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.

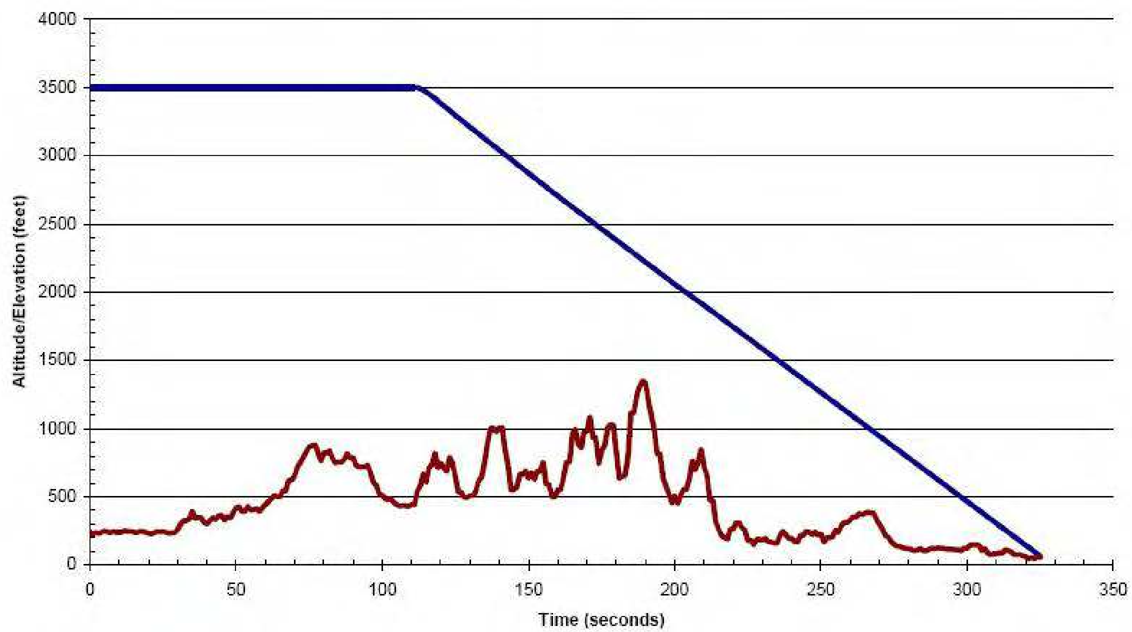
Case 1A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -960 fpm

No alert or warning occurred during the entire approach.

Case 1B:
Step down altitude: 2500' / 2200' / 2060' / 1600' / 1040'
Descent Rate: -1200 fpm

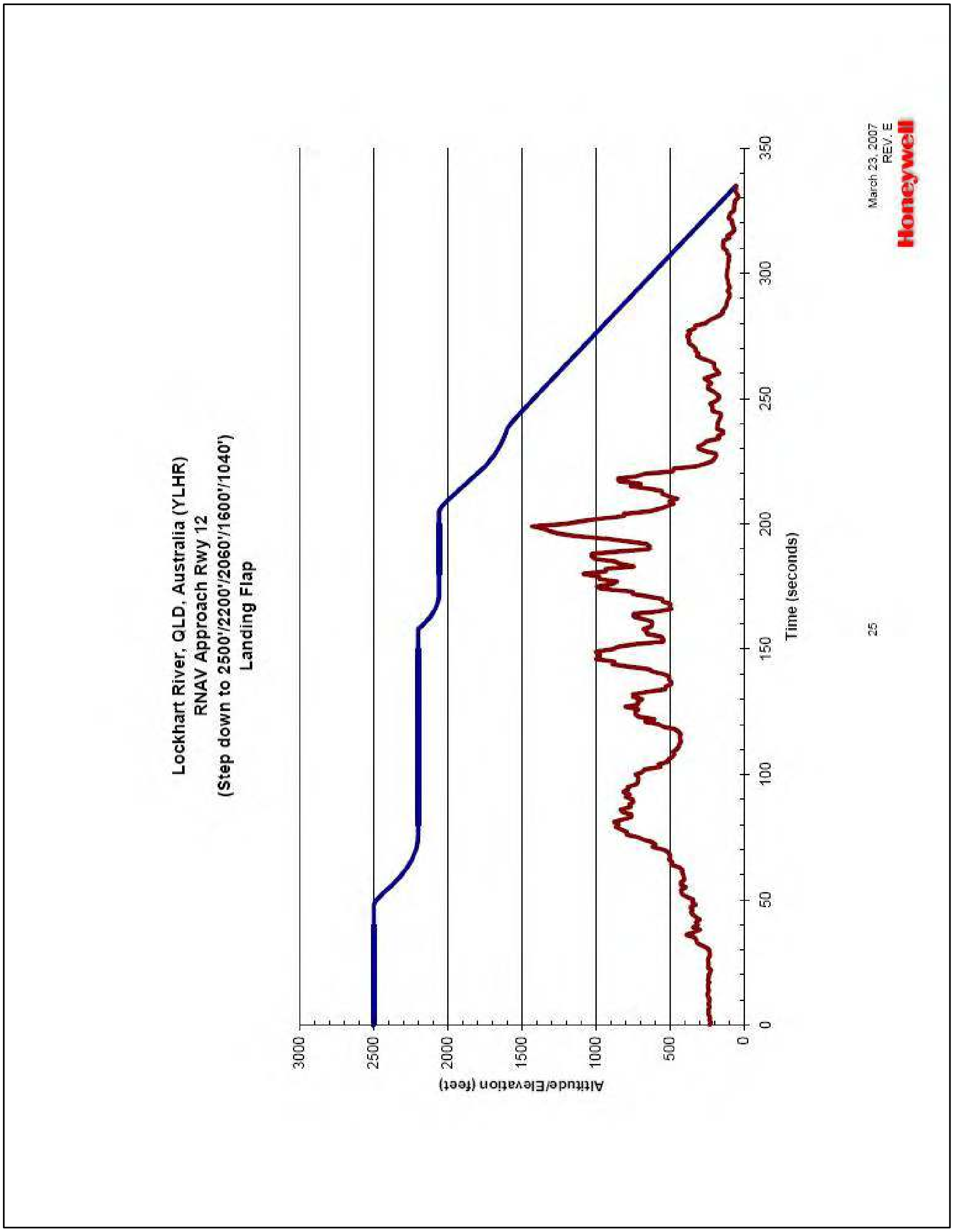
No alert or warning occurred during the entire approach.

Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
Landing Flap



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
Honeywell

Case 2

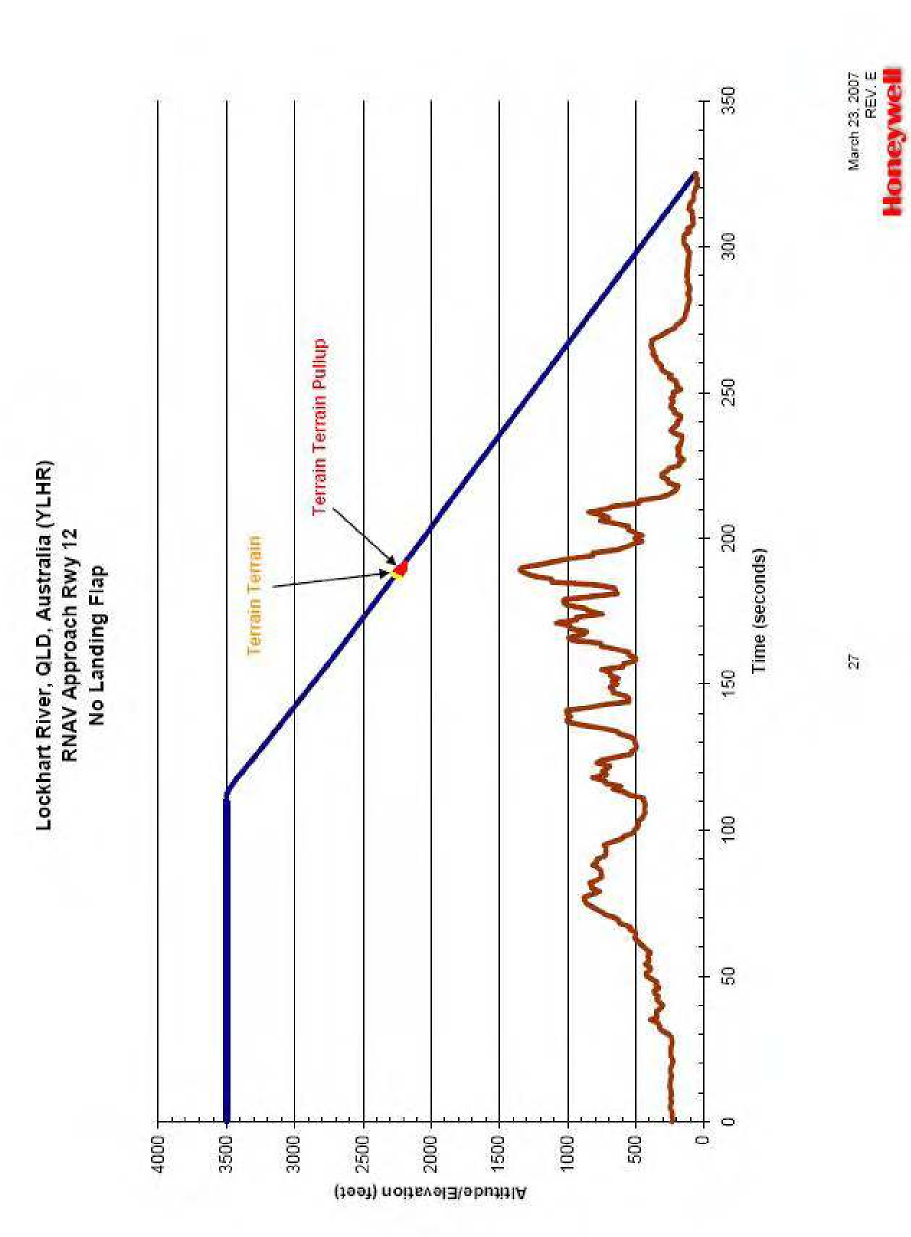
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, but the landing flaps were not set.

