Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation
AO-2008-026
Final

Loss of control
19 km SE Sydney Airport, NSW
9 April 2008
VH-OZA, Fairchild Industries
SA227 AC Metro III

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Abstract

On 9 April 2008, at 2325 Eastern Standard Time, a Fairchild Industries Inc. SA227-AC (Metro III) aircraft, registered VH-OZA, departed Sydney Airport, New South Wales on a freight charter flight to Brisbane, Queensland with one pilot on board. The aircraft was subsequently observed on radar to be turning right, contrary to air traffic control instructions to turn left to an easterly heading. The pilot reported that he had a 'slight technical fault' and no other transmissions were heard from the pilot.

Recorded radar data showed the aircraft turning right and then left, followed by a descent and climb, a second right turn and a second descent before radar returns were lost when the aircraft was at an altitude of 3,740 ft above mean sea level and descending at over 10,000 ft/min. Air traffic control initiated search actions and search vessels later recovered a small amount of aircraft wreckage floating in the ocean, south of the last recorded radar position. The pilot was presumed to be fatally injured and the aircraft was destroyed.

Both of the aircraft's on-board flight recorders were subsequently recovered from the ocean floor. They contained data from a number of previous flights, but not for the accident flight. There was no evidence of a midair breakup of the aircraft.

The investigation determined that it was highly likely that the pilot took off without alternating current electrical power supplied to the aircraft's primary flight instruments, including the pilot's artificial horizon and both flight recorders. It is most likely that the lack of a primary attitude reference during the night takeoff led to pilot spatial disorientation and subsequent loss of control of the aircraft.

A significant safety issue was identified in respect of the aircraft operator's training and checking of its pilots. As a result of audits conducted following the accident, the Civil Aviation Safety Authority imposed a number of conditions on the operator's air operator's certificate that were reportedly actioned by the operator.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory Agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

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

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

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

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

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

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

Critical safety issue: associated with an intolerable level of risk.

Significant safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable.

Minor safety issue: associated with a broadly acceptable level of risk.

FACTUAL INFORMATION

History of the flight

On 9 April 2008, at 2316 Eastern Standard Time[1], the pilot of a Fairchild Industries Inc. SA227-AC (Metro III) aircraft, registered VH-OZA (OZA), commenced taxiing at Sydney Airport, New South Wales (NSW), to conduct a freight charter flight to Brisbane, Queensland. The flight was operated under the instrument flight rules (IFR) and the pilot was the sole occupant (Figure 1).

Figure 1: VH-OZA

At 2321:43, the Sydney Aerodrome controller (ADC) [2] issued the pilot a take-off clearance from runway 16 Right (16R). Airservices Australia (Airservices) recorded information showed that the aircraft became airborne at 2323:15 and that, shortly after, the pilot was instructed to transfer to the departures controller's radio frequency.

On first radio contact with the departures controller, the pilot was advised that the aircraft was identified on radar. At 2325:30, the controller instructed the pilot to turn left onto a heading of 090^0 magnetic, which was acknowledged. Instead of the expected left turn, the controller observed on the air situation display (ASD) that the aircraft was turning right, towards the south-west. At 2325:54, the controller confirmed with the pilot that he was to turn left and at 2325:59 the pilot once again acknowledged the left turn and added 'I've got a slight technical fault here'. No further transmissions were received from the pilot. The aircraft disappeared from the controller's ASD and the controller initiated search activities to locate the aircraft.

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

2 An air traffic controller who has responsibility for managing the airspace immediately around an airport or aerodrome.

Search and rescue efforts that night by New South Wales Water Police and elements of the Royal Australian Navy were able to recover some items of floating wreckage that confirmed that the aircraft had impacted the ocean. The pilot was not located.

Witness report from the pilot of a following aircraft

Another Metro aircraft, registered VH-VEU (VEU), departed runway 16R shortly after OZA. The pilot of VEU reported that:

- he had witnessed the pilot of OZA starting the aircraft's engines
- there was a noticeable delay of about 15 minutes before OZA taxied
- he had followed OZA to the holding point of the runway
- after being cleared for takeoff, OZA rolled forwards a short distance and stopped for a few moments before continuing with the takeoff
- there was difficulty with communications and the ADC had not heard the readback from the pilot of OZA, or there was an overtransmission (he thought that OZA may have had radio problems)
- he observed OZA make an exceptionally long take-off run (longer than he would have expected with a 4 to 5 kt tailwind)
- at 5 NM (9 km) after departure, there were patches of cloud, less than scattered[3], and that the cloud base was about 3,000 ft above mean sea level (AMSL) and only about 100 ft thick
- it was not a particularly dark night, there was no turbulence and conditions were smooth
- following takeoff, he saw the lights of OZA ahead in his 10 o'clock position and stationary relative to his position and was concerned about a breakdown of separation, as his aircraft appeared to be overtaking OZA
- he heard the pilot of OZA transmit that he was experiencing a '...slight technical fault'.

Radar information

Airservices radar data for the last portion of the flight showed that the aircraft commenced a right turn, then a left turn, followed by a descent, a climb, a right turn and a second descent before the radar returns from the aircraft ceased. The last recorded radar return indicated an altitude of 3,740 ft. The recorded radar data was overlayed onto a chart showing the aircraft's track from takeoff (Figure 2).

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3 Cloud amounts are reported in oktas. An okta is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon. Few = 1 to 2 oktas, scattered = 3 to 4 oktas, broken = 5 to 7 oktas and overcast = 8 oktas.

Figure 2: Radar track of OZA

The radar data confirmed that during the climb after takeoff, the pilot was following a standard Sydney Curfew Two Departure (see the section titled *Aerodrome Information*), and that the aircraft was climbing at a rate of about 1,200 ft/min. Following the takeoff and notification by the departures controller of radar contact, the radar data indicated that:

- the aircraft deviated left and right from track
- the aircraft was levelled at around 3,000 ft for 30 seconds, although cleared by ATC to climb to flight level (FL) 170[4]
- the aircraft then reached an altitude of 3,140 ft and, soon after, descended rapidly at an average rate of 8,400 ft/min to 1,540 ft
- the descent was arrested and a climb initiated at an average rate of 8,400 ft/min

4 Level of constant atmospheric pressure related to the datum of 1013.25 hPa, expressed in hundreds of feet. FL 170 equated to about 17,000 ft.

- after reaching 4,340 ft, the aircraft descended at an average rate of about 10,400 ft/min until radar contact was lost at 3,740 ft.

An examination of the radar data for the flight is at Appendix A.

Search and wreckage recovery

At 0444 on 10 April 2008, search and rescue vessels located floating wreckage and cargo that was believed to be from the aircraft to the south of the last recorded radar position. The recovered aircraft items included a segment of a cargo strap that was used for securing cargo, an oxygen bottle, a metal container that was used for transporting medical specimens, sections of cabin flooring and soundproofing, cabin carpet and one light relay. The oxygen bottle and other recovered items exhibited no signs of being exposed to fire.

The nature of the damage of the recovered items indicated that the aircraft impacted the water at high speed (Figure 3). An examination of the cargo strap indicated that it had failed under gross overstress from exposure to impact loads. The metal medical specimen container displayed crush damage.

Figure 3: Recovered floating items

The Australian Transport Safety Bureau (ATSB) commenced a search for the main aircraft wreckage with the assistance of the New South Wales Water Police. Those initial efforts focused on locating the position of the aircraft using underwater locator beacon (ULB) detecting equipment.[5] After confirming audio signals from an ULB near the initial search area, the search area was further refined.

Under ATSB supervision, commercial salvage operators were contracted to locate and record the position of any aircraft wreckage/components. Those operations

5 The aircraft flight recorders were fitted with water-activated underwater locator beacons to assist with locating the recorders when submerged.

included the use of towed array side-scan sonar and underwater remote-operated vehicles (ROV) that were fitted with video cameras.

Poor weather conditions on the ocean surface delayed both the initial and later commercial search operations. The ocean depths in the search area ranged from 95 to 110 m and were beyond the safe range of conventional self-contained underwater breathing apparatus diving operations. Subsequent ROV operations determined that there was little natural light resulting in limited visibility on the seabed.

On 12 May 2008, a significant wreckage field was identified and recorded. The wreckage appeared to be spread over an area about 1,200 m long and 400 m wide. While it was believed that the aircraft's cockpit voice recorder (CVR) and flight data recorder (FDR) were contained within that field, they were unable to be retrieved at that time.

On 24 June 2008, a 76 m vessel was contracted for salvage and recovery operations. The vessel was fitted with a 3 t winch and was capable of dynamic positioning (DP), which allowed the vessel to maintain a geostationary position within 1 m using satellite navigation (Figure 4).

Figure 4: Deck of the salvage and recovery vessel

On 27 June 2008, the CVR was located at position 34.05.76 S, 151.14.12E and was recovered from a depth of 109 m. Numerous other items of wreckage were located and recorded via video camera on 27 and 29 June 2008. Those items included:

- the main landing gear
- the cockpit section
- a propeller blade (Figure 5)
- both engines and reduction gear boxes (Figure 6)
- the fuselage section

- the tail section
- an aileron
- a wing spar
- a section of the fuselage with cargo straps
- the empennage section
- a wing section.

Figure 5: Propeller blade on the ocean floor as displayed on the ROV monitor

Figure 6: Engine on the ocean floor displayed on the ROV monitor

On 29 June 2008, the FDR was located at position 34.05.47 S, 151.06.00 E and recovered, together with an artificial horizon instrument (AH) from the aircraft's

instrument panel. On 30 June 2008, the salvage and recovery operation was completed and both recorders and a number of items of wreckage, including the aircraft's FDR and CVR were recovered to the ATSB's technical facilities in Canberra (Figures 7 and 8).

No data from the flight was able to be recovered from either of the aircraft's FDR or CVR (Appendix B).

Figure 7: FDR on the ocean floor as displayed on the ROV monitor

Figure 8: CVR on the ocean floor as displayed on the ROV monitor

Damage to the aircraft

The video recording of the wreckage indicated that the engines, wings and tail section were scattered over a large area of the ocean floor (Figure 9).

Figure 9: Wreckage on the ocean floor as displayed on the ROV monitor

Injuries to persons

At the time of writing this report, the pilot's body had not been located. The damage to the aircraft and wreckage distribution indicates that the impact with the water was not survivable.

Personnel information

Endorsements and experience

The pilot was employed by the aircraft operator in May 2005 and was endorsed by the operator on the Metro III aircraft on 22 December 2007. The pilot also held endorsements on the Metro II[6], the Piper PA31, the Aerostar 600, the Cessna 310/340 and 402/421, and several smaller twin-engine aircraft. The pilot's special design feature endorsements included for pressurisation, retractable undercarriage and manual propeller pitch control.

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6 The Metro II and Metro III aircraft, although different models from the same aircraft manufacturer, included some systems commonality. However, Civil Aviation Order (CAO) 40.1.0 listed both aircraft as requiring separate endorsements.

Table 1: Pilot information

Type of licence	Air Transport Pilot (Aeroplane) Licence (ATPL(A))
Medical certificate	Valid Class 1 with no restrictions (valid to 25 August 2008)
Flying experience (total hours)	4,873
Hours on type	175
Hours flown in the last 30 days	65
Hours flown in the last 90 days	113

The pilot held a valid command instrument rating and had recorded 555 hours multi-engine command night flying and 649 hours instrument flying. The pilot's last recorded instrument flying was of 0.3 hours duration on 3 April 2008.

Metro III endorsement details

The operator's training and checking manual required the completion of ground school and an engineering examination to be passed prior to a candidate commencing the flying training component of an aircraft endorsement. Although the operator provided an unassessed copy of a Metro III ground theory examination as part of the directly involved party process, and indicated that it had been recovered from the pilot's home, there was no documentation in the pilot's company training file to indicate that the pilot completed an engineering examination as part of his endorsement.

There was a completed ground theory examination for the Piper PA31P-350 Mojave in the aircraft operator's training records for the pilot.

The flying component of the pilot's Metro III endorsement was conducted by the operator's designated chief pilot on 7, 9 and 22 December 2007. That training was recorded by the operator on forms 'TREX'1, 2, 3 and 4 as indicated in Table 2.

Table 2: TREX training form entries

Form	Date	Entry
TREX 1	7 December 2007	Noted the ground operation of the aircraft. Indicated 2.5 hours of flight time in OZA and 0.5 hours of instrument flight time.
TREX 2	7 and 9 December 2007	Noted the conduct of pre-flight checks, takeoff, upper air work, engine handling, system operation and instrument flight. All items assessed as 'satisfactory' and the form indicated a total of 3.3 hours of flight time, including 1.0 hour at night and 0.3 hours of instrument flight.
TREX 3	9 December 2007	Noted asymmetric flight, including engine shutdown and re-start, engine failure in the cruise, and asymmetric circuits. Those circuits included engine failure after V_1, on climbout, on approach and a single-engine go-around. It also incorporated electrical and landing gear failures. Performance assessed as 'satisfactory'.
TREX 4	22 December 2007	Night circuits. Each item was annotated 'satisfactory'. Total of 1.0 hour of night flight.

Another form, titled 'Conversion to Type', showed additional training on those dates for a total flight time of 4.8 hours (day) and 2 hours (night). That training entailed the normal and emergency operation of the aircraft and was annotated as 'satisfactory'.

The in-command under supervision (ICUS)[7] component of the pilot's endorsement flying was completed from 2 December 2007 to 7 February 2008 and totalled 74 hours (Table 3). Several of the completed ICUS forms on the pilot's file were not signed or dated by the pilot. Of the supervising pilots that were listed in the pilot's logbook for those ICUS flights, none were approved by the Civil Aviation Safety Authority (CASA) to act in supervisory roles (see the section titled *Personnel and requirements under a training and checking organisation*).The pilot's most recent 'base check' was conducted on 11 February 2008.

Table 3: ICUS and check flying

Date	Type of check
22 December 2007	Conversion to type/ emergency procedures/ competency
24 December 2007	ICUS
7 January 2008	ICUS
8 January 2008	ICUS
12 January 2008	ICUS
14 January 2008	ICUS
15 January 2008	ICUS
19 January 2008	ICUS
20 January 2008	ICUS
23 January 2008	ICUS
24 January 2008	ICUS
30 January 2008	ICUS
31 January 2008	ICUS
4 February 2008	ICUS
5 February 2008	ICUS
6 February 2008	ICUS
7 February 2008	ICUS
11 February 2008	Base proficiency check
11 February 2008	Emergency procedures/ competency

Health and fitness

The pilot was reported to have been fit, healthy and well rested for the flight. He was accustomed to flying on a schedule that included late night flights and last completed such a flight on 3 April 2008.

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[7] ICUS. The performance of the duties and functions of the pilot in command while being supervised by an aircraft operator's designated pilot in command.

The loading supervisor, who assisted and supervised the loading of the aircraft for the flight, reported that the pilot 'appeared in fine spirits as was his usual demeanour'. Another pilot, who accompanied the pilot from Bankstown to Sydney Airport that day, confirmed that the pilot was in good spirits. In addition, a review of communications between the pilot and ATC the night did not suggest any problem in the pilots performance of his duties.

A review of the pilot's health records found nothing to suggest any physiological or psychological factors that would have influenced the pilot's performance.

Flight and duty times

The last flight and duty times recorded on the operator's files for the pilot was on 3 April 2008. Those times included:

- 6.0 duty hours and 4.6 flight hours that day
- 26.4 duty hours and 16.8 flight hours in the last 7 days
- 45 duty hours and 31.2 flight hours in the last 14 days.

It was reported that the pilot normally remained at the operator's offices in Bankstown after the start of his duty hours. The pilot's flight and duty times for the 4 days leading up to the accident were determined based on interviews and flight sheets and are listed in Table 4.

Table 4: Flight and duty times

Date	Duty time[8]	Flight hours	Notes
6 April 2008	Off work	Nil	
7 April 2008	1505 to 2147	6.4	Flight time shared with another pilot.
8 April 2008	2100 to 0500 (estimated)	3.5[9]	Woken at 2000 hours
9 April 2008	2000 to 0500 (estimated)	0.1	Woken at 1900 hours

Aircraft information

The Metro III aircraft had capacity for two flight crew and 19 passengers. The aircraft type certificate and flight manual permitted the operation of the aircraft by one flight crew. The aircraft could also be configured for cargo operations.

The aircraft was first registered in Australia on 25 February 1998 as VH-IAW and subsequently changed to OZA. The general aircraft, engine and propeller and recent engine and propeller maintenance information is listed at Tables 5, 6, 7 and 8.

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8 The operator defined a duty period as staring 45 minutes prior to the scheduled departure time of a flight and concluding no earlier than 15 minutes after the arrival of the aircraft at its destination.

9 Based on the duration of a previously-recorded similar cargo flight from Sydney to Brisbane and return.

Table 5: General aircraft information

Manufacturer	Fairchild Industries Inc.
Model	SA227-AC (Metro III)
Serial Number	AC-600
Registration	VH-OZA
Year of manufacture	1984
Certificate of airworthiness	Issue date 18 March 2007
Certificate of registration	Issue date 1 May 2007
Maintenance Release	Issued on 21 February 2008, valid to 32,355 hours total time in service (TTIS) or 21 February 2009
Total airframe hours/ landings	32,339 / 46,710

Table 6: Engine information

Manufacturer	Garrett
Model	TPE331-11U-661G
Type	Turboprop
Serial Numbers	Left P44339C / Right P44320C
Time since overhaul	Left 6,313.9 hours / Right 5,967.1 hours as of 22 February 2008

Table 7: Recent significant engine and propeller maintenance

Date / TTIS	**Maintenance completed**
21 February 2008 / 32,205 hours	Right engine removed for repair (accessory gear case corrosion) and reinstalled. Right engine fuel nozzles removed, cleaned and reinstalled.
14 March 2008 / 32,279 hours	Left engine fuel nozzles removed, cleaned and reinstalled.
17 December 2007 / 32,131 hours	Right engine fuel nozzles removed, cleaned and reinstalled. Right propeller removed, repaired and reinstalled (would not stay on locks).
14 November 2007 / 32,056 hours	Right propeller would not stay on locks.
11 May 2007 / 31,827 hours	Right engine removed for repair (low power output), hot section repairs completed and engine reinstalled.

Table 8: Propeller information

Manufacturer	Dowty Rotol
Model	R321/4-82-F/8 (hub model)
Type	Four-bladed, full-feathering
Serial Number	Right DRG-2565-87 / Left DRG-1383-81
Time since overhaul	Right 1,994 hours / Left 1,618 hours as of 22 February 2008
Total time in service	Right 1,994 hours / Left 2,886 hours as of 22 February 2008

Aircraft maintenance

A review of the aircraft's historical aircraft, engine, propeller, component historical and computer-based maintenance documentation did not uncover any anomalies. There were no annotated defects on the last recorded maintenance documentation.

The aircraft was being maintained by a third party maintenance provider in accordance with the aircraft manufacturer's approved phase inspection schedule. The last inspection of the aircraft, a service check, was completed on 14 March 2008 at 32,279 hours TTIS. Recent significant maintenance items are listed at Table 9.

Table 9: Recent significant maintenance

Date and TTIS	Maintenance completed
7 February 2008 / 32,205 hours	Map light and instrument panel lights replaced.[10]
22 January 2008 / 32,187 hours	'Pitch out of trim' wiring repaired at warning horn. Left battery relay removed and replaced (battery would not come on line).
14 November 2007 / 32,056 hours	Five inoperative annunciator panel light globes replaced.[11]
15 June 2007 / 31,879 hours	Left engine starter/generator removed and replaced.
12 April 2007 / 31,823 hours	Six inoperative annunciator panel light globes replaced.
10 February 2007 / 31,760 hours	10 inoperative annunciator panel light globes replaced.

10 Specific panel lights not specified.

11 There was no entry in any other aircraft documentation about the replacement of any annunciator panel light globes.

Flight Recorders

Recorder installation

As of 11 October 1991, the United States (US) Federal Aviation Administration (FAA) mandated the installation of a cockpit voice recorder (CVR) system to US civil registered, multi-engine, turbine-powered aircraft with passenger seating of six passengers or more, and for which two pilots are required by type certificate or operating rule.

On 4 September 1991, a CVR system was installed in the aircraft while the aircraft was registered and being operated in the US. Aircraft wiring diagrams indicated that the CVR system was powered from the left 115 Volts alternating current (VAC) bus, as was required by the aircraft manufacturer's wiring diagrams valid at the time. On 23 September 1991, the aircraft manufacturer issued Service Bulletin (SB) 227-23-001, a non-mandatory bulletin to '*Provide Cockpit Voice Recorder installation to meet requirements of F.A.R. [Federal Aviation Regulation] 91.609 and 135.151*'.[12] SB 227-23-001 was effective for Metro III model SA227-AC aircraft, serial numbers AC-406, 415, 416, 420 to 782 and 785 to 789, and model SA227-BC aircraft, serial numbers BC-762, 764 and 766 to 783. That service bulletin had not been incorporated in OZA (serial number AC-600).

On 3 March 1998, following the importation of the aircraft into Australia, and as required by Australian regulations, a flight data recorder (FDR) system was installed in the aircraft. An aircraft logbook entry noted that the FDR system wiring installation was in accordance with relevant Civil Aviation Regulation (CAR) 35-approved documentation.[13] The CAR 35-approved wiring diagram for the installation required the FDR to be electrically powered from the right 115 VAC bus and the FDR PWR FAIL advisory that was displayed on the central warning (annunciator) panel.

The aircraft manufacturer's wiring diagrams indicated that on later models of Metro III aircraft (serial numbers 706 to 789), CVR and FDR systems could be installed at the factory at the customer's request. The wiring diagrams for those serial number aircraft showed that both the CVR and FDR systems were powered from the left 115 VAC bus via the same tag strip connection as used in OZA.

Aircraft manufacturer CVR installation diagrams for the Metro 23 model SA227-DC aircraft, indicated that the CVR system was powered from the left or right essential 28 Volt direct current (VDC) bus, and that the FDR system was powered from the left 115 VAC bus.

In OZA, both recorders were powered by 115 VAC via two circuit breakers: the CVR on the left 115 VAC bus and the FDR on the right 115 VAC bus. The circuit breakers were located in the cockpit and accessible to the pilot.

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12 This option permitted the installation of the CVR with an electrical power source from the 28 Volts direct current (VDC) bus instead of the VAC bus.

13 CASA authority for the design of a modification or repair of an aircraft or component.

Recorder requirements

Civil Aviation Order (CAO) 20.18 required the installation of a CVR and FDR in all Australian-registered aircraft that were manufactured after 1965 and had a maximum take-off weight of more than 5,700 kg.