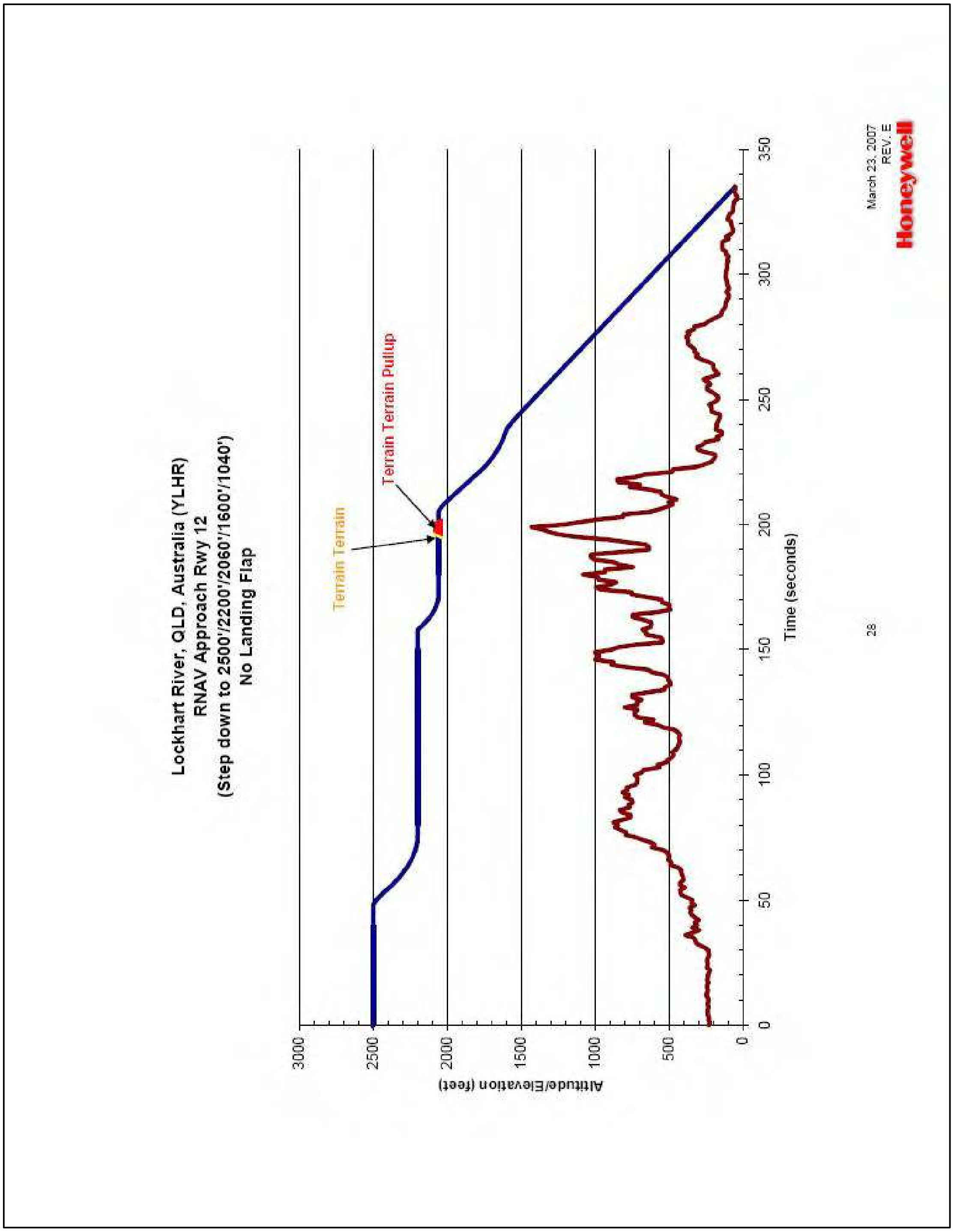
Case 2A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -960 fpm

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
Altitude/Elevation (feet)
4000
3500
3000
2500
2000
1500
1000
500
0
Time (seconds)
0
50
100
150
200
250
300
350
Terrain Terrain
Terrain Terrain Pullup
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
Terrain Terrain
Terrain Terrain Pullup
Altitude/Elevation (feet)
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
Time (seconds)
28
March 23, 2007
REV. E
Honeywell