The power requirements for FDR installations were listed in CAO 103.19 and included that:

> The flight data recorder must receive its electrical power from the bus that provides the maximum reliability for operation of the flight data recorder without jeopardising service to essential or emergency loads.

CAO 103.20 contained a similar power supply statement in respect of CVRs.

Recorders maintenance

Both recorders had been replaced in the aircraft within the last 80 flight hours (Table 10).

Table 10: Recent significant recorders maintenance

Date and hours	Maintenance completed
14 March 2008 / 32,279.8	FDR replaced. FDR part number 980-4100-FWUS serial number 2419 removed. FDR part number 980-4100-FWUS serial number 1313 installed. Underwater locator beacon (ULB) part number ELP-362D serial number 11364 battery expiry date January 2010.
7 March 2008 / 32,263.6	FDR replaced. FDR part number 980-4100-FWUS serial number 1313 removed serviceable. ULB part number ELP-362D serial number 11364 battery expiry date January 2010. FDR part number 980-4100-FWUS serial number 2419 (ex VH-OZN) installed. ULB part number DK120 serial number 22769 battery expiry date January 2011. CVR replaced. Loan CVR replaced with purchased CVR. CVR part number 93-A100-82, serial number 53749 removed. CVR part number 93-A100-82, serial number 55650 installed.

Date and hours	Maintenance completed
21 February 2008/ 32,205.8	CVR replaced. Part number 93-A100-82 serial number 53749 fitted.[14]

Flight recorder advisory and CVR test

FDR

The FDR stored about 25 hours of flight information on an endless loop tape. There were no controls or switches associated with the unit and its operation was automatic when 115 VAC power was available. The FDR wiring included a ‘G switch’ or inertia switch that disabled the unit in the event of a high energy impact, in order to preserve the stored data. In addition, power to the unit could be removed by de-energizing a circuit breaker that was located in the cockpit.

The unit included a built-in self-test that required about 1 minute to complete and was initiated each time power was supplied to the recorder. The FDR FAIL advisory light on the main instrument panel cycled on and off during the self-test, but was required to be off at the end of the test. The FDR FAIL advisory light remained illuminated when 115 VAC was not available to the FDR or the FDR’s internal monitor detected an unserviceability.

CVR

The CVR system comprised the CVR unit, a control unit, and an area microphone and interface to microphones located at each flight crew position. The CVR unit was capable of recording four channels of information for about 30 minutes on an endless loop tape. The CVR control unit included a CVR TEST button on the copilot’s side of the main instrument panel with a test panel, headphone jack and an ERASE button. There was no ON/OFF switch and the recorder operated whenever 115 VAC power was available. However, power to the unit could be removed by de-energizing a circuit breaker that was located in the cockpit.

The CVR TEST button, when pressed and held for a minimum of 5 seconds, initiated a built-in test of the CVR unit (see the section titled *Checklist items*). At test, each of the four recording channels was checked, a test tone was generated and recorded on each channel, and the test meter needle was driven to the green band. Failure of the needle to remain in the green band indicated a fault with the unit. If a headset was plugged into the head phone jack, the test tone could be heard during the built-in test. A failure of the CVR unit could only be detected by activating the TEST function and observing the meter movement or by monitoring the audio program via the headset jack located on the CVR control unit.

As in the case of the FDR, the CVR wiring included a ‘G switch’ or inertia switch that disabled the unit in the event of a high impact in order to preserve the stored data.

Fuel

On 9 April 2008 at 2122, the aircraft was refuelled with 600 L (480 kg) of aviation turbine fuel at Sydney Airport. That amount added to the 436 L (349 kg) recorded

[14] The replacement unit was on loan to the operator.

as being in the aircraft, resulting in a total of 1,036 L (829 kg) of fuel on board at the time of taxi.

Aircraft operators who subsequently used the same fuel source reported no problems with the fuel.

Weight and balance information

On 1 March 2004, the aircraft was structurally modified in accordance with the aircraft manufacturer's SA227 Series Service Bulletin SB11-011, which was issued on 4 November 2003 and increased the maximum zero fuel weight to 6,305 kg. The aircraft's certified maximum take-off weight was 7,258 kg, with the permissible centre of gravity (c.g) range at that weight from 6,662 to 7,035 mm.

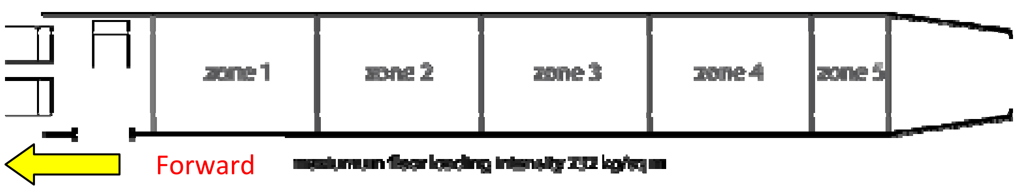
The aircraft was last reweighed on 12 November 2007. At that time, it was configured for 19 passengers and two flight crew, and the aircraft's empty weight was 4,159.2 kg. The aircraft's c.g arm 6,591.5 mm aft of the datum.

Aircraft loading

A number of the operator's pilots were interviewed regarding normal practice for loading the aircraft and for a departure from Sydney Airport. Those pilots reported that (Figure 10):

- There were a total of 5 zones in the aircraft cabin, with Zone 1 behind the net (webbing bulkhead) at the forward end of the cabin and Zone 5 at the rear of the cabin.
- Aircraft loading at Sydney was performed by authorised contractor personnel using a mechanical ramp. Baggage/cargo items were taken from trolleys and passed up the ramp, through the rear cargo door to a number of loaders (usually 2 or 3) who were in the aircraft.
- The contents of each trolley were weighed and a placard on the trolley showed the weight of freight on that trolley.
- When the freight for each zone was loaded, that zone would be closed via the installation of a net or webbing bulkhead with eight quick attach points, and the next zone loaded, and so on until Zone 5.
- Dangerous goods were normally always put at the back of Zone 4 or in Zone 5 where they were readily accessible through the cargo door at the rear of the cabin).

Figure 10: Metro III cabin loading layout



The authorised contractor documented the aircraft's load on a load chart. According to the loading documentation[15] that was supplied to the investigation, the loading for the flight was as indicated in Table 11.

Table 11: Information from the aircraft load chart for the flight

Area	Cargo	Amount in kg	Notes
Nose baggage compartment	Australia Post mail bags	80	Maximum allowable 363 kg
Zone 1	Australia Post mail bags	500	Maximum allowable 521 kg
Zone 2	Australia Post mail bags	460	Maximum allowable 521 kg
Zone 3	Australia Post mail bags	416	Maximum allowable 521 kg
Zone 4	Dangerous goods / general freight	328	Maximum allowable 521 kg
Zone 5	Nil	Nil	Maximum allowable 272 kg

That loading resulted in a total cargo weight for the flight of 1,784 kg.

According to the aircraft's loading documentation, the total fuel weight for the takeoff was 1,025 kg. The aircraft's take-off weight was estimated to be 6,869 kg, which was within the aircraft manufacturer's limits (Table 12).

Table 12: Aircraft's take-off weight calculations based on the load chart

Item	Weight (kg)
Aircraft operating weight	4,060
Cargo	1,784
Fuel	1,025
Total	**6,869**

Based on the loading documentation, the c.g for the takeoff was within the aircraft manufacturer's limits (Table 13).

Table 13: Weight and balance calculations

Item	Weight (kg)	Moment arm (mm)	Index
Aircraft empty weight (single-pilot operation)[16]	4,060	6,457	26,215,420
Fuel	1,025	6,804	6,974,100
Baggage compartment	80	1,066	85,280
Cargo zone 1	500	5,181	2,590,500

15 The load documentation incorrectly annotated that the aircraft's 'operating weight' was 4,060 kg, or 99 kg less that the last annotated reweigh of the aircraft.

16 Pilot's weight included.

Item	Weight (kg)	Moment arm (mm)	Index
Cargo zone 2	460	7,264	3,341,440
Cargo zone 3	416	9,347	3,888,352
Cargo zone 4	328	11,455	3,757,240
Cargo zone 5	Nil	Nil	Nil
Total	6,869	6,821	46,852,332

An examination of the loading documentation for dangerous cargo identified two items of dangerous goods; 55.7 kg of dry ice and 1 L of acrylamide solution. In relation to those dangerous goods, the load sheet was annotated that:

> There is no evidence that any damaged or leaking packages containing dangerous goods have been loaded on the aircraft.

Acrylamide solution is from the chemical family of unsaturated aliphatic amide in aqueous solutions, and is used as a laboratory reagent. It is a clear, colourless and odourless liquid solution. The material safety data sheet for the product included the following information in the case of emergency:

> Leak and Spill Procedure: Evacuate area. Eliminate all ignition sources. Cleanup personnel must be thoroughly trained in the handling of hazardous materials, and must wear protective equipment and clothing sufficient to prevent any inhalation of vapours or mists and any contact with skin and eyes.

and that:

> [if] Inhaled: Irritating to nose and throat. Highly toxic. Skin exposure is the usual cause of toxicity in the workplace, but inhalation can also be a hazard. Acute poisoning usually leads to CNS [central nervous system] disturbances such as drowsiness, tingling sensations, fatigue, weakness, stumbling, slurred speech and shaking.

Witness report from the aircraft loader

The aircraft loading supervisor for the departure confirmed that the freight that was loaded into OZA that night consisted of mail items, general freight and some dangerous goods items and that this was a typical load. The supervisor confirmed that the load was distributed in the aircraft's loading zones as described on the loading documentation, and that the cargo nets were secured after each zone was loaded. The pilot was reported to have supervised the loading.

The loading supervisor reported that he had spoken to the pilot after the loading was completed, and that no issues were highlighted by the pilot. He also reported that the aircraft remained on the bay for about 5 minutes after the pilot started the engines, and that both engines were started normally from a ground power unit (GPU).[17] The operator later advised that a delay of 5 minutes as reported was not considered a delay for this aircraft type.

The loading supervisor reported that a minimum of five and a maximum of 12 aircraft during 'busy times' would share two GPUs, but that because of

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[17] The loading supervisor reported that typically the aircraft used battery power during loading to provide cabin lighting and that the GPU was used for engine starting only.

mechanical problems, usually only one GPU was available and that it was repositioned between aircraft for engine starting.

In respect of engine starting, the operator's Operations Manual Part B10 noted:

> Where possible a GPU should be used to provide power for engine starting.

and that:

> The use of aircraft batteries should be avoided as the sole source of power for internal lighting when loading or reconfiguration operations are in progress.

A number of the operator's personnel advised that during cargo loading, if a GPU was not available, and in order to conserve battery power, pilots often switched the 28 VDC right essential bus tie switch to the OFF position.[18] Those operator personnel also reported that pilots normally preferred to keep the No 1 inverter selected as providing primary power. There was a checklist item that required pilots to switch from inverter No 1 to inverter No 2 and to check for correct operation by monitoring an AC BUS advisory light.

The loading supervisor also noted that on the night, another Metro aircraft was waiting to use the same bay and he saw OZA move to another location and hold before taxiing. During that time, he had a clear view of the pilot in OZA and saw that he was busy working on something in the cockpit. He reported that 'the pilot [of OZA] appeared to be looking at something on the instrument panel, probably in the centre console'.