Case 3

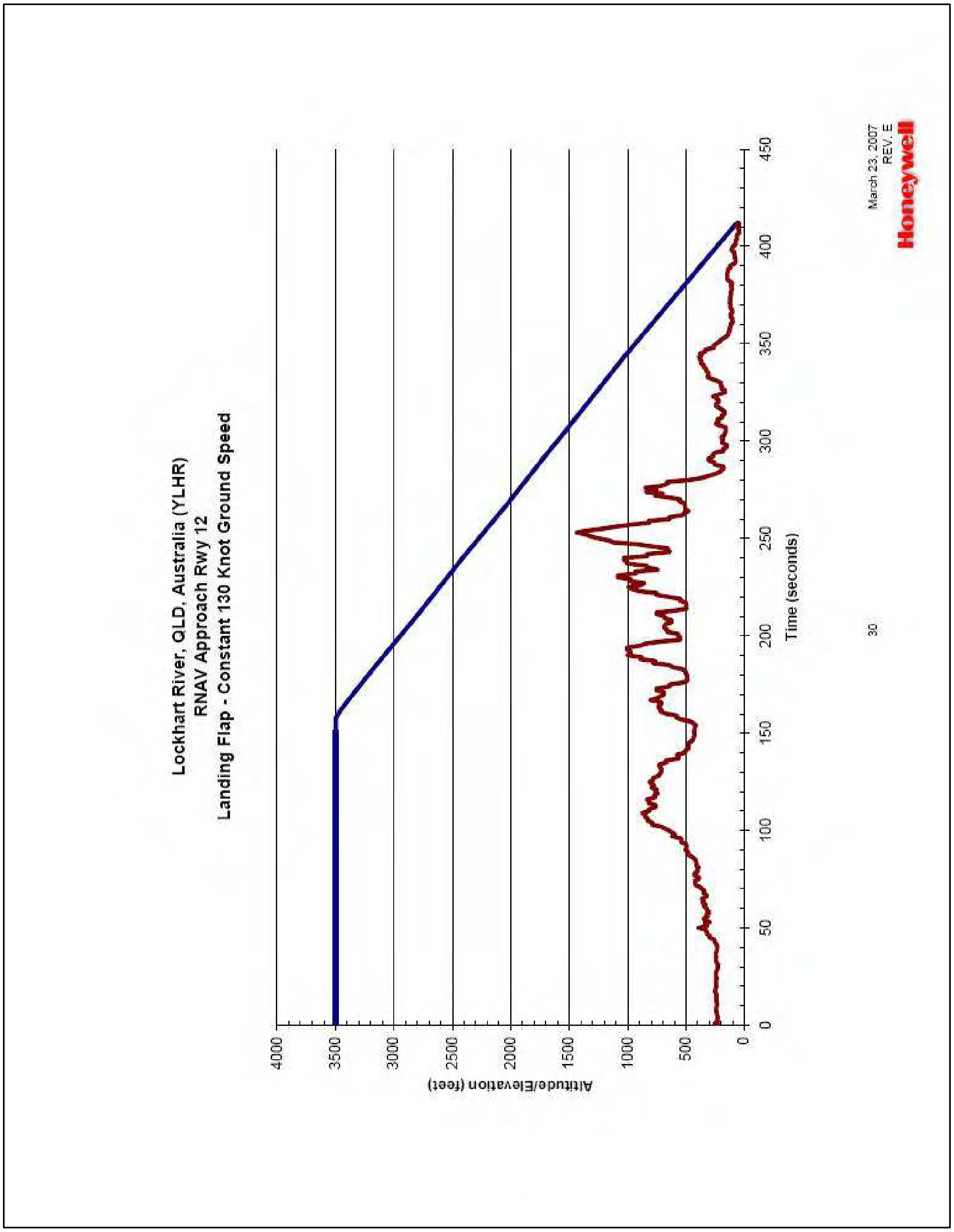
During the normal approach (RNAV RWY 12) simulation, the landing gear was lowered at FAF, and the landing flaps were set soon after the landing gear was down. The scenario is same as Case 1, except a constant ground speed of 130 knots was used throughout the approach.

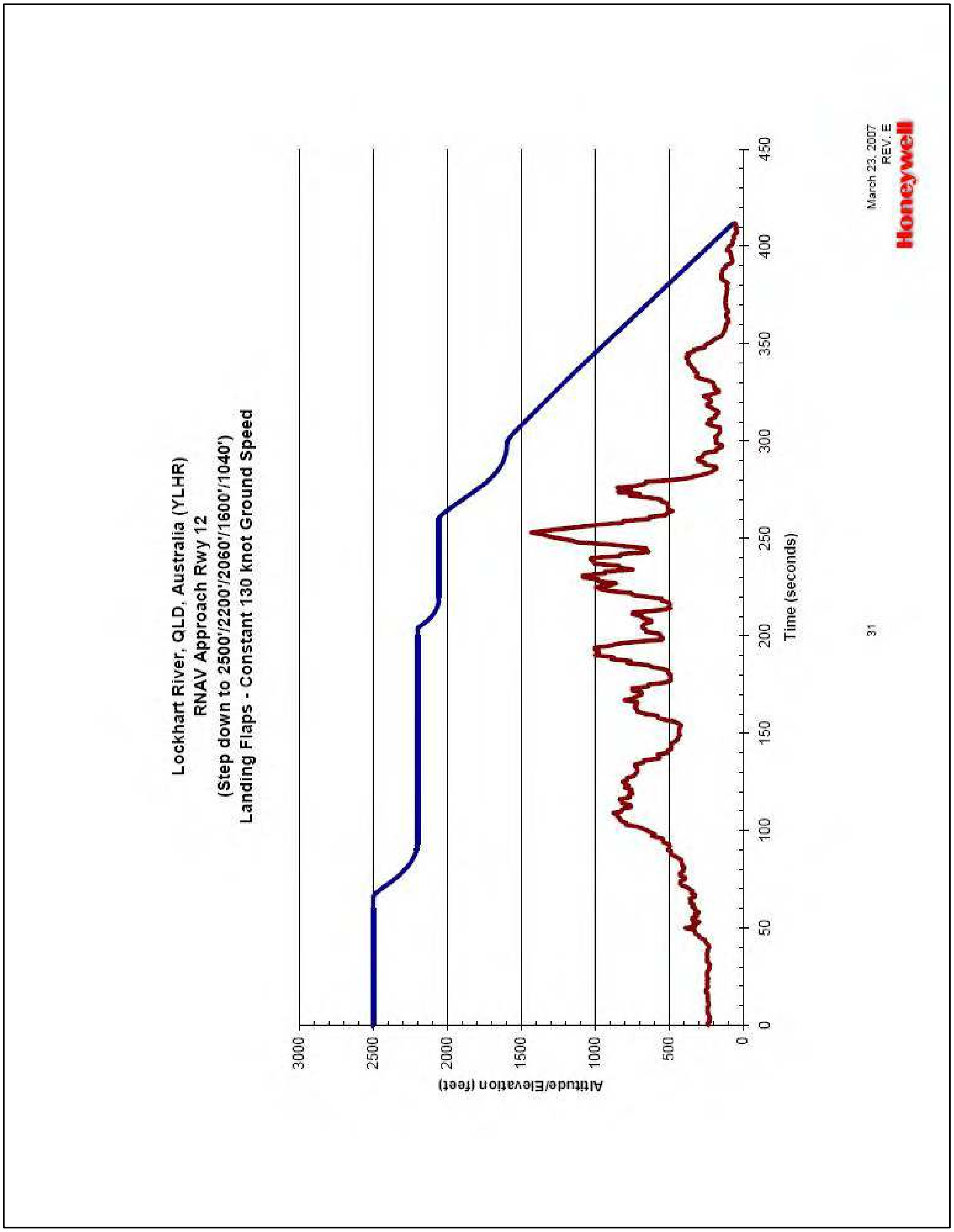
Case 3A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -800 fpm

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.

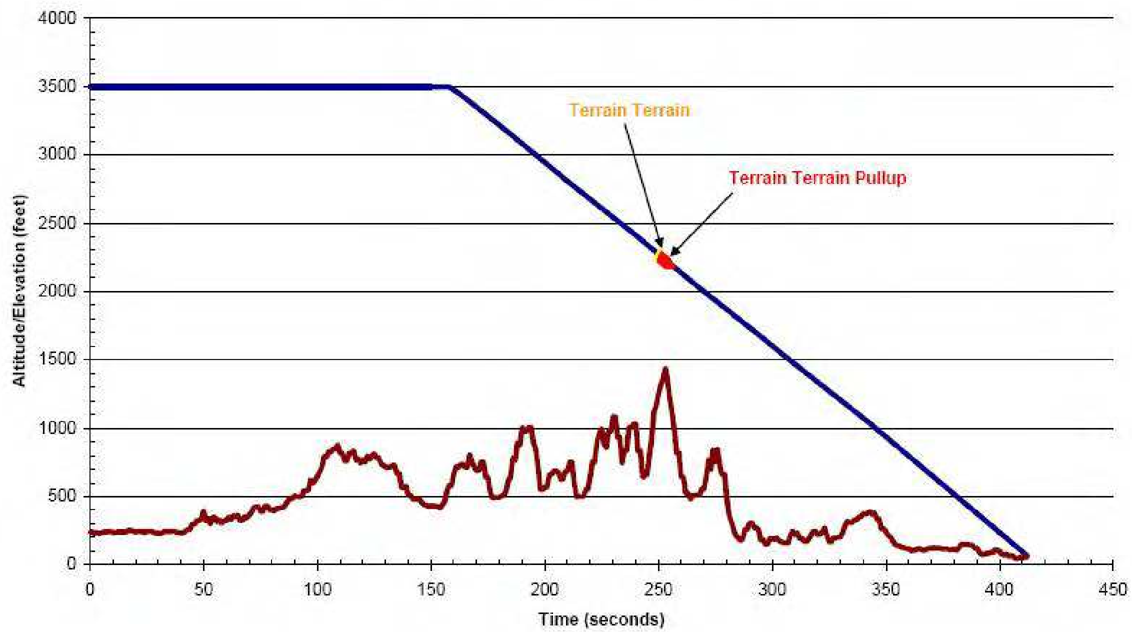
Case 4A:
Step down altitude: 3500' / 2860' / 2115' / 1600' / 1040'
Descent Rate: -800 fpm