Aircraft electrical system

The Metro III aircraft was equipped with 28 VDC and 115 V and 26 V alternating current (AC) electrical power systems. Those systems worked in conjunction to provide electrical power to the required aircraft systems. Monitoring and warning devices were provided to inform the flight crew of the systems' operational status. DC and AC electrical power was distributed to the aircraft's systems via independent bus systems (Figure 11).

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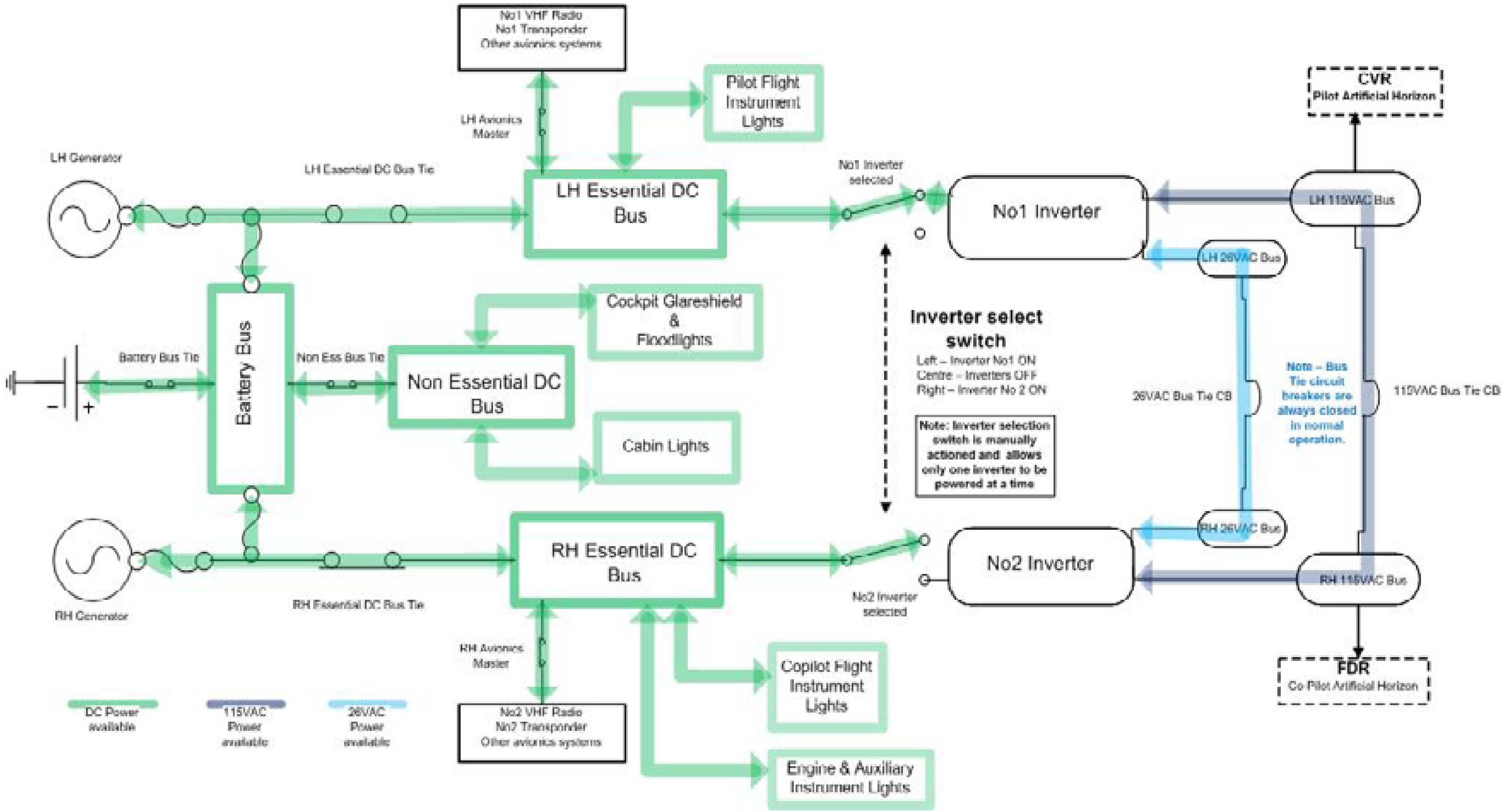
18 Turning the 28 VDC right essential bus tie switch to OFF removes power from the copilot's flight instrument internal lighting and the engine and auxiliary instrument internal lighting.

Figure 11: Simplified DC and AC electrical system



Direct current system

Electrical power for the aircraft was provided by the DC electrical power system. The aircraft was fitted with two 24 VDC nickel-cadmium batteries and two engine-driven 24 VDC starter/generators (generator). The function of the batteries was to provide a source of power for engine starting and emergency power in the event of generator failure. That ensured the operation of all essential and emergency electrical and avionics systems such as radios and lights. Each battery was connected through a battery relay to the battery bus relay then to the battery bus.

The starter/generators, when operating in the generator mode, provided the aircraft's primary source of DC power when the engines were running. Provision was also made for the connection of DC power from an external ground power source for engine starting purposes. The external ground power source could either be a 24 VDC battery cart or a 24 VDC GPU.

During engine operation, each engine-mounted starter/generator provided power through a 325 ampere (A) current limiter to the battery bus to charge the batteries.

DC power distribution

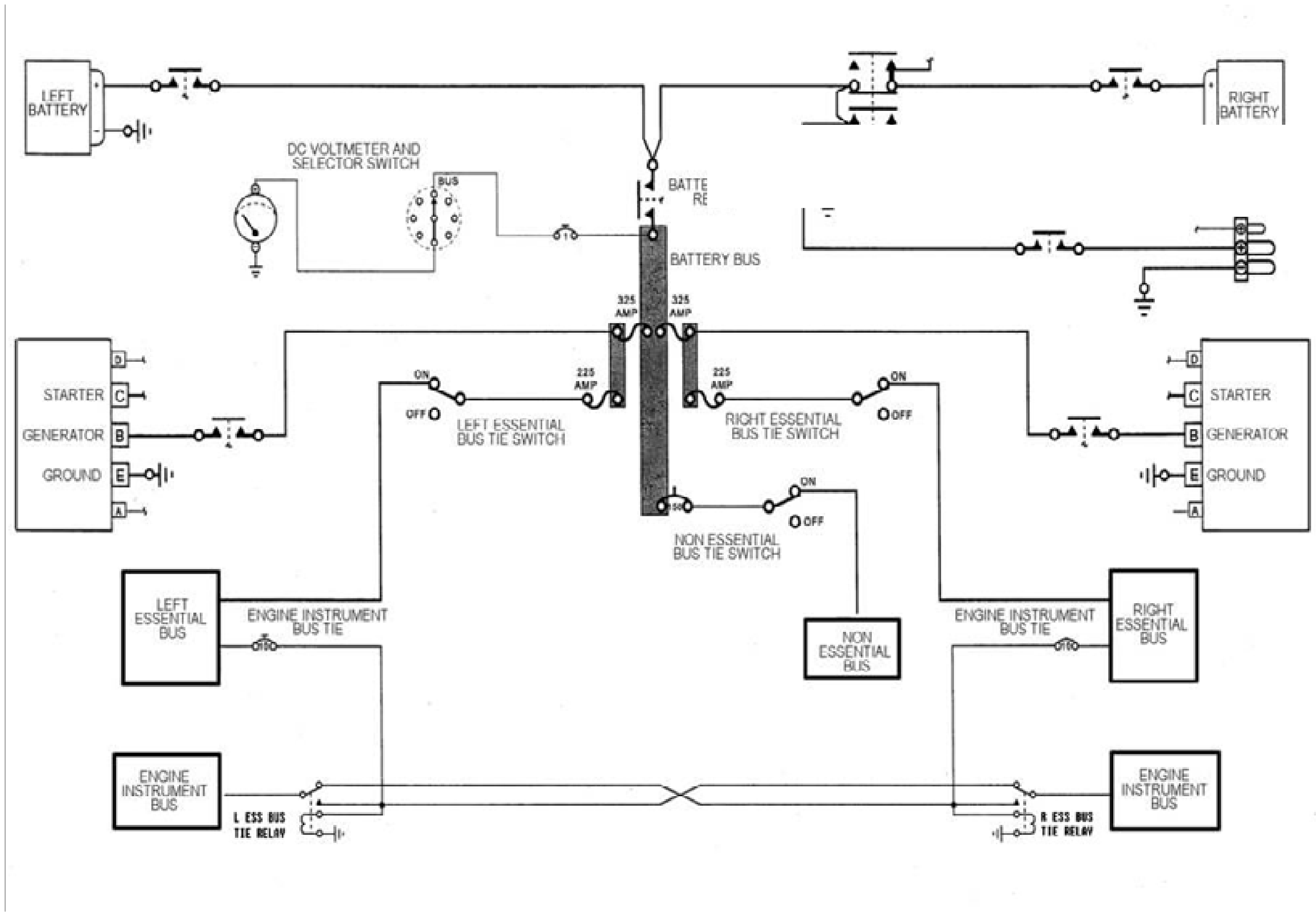
The DC power distribution system was a segmented, three bus system consisting of the left and right essential 28 VDC buses and a non-essential 28 VDC bus. Each bus could be selectively disabled and had overvoltage and overload protection.

When either battery, either generator, or a GPU was operating and the associated battery or generator switch was in the ON position, DC power was available to the battery bus. The battery bus formed the central distribution point for DC power, from where power could be provided to any of the three DC distribution buses.

The batteries were connected to the battery bus through a battery relay and battery bus relay. When connected, power from the GPU was supplied to the battery bus through the battery bus relay. Power was supplied from the battery bus to the left essential bus through a 225 A current limiter and a bus tie switch, which was located in the left console. Power was supplied to the right essential bus through a 225 A current limiter and a bus tie switch, and to the non-essential bus through a 150 A circuit breaker and bus tie switch. These latter bus tie switches were located on the right cockpit console.

Power supplied to each bus was further distributed to the individual load systems through the use of smaller bus bars and circuit breakers (Figure 12).

Figure 12: Simplified diagram of DC bus system



Certain aircraft systems were arranged so that they could use electrical power from more than one DC bus in case of a DC bus failure. In normal operation, the left and right engine instrument bus was supplied with power from the respective essential bus through an engine instrument bus tie circuit breaker and bus tie relay. If a DC bus failed, the bus tie relay relaxed and DC power was automatically restored to the engine instrument bus from the other functioning essential DC bus.

There were also ten circuits that could be manually switched to the left or right essential buses by means of bus transfer switches that were located on the left cockpit console. Normally, all ten circuits were switched to the left essential bus, and provided electrical power to the following systems or functions:

- pilot's DC flight instruments, including the encoding altimeter and radio magnetic indicator
- pilot's turn and bank indicator
- fuel cross-flow valve
- landing gear control
- landing gear position indicator
- cabin pressure dump
- surface de-icer boots
- left engine intake heat
- right engine intake heat
- left windshield heat.

Direct current monitoring and advisories

Battery temperature was monitored by a battery temperature indicator, located on the lower right side instrument panel, which used a meter to display the sensed temperature of each battery. The indicator also contained an amber WARM and a red HOT caution advisory light. Two switches were located adjacent to the indicator. One provided an indicator light test function, and the other a meter range extended function to allow the indication of temperatures from 50 °F (10 °C) to 100 °F (38 °C).