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

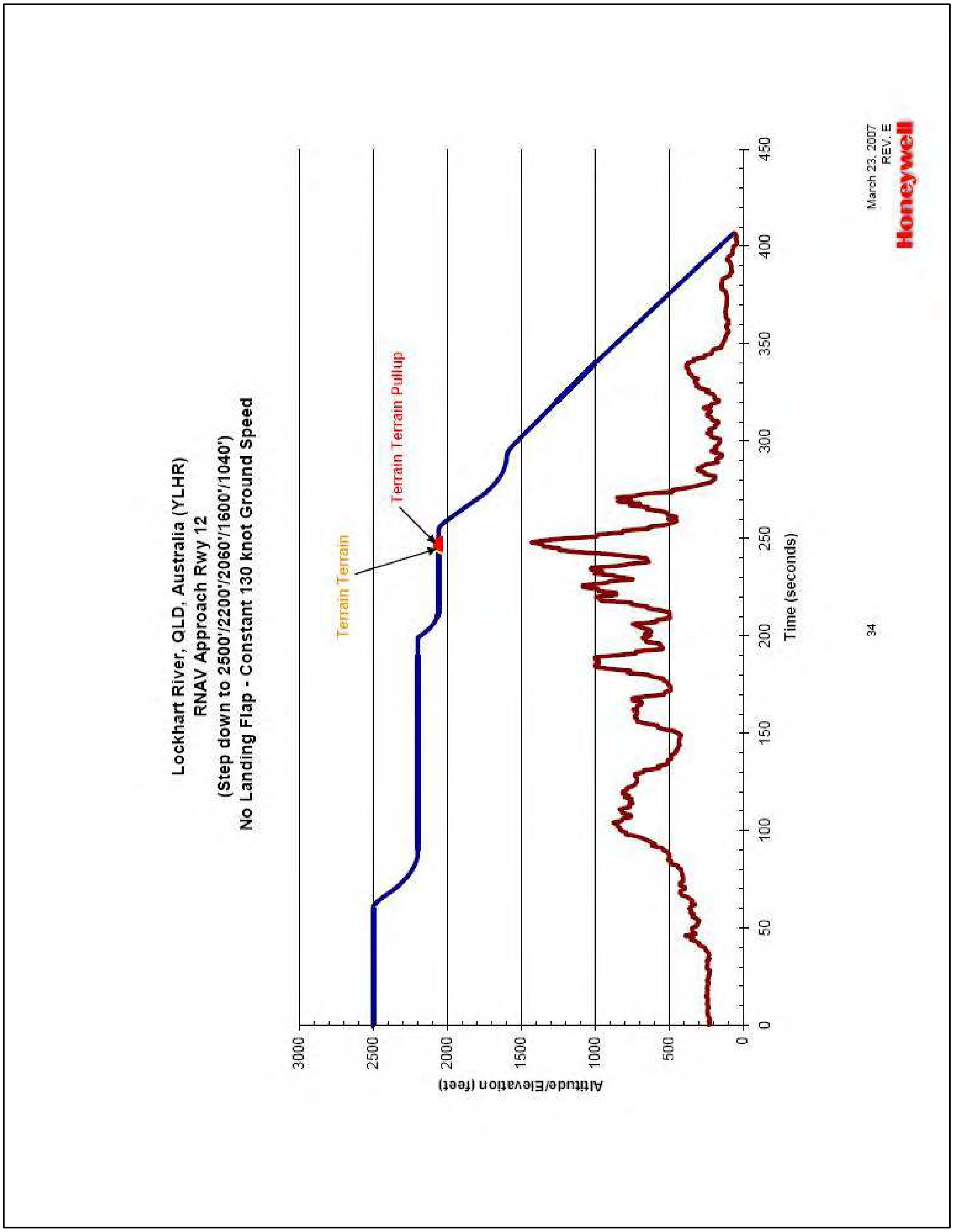
Mode 2A alerts/warnings were issued as shown in the plot below.

Lockhart River, QLD, Australia (YLHR)
RNAV Approach Rwy 12
No Landing Flap - Constant 130 knot Ground Speed