The voltage on each bus could be monitored by the DC voltmeter and selector switch that was located on the left console. The selector switch positions were:

- left battery
- right battery
- left generator
- right generator
- battery bus
- GPU.

To read the output of the selected battery or generator, the corresponding battery or generator switch needed to be placed in the OFF position or the voltmeter would only display the battery bus voltage.

Two DC ammeters, connected as loadmeters, were installed on the left cockpit console to indicate the respective generator's output to the bus system and the batteries. A further two DC ammeters were fitted to an indicator known as the tri-unit meter, which was located on the left cockpit console. One of those ammeters indicated the current flowing to the left or right propeller de-ice boots, as selected by the pilot. The other ammeter monitored the current flowing to the de-ice element in each of the aircraft's pitot probes.[19] Either pitot probe 1 or pitot probe 2 could be monitored by pilot selection.

The central warning system annunciator panel contained advisory lights indicating the status of the DC system. The system included battery over-temperature, battery disconnect, battery fault and generator fail advisories.

Alternating current system

Either of the two 28 VDC-powered 350 volt-amperes static inverters[20] (inverter) was able to power the 115 VAC and 26 VAC electrical buses to provide power for VAC equipment and to supply the avionics systems and flight instruments. Power for the inverters was supplied through a 25 A No 1 INVERTER ESS circuit breaker and relay from the left essential 28 VDC bus for the left side and a No 2 INVERTER ESS circuit breaker and relay from the right essential 28 VDC bus for the right side. The control relay for inverter No 1 was powered from the left essential 28 VDC bus and the control relay for inverter No 2 was powered from the right essential 28 VDC bus.

Additionally, a 2 A 115 VAC BUS TIE circuit breaker connected the two buses and a 2 A 26 VAC BUS TIE circuit breaker connected the left and right 26 VAC buses.

Inverter operation was pilot selectable with a 3-position inverter select switch (No 1, OFF and No 2), with only one inverter able to be used at any time. In the event of an inverter failure, the pilot could manually select the other inverter to power the VAC buses (Figure 13).

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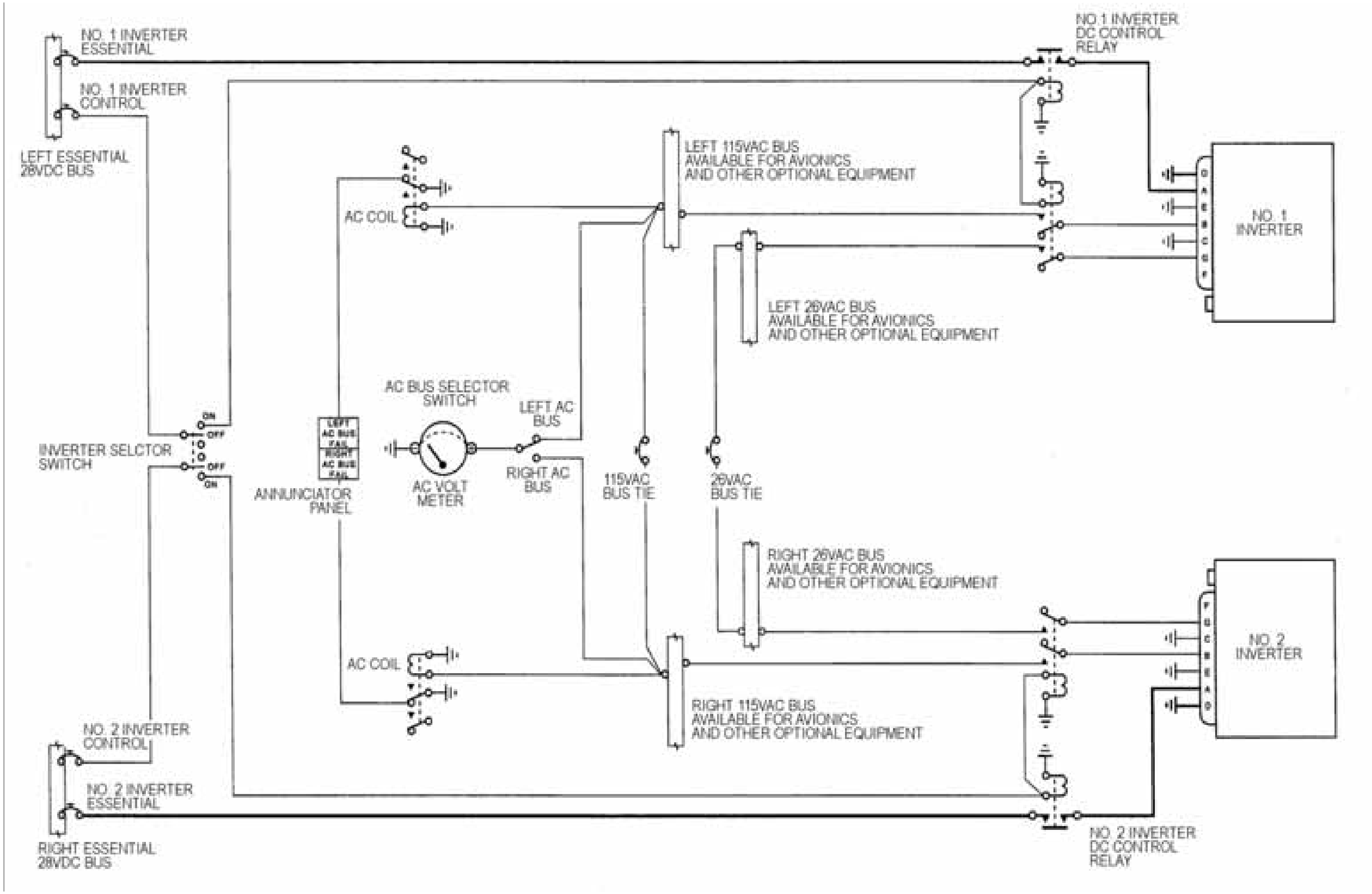
19 Used to measure the airspeed of the aircraft.

20 Unit that converts DC electrical input to an AC output.

Figure 13: Simplified diagram of AC bus system



Alternating current caution advisories and monitoring

The AC caution advisory and monitoring systems comprised a bus-selectable voltmeter that was located on the left console in the tri-unit meter, and two bus failure caution advisory lights that were located in the central warning annunciator panel. The AC monitoring and advisory system only monitored the 115 VAC buses. The AC voltmeter allowed either 115 VAC bus to be monitored by pilot activation of a selector switch.

Figures 14 and 15 show the cockpit layout in Metro III aircraft, registered VH-OZN (OZN). OZN portrays a very similar but not identical configuration to OZA. During single-pilot operations, the pilot was seated in the left seat.

Figure 14: Cockpit layout of OZN

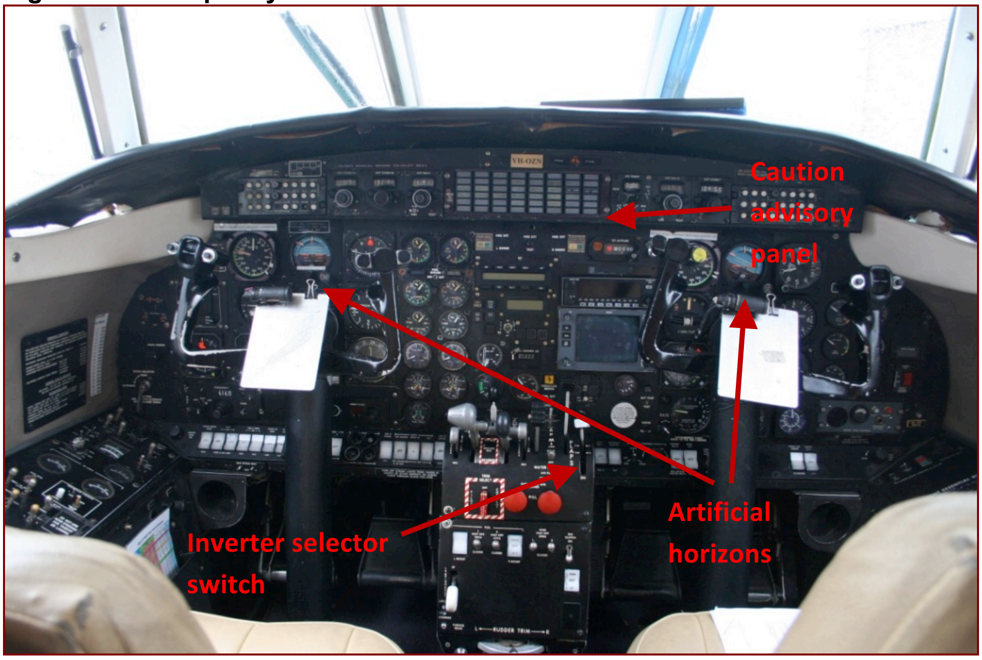
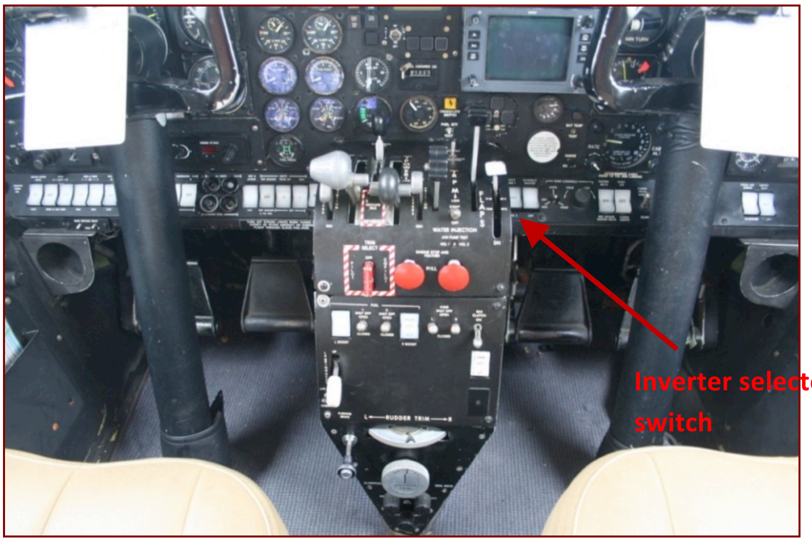


Figure 15: Cockpit layout of OZN, showing the location of the inverter selector switch



Each 115 VAC bus also powered a bus failure relay. If electrical power was lost to the respective bus, the bus failure relay relaxed and the caution advisory light illuminated. Illumination of one AC fail (L or R AC BUS) light was usually an indication of an AC bus tie circuit breaker failure.[21] Illumination of both the L AC BUS and R AC BUS lights was usually an indication of an AC power source failure, typically an inverter failure. The L AC BUS and R AC BUS light capsules each included two light globes for redundancy (Figure 16).

Figure 16: Photo of OZA caution advisory panel

Transponder equipment

The aircraft was fitted with two transponders, which were powered from the left and right 28VDC avionics buses respectively. A transponder is a transmitter/receiver that transmits a response to an interrogation from a ground station secondary surveillance radar (SSR). Two response modes were used as follows:

- a Mode A response that enabled the aircraft's position relative to the interrogating ground station to be determined and also provides aircraft identification information to that station
- a Mode C response that provides the ground station with the aircraft's altitude relative to a standard pressure setting of 1013.2 hPa (see Appendix A).

Examination of the recorded SSR data showed that SSR returns from the aircraft were lost between 2326:20 and 2326:27 and after 2327:09. A loss of secondary radar can be due to:

- a secondary radar sensor failure

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21 In normal operation, both the 115 VAC and 26 VDC bus tie circuit breakers would be in the engaged position.

- range limitations of the secondary radar
- an electrical power loss or unserviceability of the on board aircraft transponder
- the aircraft shielding of the antenna.

The last secondary Mode C return (position and altitude information) was at 2327:00, with the aircraft at an altitude of 3,740 ft above mean sea level (AMSL). The last secondary Mode A return (position only with no altitude information) was at 2327:09.

Checklist items

The aircraft operator's Operations Manual *Flight Deck Preparation Expanded Checklist* Part B10 item 20 noted the following check of the inverter system:

> WITH THE INVERTER SWITCH IN THE OFF POSITION, CHECK THAT THE AMBER L/R AC BUS LIGHTS ON THE ANNUNCIATOR PANEL ARE ILLUMINATED. SELECT INVT No1 AND CHECK THAT BOTH AC BUS LIGHTS GO OUT AND THAT THE AC VOLTMETER SHOWS 110-120 VAC ON THE LEFT AND RIGHT BUSES. SELECT No2 INVT, CHECKING THAT BOTH AC BUS LIGHTS ILLUMINATE AS THE SWITCH PASSES THROUGH THE OFF POSITION. REPEAT THE PROCEDURE FOR No2 INVT.

Item 22 of that checklist noted the following concerning the CVR and FDR:

> CHECK TEST FUNCTIONS AND SET.

Under *Flight Deck Preparation* normal procedures, Part B10 also included a requirement to test the annunciator panel lights.

The aircraft flight manual also included a requirement for flights under the night visual flight rules to ensure adequate electrical energy to operate all electrical and radio equipment. Operations under the instrument flight rules included the requirement for an operational gyroscopic bank and pitch indicator (artificial horizon).

Meteorological information

Meteorological information broadcast on the Sydney Airport computerised automatic terminal information system (CATIS) at the time of the accident indicated that the wind was 230° magnetic (M) at 6 kts, visibility was greater than 10 km and the cloud was few[22] at 2,800 ft AMSL. The pilot of VEU, flying behind OZA, later reported that about 5 NM (8 km) south of Sydney, there were patches of cloud at about 3,000 ft that was about 100 ft thick.

The moon set at 1934 that night, consistent with no illumination by the moon during the flight.

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22 Cloud amounts are reported in oktas. An okta is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon. Few = 1 to 2 oktas, scattered = 3 to 4 oktas, broken = 5 to 7 oktas and overcast = 8 oktas.

Radio communications

Radio communications during the flight were with Sydney air traffic control (ATC) surface movement controller (SMC) for taxiing, ADC for takeoff and the Departure controller following takeoff. Those communications are listed at Table 14.

Table 14: Communications with controllers

Time	From	Broadcast
2316:33	Pilot of OZA	Sydney ground good day oscar zulu alpha an IFR metro one POB [persons on board] for Brisbane in receipt of whiskey domestic five requesting taxi clearance
2316:43	SMC	Oscar zulu alpha taxi via golf hold short of bravo
2316:47	Unknown	Overtransmission
2116:54	SMC	We got umm open mic overtransmission and ahh no readback received
2317:01	SMC	Oscar zulu alpha taxi via golf hold short of bravo
2317:05	Unknown	Interference including tone noises
2317:10	Unknown	Open microphone interference again
2317:12	SMC	Oscar zulu alpha taxi via golf hold short of bravo
2317:16	Pilot of OZA	Taxi via golf hold short bravo oscar zulu alpha
2320:42	SMC	Oscar zulu alpha taxi onto point golf call me ready on one two zero five
2320:48	Pilot of OZA	Golf and one two zero five oscar zulu alpha
2321:37	Pilot of OZA	Sydney tower good day oscar zulu alpha ready one six right ah for Brisbane curfew two departure
2321:43	ADC	Oscar zulu alpha golf intersection runway one six clear for takeoff
2321:48	Pilot of OZA	Golf intersection one six right clear for takeoff oscar zulu alpha
2323:41	ADC	Oscar zulu alpha contact departures one two eight three
2323:45	Pilot of OZA	One two eight three oscar

Time	From	Broadcast
		zulu alpha
2323.56	Pilot of OZA	Sydney departure good day oscar zulu alpha is on climb three thousand passing one thousand three hundred intercepting one six eight
2324.04	Departures controller	Oscar zulu alpha good day Sydney departures identified climb to flight level one seven zero
2324.10	Pilot of OZA	Climb flight level one seven zero oscar zulu alpha
2325.30	Departures controller	Oscar zulu alpha turn left heading zero niner zero
2325.34	Pilot of OZA	Left zero niner zero oscar zulu alpha
2325.55	Departures controller	Oscar zulu alpha just confirm left on heading zero niner zero
2325.59	Pilot of OZA	Left zero niner zero uhh we've got a slight technical uhh fault here oscar zulu alpha **Note**: No further radio transmissions were received from the pilot of OZA
2327.13	Departures controller	Oscar zulu alpha just confirm operations are normal
2327.31	Departures controller	Oscar zulu alpha Sydney approach
2327.39	Departures controller	Oscar zulu alpha Sydney approach
		After no further transmissions were received from the pilot of OZA, ATC initiated a DISTRESS phase and search for the aircraft.

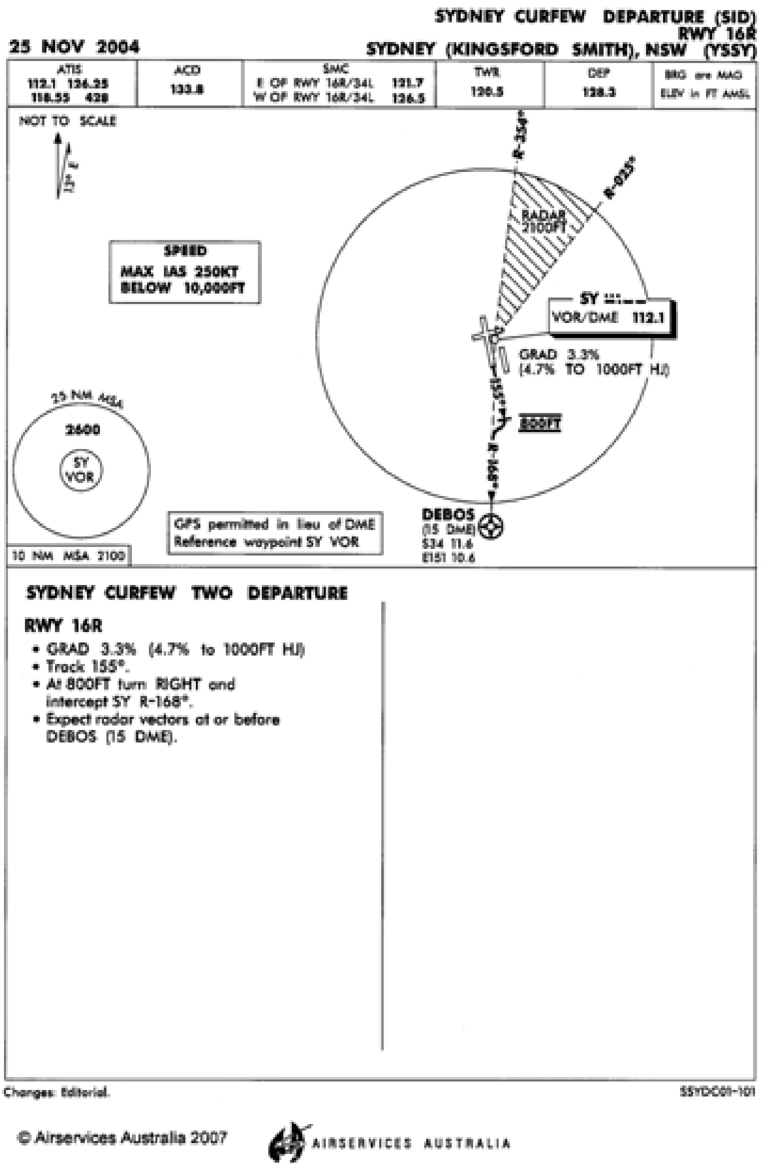
Aerodrome information

On the night, the aircraft was initially parked in the area of 'domestic 5' parking position. That area was normally recorded by video surveillance cameras. An examination of the available recorded video showed that there were no images of the aircraft on the ramp.

Sydney (Kingsford Smith) Airport had three runways, runway 07/25, runway 16L/34R and 16R/34L. Operations were subject to curfew restrictions between 2300 and 0600, when flights were restricted to mainly freight operations. After 2300 aircraft such as OZA were exempt from the curfew restrictions but were limited to landing on runway 34L and taking off on runway 16R, east of intersection Golf. Unrestricted operations resumed at 0600 each morning.

All aircraft operating during the hours of the curfew were issued the 'Sydney Curfew Departure runway 16'. That standard instrument departure (SID) required the aircraft to track 155° M and, on reaching 800 ft, to turn right and intercept the 168° radial from the Sydney very high frequency (VHF) omni-directional radio range (VOR) navigation aid. Once established on that radial, the pilot could expect a radar vector (a heading instruction from ATC) at or before the DEBOS waypoint. In nil wind, the heading change required to intercept the 168° radial from the 155° heading was less than 30° (Figure 17). Also refer to Appendix A.

Figure 17: Sydney Airport curfew departure



Fire

An examination of the recovered and photographed aircraft wreckage indicated that there was no in-flight fire. However, there was evidence of fire or heat affecting the outer casings of the CVR and FDR (Appendix C).

Tests and research

Aircraft electrical power testing

In an attempt to further understand the relationship between the possible simultaneous electrical power supply failure modes of both the CVR and FDR, and any technical issues apparent to the pilot during the flight, a number of electrical power tests were carried out on a similar aircraft to OZA. That SA227-AC aircraft, registered VH-OZN (OZN) and serial number AC665, was owned and operated by the same operator, and was reported as being wired identically to OZA. OZN was tested with the assistance of the operator's technical personnel under ATSB supervision.

Testing of the system with the 28 VDC right essential bus tie switch in the OFF position[23] and the inverter selector switch in the No 2 position, determined that the:

- CVR would not test normal (no power)
- pilot's and copilot's AHs were off-line, but indicated wings level and displayed a striped 'inoperative' flag (indicating no power supply)
- pilot's and copilot's radio magnetic indicators were off-line, with inoperative flags displayed on each indicator
- horizontal situation display indicator displayed an inoperative flag (indicating no power supply)
- autopilot was inoperative
- Nav 2 (navigation 2) was inoperative
- VHF radio Comm 2 (VHF communications 2)[24] was inoperative
- transponder 2 was inoperative
- weather radar was inoperative
- L AC BUS advisory light was illuminated
- R AC BUS advisory light was illuminated.

The operation of an aircraft without key flight instruments, such as seen in the testing, was often referred to as limited or partial panel. During limited panel operations, a pilot operates an aircraft in the absence of external cues and without key flight instruments, including gyroscope-based attitude reference instruments such as an AH or attitude indicator.

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23 The switch was located in the right rear of the cockpit, behind and slightly to the right of the copilot's seat.

24 OZA had multiple VHF radios installed to permit pilots to broadcast and monitor several frequencies.

The following items operated normally in that configuration:

- the pilot's and copilot's turn and bank indicators
- VHF radio Comm 1A (VHF communications 1A)
- VHF radio Comm 1B (VHF communications 1B)
- transponder 1
- the aircraft's Global Positioning System.