33

March 23, 2007
REV. E


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

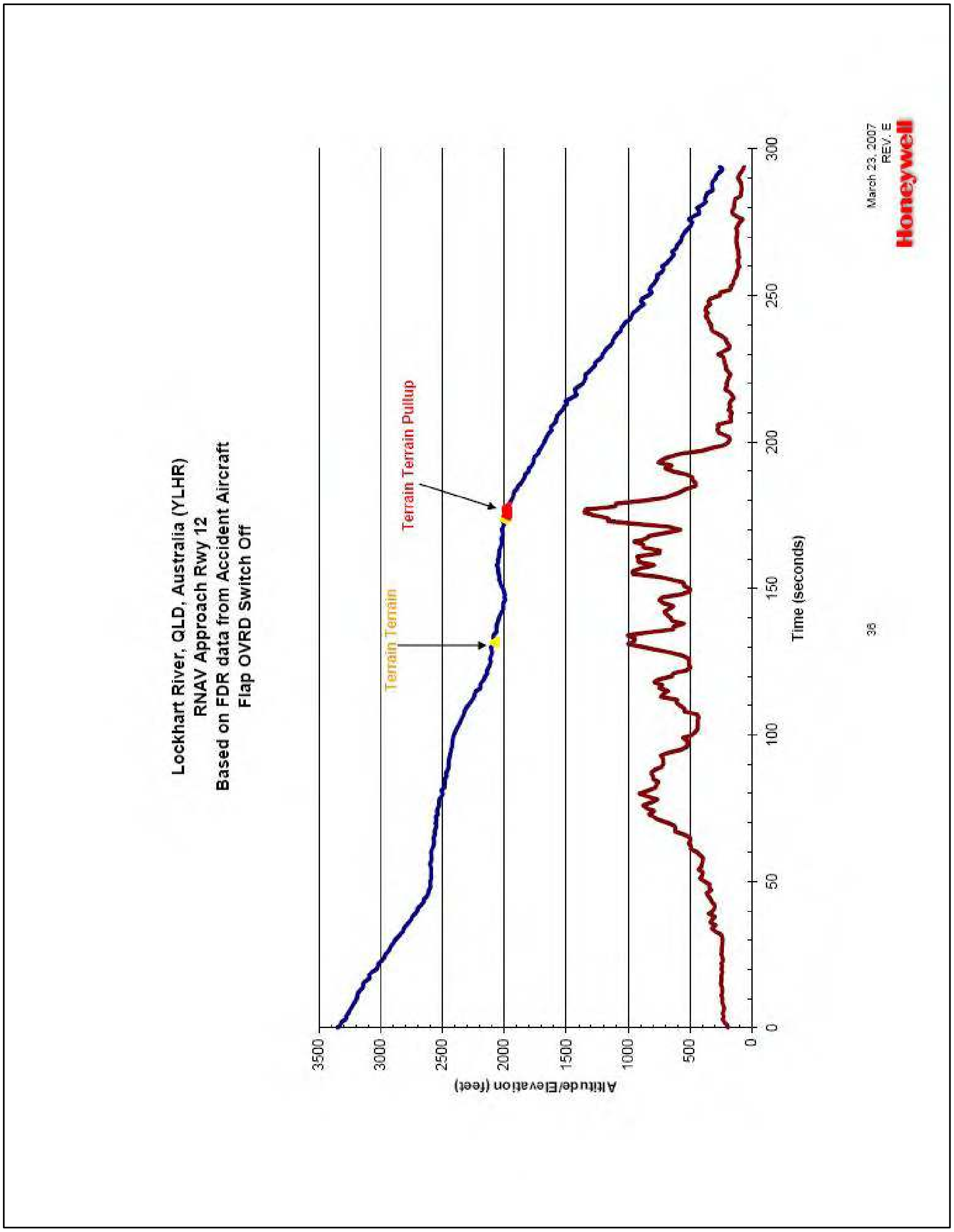
The accident aircraft has made a previous successful approach to runway 12. This data was captured on the flight recorder. This data was used to simulate the GPWS. As was done for the actual accident simulation presented above the radio altitude values where derived from a digital elevation model (DEM).