Subsequent advice from maintenance personnel was that selection of the right essential 28 VDC bus tie switch to the OFF position precluded the start of the right engine, as there was no power available to the start control circuit.

Examination of the recovered artificial horizon

The aircraft was equipped with two 115 VAC electrically–driven AHs. Typically, a 115 VAC electrically-driven AH gyroscope rotor spins at between 20,000 and 23,000 rpm. Once energised, the AH gyroscope rotor takes several minutes to 'wind down' and cease rotating.[25]

One of the aircraft's two AHs was recovered from the wreckage and showed substantial impact damage. Technical examination was unable to determine if the recovered instrument was from the pilot's or copilot's position, as both instruments were identical except for serial numbers that were not recorded in the aircraft's documentation.

The gyroscope rotor was removed from the AH and examined for indications of rotation at the time of the impact with the water (Figure 18).

Figure 18: Recovered artificial horizon

Examination of the inside of the gyroscope casing end cap found rotor fan blade impact marks. Those impact marks displayed no evidence of rotational scoring from

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[25] According to CASA Airworthiness Article AAC 1-87 regarding gyro failures, 'Approximately 20 minutes is usually enough to ensure all gyroscopic instruments have stopped.'

the gyroscope rotor fan blades, consistent with the gyroscope rotor not rotating (the instrument was not electrically powered or there had been some other failure of the gyroscope motor) at the time of impact (Figures 19 and 20).

Figure 19: Gyroscope rotor casing fan blade impact marks

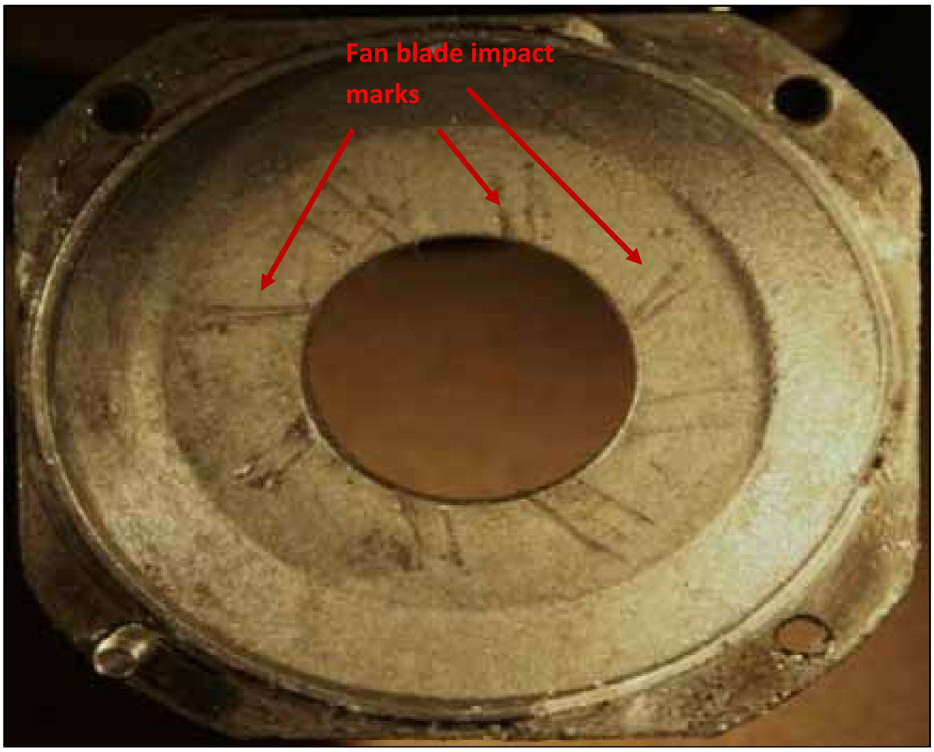
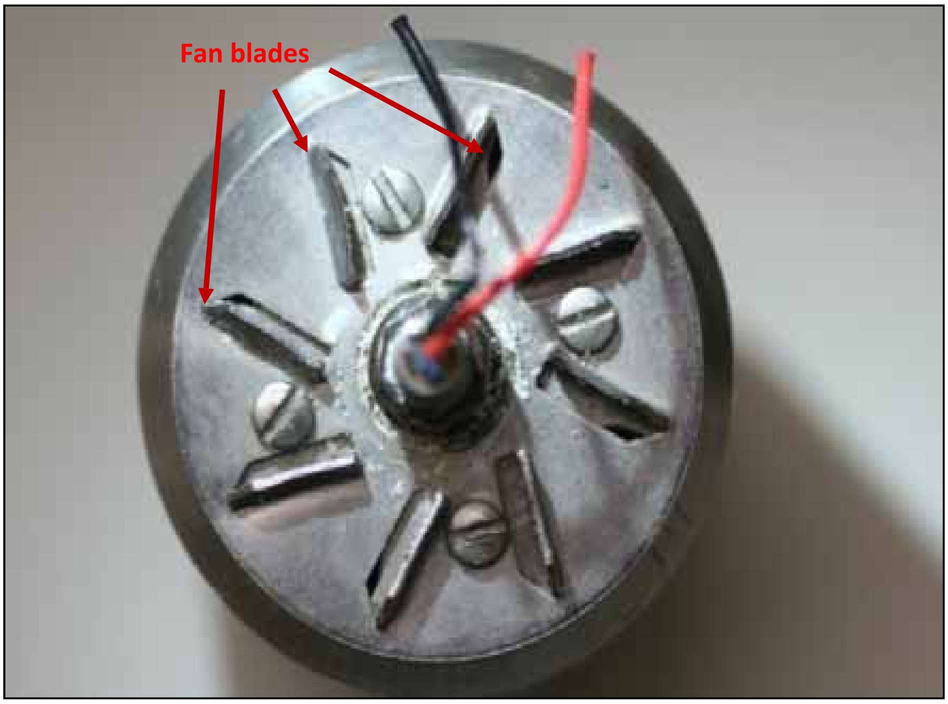


Figure 20: Gyroscope rotor fan blades



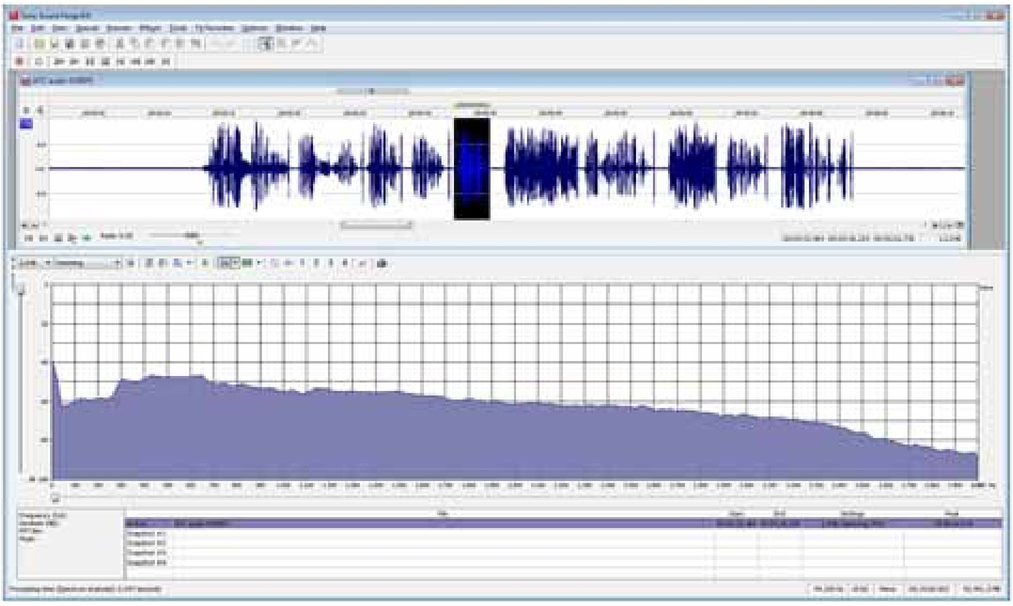
Air/ground communications

An examination was carried out on the recorded air/ground communications between air traffic control and the pilots of OZA, VEU and another Metro aircraft, registered VH-EEO (EEO) that were operating at Sydney on the night of the accident. Those VHF radio transmissions were examined using spectrographic analysis software to depict the frequency spectrum of each transmission.

The results of the analysis showed a number of interferences in the transmissions from VEU and EEO at frequencies 397, 1,193, 1,992 and 2,782 Hz. The radio transmissions from VEU also included an interference line at frequency 3,573 Hz. Those interference frequency spikes were consistent with being harmonics of the AC electrical system frequency of 400 Hz.

There were no corresponding interference frequencies in any of the recorded transmissions from the pilot of OZA (Figure 21).

Figure 21: VHF radio transmissions - OZA

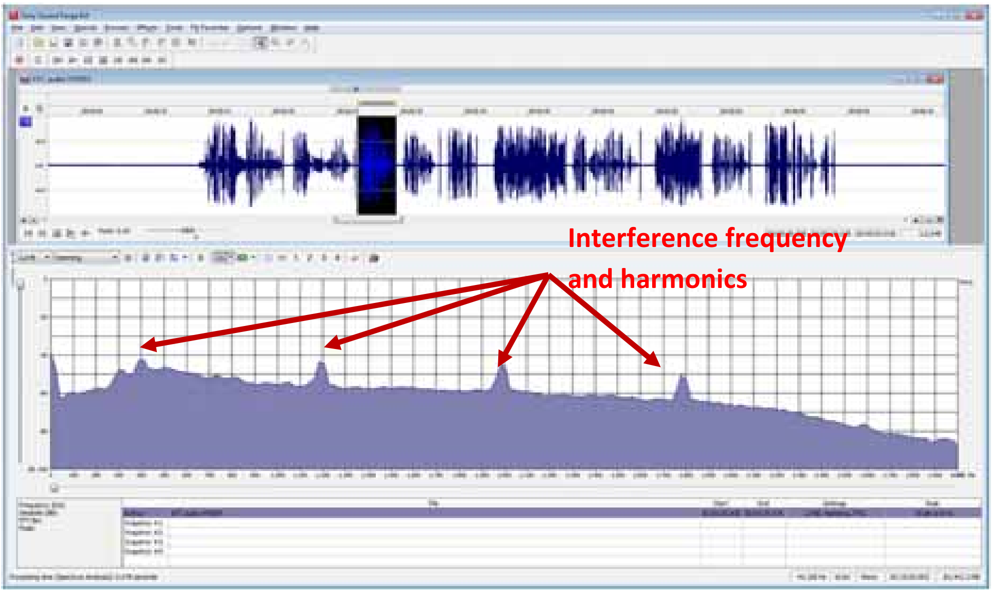


A test recording was made of a number of VHF radio transmissions from VEU at Canberra Airport, Australian Capital Territory. Eight radio transmissions were made using both of the aircraft's VHF radios (four transmissions on VHF 1 and four transmissions on VHF 2) with the following electrical system configurations:

- battery power only
- engines started, DC power only
- engines running, inverter 1 ON (AC power)
- engines running, inverter 2 ON (AC power).

An examination of the radio transmissions from VEU at Canberra showed that the interference at frequencies 397, 1,193, 1,992 and 2,788 Hz was only present when the aircraft's AC power supply was selected ON (Figure 22).

Figure 22: VHF radio transmissions - VEU



Organisation and management information

Details of organisation and management information related to this investigation are set out in Appendix D to this report. The following is a summary of that information.