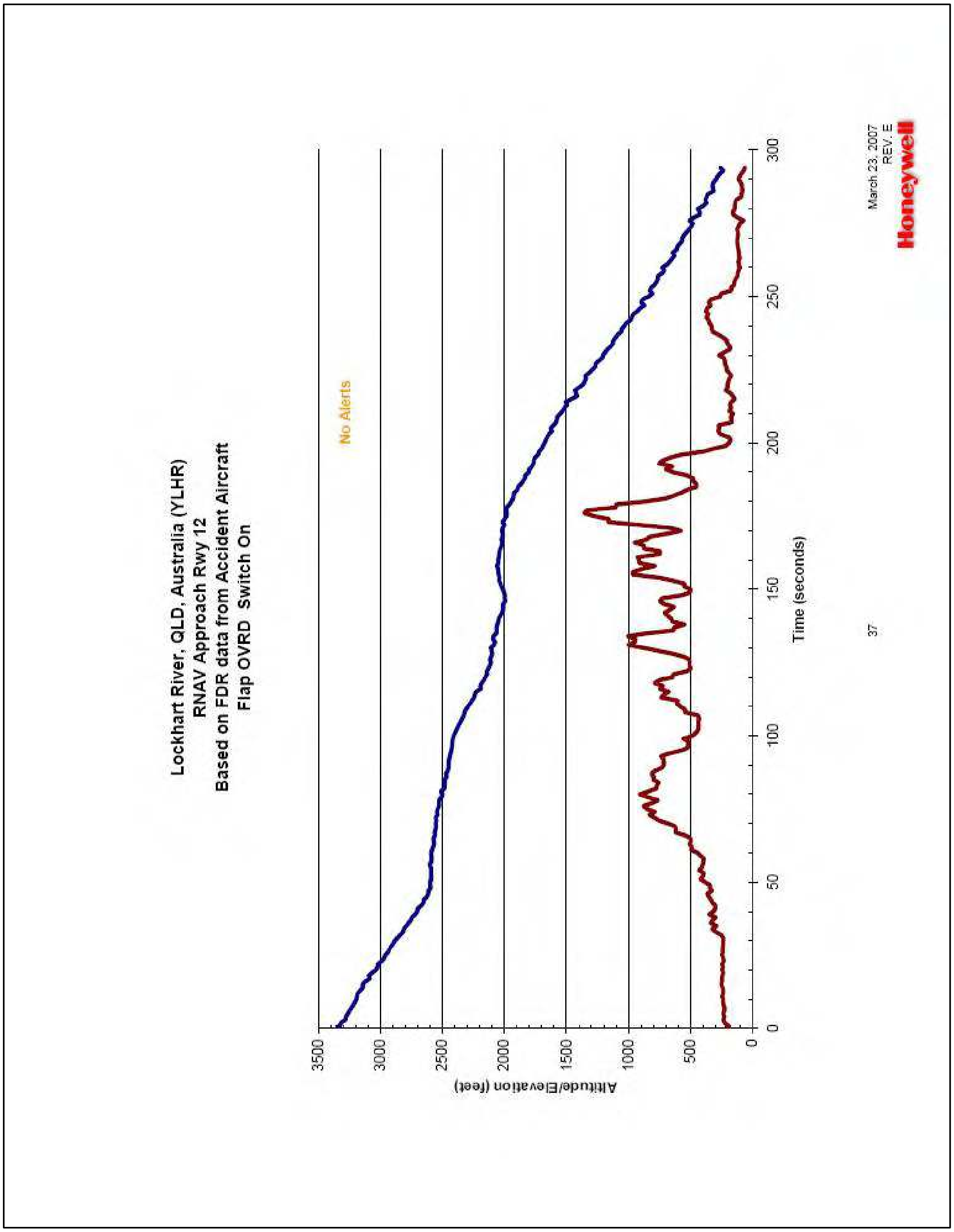
Case 1A – Flap OVRD Switch Off

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)
Time (seconds)
March 23, 2007
REV. E
Honeywell
38



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
Honeywell

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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.

Date	Event and Comments
15/4/1999	The Transair chief pilot purchased a copy of the CASA *Air Operator Certification Manual* (AOC Manual).
7/6/1999	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.
1/9/1999	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.
3/9/1999	Transair supplied additional information in support of their application to have RPT freight operations added to their AOC.
24/9/1999	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.
Commencement of first RPT cargo only international operations	
29/10/1999	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.
6/12/1999	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. It was subsequently discovered that Transair were using an unapproved aircraft on the freight operation.

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.

Date	Event and Comments
31/8/2000	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.
26/10/2000	AOC 426646-15 renewed for the period 26/10/2000 to 31/10/2001. There were no changes from the previously issued AOC.
27/3/2001	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.
27/3/2001 to 30/3/2001	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
7/6/2001	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.
21/8/2001	CASA reapproved Transair's check and training organisation under CAR 217 (3). CASA also indicated that the *Transair Operations Manual* was acceptable.
30/8/2001	Transair forwarded a new AOC legislative compliance statement to CASA.

<table>
<tr><th>Date</th><th>Event and Comments</th></tr>
<tr><td>September 2001</td><td>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.</td></tr>
<tr><td>3/9/2001 to 10/9/2001</td><td>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</td></tr>
<tr><td>12/9/2001</td><td>Transair requested addition of RPT operations to PNG to be added to its AOC.</td></tr>
</table>

<table>
<tr><th>Date</th><th>Event and Comments</th></tr>
<tr><td colspan="2">Commencement of Christmas Island (first international RPT passenger) operations</td></tr>
<tr><td>17/9/2001</td><td>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</td></tr>
<tr><td colspan="2">Commencement of Bamaga (first Australian RPT passenger) operations</td></tr>
<tr><td>17/9/2001</td><td>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.</td></tr>
<tr><td>2/10/2001</td><td>Transair requested addition of the Cairns – Bamaga – Cairns RPT route to its AOC.</td></tr>
<tr><td>5/10/2001</td><td>AOC 426646-17 issued for the period 5/10/2001 to 31/10/2004. Addition of Cairns – Bamaga – Cairns as an RPT route.</td></tr>
<tr><td>26/11/2001 to 30/11/2001</td><td>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</td></tr>
</table>

<table>
<tr><th>Date</th><th>Event and Comments</th></tr>
<tr><td></td><td>• 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</td></tr>
<tr><td>December 2001</td><td>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.</td></tr>
<tr><td>30/8/2002</td><td>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.</td></tr>
<tr><td>30/9/2002 to 4/10/2002</td><td>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</td></tr>
</table>

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.

<table>
<tr><th>Date</th><th>Event and Comments</th></tr>
<tr><td>23/7/2004</td><td>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</td></tr>
<tr><td>16/8/2004 to 20/8/2004</td><td>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</td></tr>
</table>

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	**Company Culture Total** (+) ____ *
80-105 points	Improvement needed	
Less than 80 points	High CFIT risk	

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;

Flight Safety Foundation Standard Operating Procedures Template (Rev. 1.1, 11/00) 6

- 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."

Suite 300, 601 Madison Street, Alexandria, VA 22314-1756 U.S. • Telephone: +1 (703) 739-6700, Fax: +1 (703) 739-6708
www.flightsafety.org

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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