Permission to operate

The operator had held an Air Operator's Certificate (AOC) under the provisions of Section 27 of the *Civil Aviation Act 1988* (the CA Act) since the mid-1980s. The most recent AOC was issued on 31 October 2006. That AOC authorised charter and aerial work operations in aircraft above and below a maximum take-off weight of 5,700 kg.

The CA Act places a number of responsibilities on an AOC holder, including compliance with the CA Act, taking reasonable care and diligence with regard to AOC-related activity and maintaining an appropriate organisation, personnel and management structure.

Operations manual requirements

Under Civil Aviation Regulation (CAR) 215 *Operations manual*, the operator was required to provide an operations manual containing information, procedures and instructions in relation to the flight operations of all the types of aircraft operated by the operator. This included information pertaining to the training and checking of the operator's personnel.

Normal aircraft take-off operations

The operator's pilots and the chief pilot reported that it was normal practice for pilots to engage the autopilot in the climb by 1,000 ft above ground level. That procedure was not specified in the operations manual but was preferred by the chief pilot. In addition, those pilots noted that the takeoff was normally completed with ¼ flap and that the landing gear was retracted after achieving a positive rate of climb.

Training and checking organisation

The operator was required under CAR 217 to establish a Training and Checking organisation so as to ensure that members of the operator's operating crews maintained their competency.

On 13 May 2004, CASA approved the operator's training and checking organisation under CAR 217. That included approval of the contents of the operator's Training and Checking Manual.

Guidance from CASA indicated that a typical training and checking organisation could be expected to include the positions of:

- chief pilot or head of training and checking
- senior check pilot
- training pilot
- supervisory pilot.

The operator also established the position of deputy chief pilot. The operator chose to not identify a senior check pilot; a head of check and training was established in addition to the position of chief pilot.

Chief pilot

The chief pilot is one of the key personnel positions for holding an AOC. To become a chief pilot required CASA approval. Without an approved chief pilot, an organisation cannot exercise the privileges of an AOC.

The operator's chief pilot nominee, who also held a Grade 3 (Aeroplane) Flight Instructor Rating, was originally nominated for the position on 29 June 2004. However, on 9 September 2004, CASA informed the operator that the nominee did not to meet the required minimum standards. CASA subsequently approved the appointment of the operator's chief pilot, on 21 November 2005.

The duties of the chief pilot were set in the operator's operations manual Part C *Duties and Responsibilities*. These included:

- Scheduling all training and checking requirements for Company flight crew
- Managing the effective and efficient utilisation of all check and training pilots under the training and checking organisation
- Monitoring the individual progress and performance of flight crew undergoing air and ground training
- Taking timely remedial action in cases of unsatisfactory progress by flight crew during air and ground training
- The safety standards of all flight crew
- Arranging the initial, upgrade, and recurrent training and checking requirements for all flight crew

- Ensuring the security of all examination material

On 27 July 2007, the chief pilot was approved by CASA, subject to conditions, to give conversion training on the Metro III aircraft.

Deputy chief pilot

The operator advised that at the time of the accident, a deputy chief pilot position existed, whose duties included assisting the chief pilot with the administration of the training and checking organisation. An examination of the operations manual distribution index did not include a deputy chief pilot, and there was no evidence to indicate that a staff member was approved in that position by CASA.

Head of training and checking

On 13 May 2004, the operator’s nominated head of training and checking was approved by CASA. That person was not employed full-time by the operator, and was located in another state of Australia.

Part C *Duties and Responsibilities* of the operations manual listed the duties of the head of training and checking as:

> The Head of Training and Checking is responsible to the Chief Pilot.
>
> He/She is responsible for the effective management of the Training and Checking Organisation.

Additional positions within the operator’s training and checking organisation were responsible for the operating standards and competency assessment of flight crew. Those included check, training and supervisory captains.

Check captains

A check captain was a person approved by CASA under CAO 82.1 to conduct crew proficiency checks.

The operations manual listed two pilots as holding check pilot approval (check captains). That included the head of training and checking and a second pilot who was also based interstate and was the chief pilot of another organisation. Both of those pilots were approved by CASA on 13 May 2004.

Although the operator’s chief pilot held a check pilot approval from CASA, he was not listed in the operations manual as an approved check pilot.

Training captains

A training captain was a person who was approved by CASA to conduct endorsement and other flight training. The operator’s training and checking manual defined the responsibilities of a training captain as being limited to line training.

According to the training and checking manual, training captains were required to have 2,000 hours total flying experience, 1,500 hours command flying experience, 1,000 hours multi-engine flying experience, a commercial pilot license, a command instrument rating, and 100 hours in command on type (which could be waived by the chief pilot).

On 4 January 2005, the operator notified CASA that the chief pilot was a nominated training captain. The chief pilot's name was not listed in the operations manual as an approved check pilot.

Supervisory captains

A supervisory pilot's role was to conduct the line training required for pilots (captains, first officers or second officers) to achieve "checked to line" status.

Pilots that were nominated to supervisory positions within the training and checking organisation had to be approved by CASA.

Endorsement training

The training and checking manual noted that the operator's endorsement training on the Metro III was divided into two components: a ground theory course and airborne conversion training. The ground theory course culminated in a ground theory examination.

An initial examination of the operator's pilot file did not reveal any documentary evidence of a completed ground theory course or written examination by the pilot on the Metro III aircraft. However, operator personnel later provided a copy of a ground theory course examination dated 17 December 2007, which was reported to have been discovered at the pilot's home. There was no indication that the examination had been presented to the operator for assessment, and it was evident that the version of the examination provided was different to that in the operator's training and checking manual.

Several of the operator's pilots who underwent Metro III endorsement training with the operator's chief pilot reported that they were not given a formal ground theory course as part of that training.

The flying component of the pilot's endorsement training was carried out by the chief pilot and the appropriate forms from the training and checking manual were included in the pilot's file. Training and checking manual Part C6 *Endorsement syllabus* indicated that the only persons authorised to carry out the endorsement training were approved check captains.

Check to line

Following endorsement on the Metro III, the pilot was required to undergo a period of line training, with either an approved training captain or a check captain. That training was to consist of a period of at least 50 hours in command under supervision (ICUS).

Following line training, the pilot was to undergo a 'check to line' in accordance with the applicable section of the operator's training and checking manual. The persons that were authorised by the operator to conduct the check were listed as 'check captains listed in the Approved Persons List', which was contained in the training and checking manual.

The head of training and checking reported that he was not contacted regarding on-going endorsement or check to line training for the pilot or of the role of supervisory pilots. However, the operator later reported that the head of training and checking was aware of the pilot 'flying the aircraft'.

According to the pilot's logbook and file, he completed a base check with the chief pilot on 11 February 2008. The operations manual required that a 'check to line form' be completed following the check to line. There was no documentary evidence in the operator's pilot file of a completed check to line form in the Metro III aircraft.

CASA surveillance activity

General

CASA undertook a number of different audits and reviews of the operator in the period before the accident. Some did not detect any significant issues; others noted requests for corrective action and observations.

OZA ramp inspections

The last recorded ramp inspection of the aircraft took place on 10 January 2005. A number of aircraft discrepancies were noted, including that:

- the left main landing gear tyre was worn
- there was erosion damage to the upper surface of the aircraft's radome[26]
- the left engine compressor blades exhibited impact damage
- there was excessive aileron free play
- there was a fuel leak from the right wing tank.

The previous ramp inspection was on 17 September 2003.

Surveillance and regulatory actions following the accident

Following the accident involving OZA, from 11 to 28 June 2008 CASA undertook a risk-based audit of the operator and, as part of that audit, issued a number of requests for corrective action to address a number of deficiencies discovered during the audit.

One deficiency related to the use of pilots in training or supervisory roles on ICUS flights, without a number of the supervising pilots having been trained and approved for that role in accordance with the operator's training and checking manual. The CASA audit report also noted that the three 'training captains' who carried out the ICUS flights with the pilot of OZA had not been approved as training captains and had no formal supervisory training.

In respect of the training provided to the pilot of OZA, the report noted that the pilot's 'check to line' was not completed in accordance with the operator's training and checking manual Part C, which required a base check followed by a line check of at least two sectors.

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[26] The operator advised that the return flight had no passengers on board.

In addition, the report commented on a number of discrepancies in the chief pilot's logbook. Notably, a period of 39 days was identified where flights were not logged in the logbook, or where there were fewer hours noted than annotated in the operator's duty time records. The base check that was noted in the training documentation for the pilot of OZA as being completed on 11 February 2008 was not recorded in the chief pilot's logbook.

Operator's response to the CASA audit

In respect of the approval by the operator of training captains, on 30 July 2008 the chief pilot commented that:

> Pilots were appointed in accordance with company operations manual Part C Section 1.5.5 – "Supervisory Captains shall be appointed by the chief pilot". Company documentation failed to reflect correct procedure in particular relevance to CAO 82.1.3. However, company operations manual was inherited unchanged in this section since 2005. Inadequate referencing led to the breakdown of this section of pilot administration.

Administrative action by CASA after the audit

As a result of the audit, CASA determined that the operator posed a 'Serious and Imminent Risk' to safety in its present form. One of the options to address that risk was to vary the operator's AOC. Following discussions with CASA, the operator agreed to have a number of conditions applied to its AOC. CASA administrative action was also taken in relation to the then chief pilot's approvals

The chief pilot resigned from his position shortly after the CASA audit.[27]

As part of the CASA audit, the audit team contacted the operator's head of training and checking to discuss the identified training issues. The head of training and checking advised CASA that, although he still officially held that position, his assumption was that the then chief pilot had assumed responsibility for that role, even though it had not been formalised.

On 20 June 2008, the head of training and checking notified CASA that his role after the CASA appointment of the chief pilot on 26 July 2007 had been to supplement the chief pilot, and that his understanding was that the chief pilot was the new head of training and checking.[28] He reported that he was unaware of any of the endorsements that had been issued, or of the pilots that had been made supervisory/training captains in the intervening period. The CASA audit concluded that 'the standards, particularly in training and checking are far below what is an acceptable standard for any operator'.

On 1 July 2008, CASA issued two Safety Alerts to the operator as a result of the findings of the audit. One addressed the endorsement of the operator's pilots by the

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[27] The chief pilot at the time of the accident resigned on 9 September 2008 and a replacement chief pilot was approved that day.

[28] Following the accident and subsequent audit by CASA, the head of training and checking resigned and a replacement head of training and checking was approved by CASA on 29 August 2008.

then chief pilot and the other addressed the need for the provision of additional ICUS flying to another pilot as required by CAO 40.1.0 8A.[29]

Additional information

Competency-based training and assessment

The intent of CAR 217 was to ensure that the operator's personnel were competent after undergoing ground and flight training and that, once they were certified as being competent, they maintained it by being checked at regular intervals. Assessing a person's competency requires a robust system in place that allows the collection and recording of evidence that can be gathered under a number of varying conditions. To be valid, that evidence needs to be objective and measured against agreed standards. A cornerstone of a competency-based assessment system is the: [30]

> ...rigorous and objective assessment of the trainee against valid standards.

The need for the objective assessment of competency holds true for both ground and flight training or for the combination of both. Errors in, or circumventing the competency assessment process, or the incorrect attribution of competency can lead to persons who lack the required competency, or have not yet displayed competence in all expected conditions, taking part in the aviation environment. In consequence, those persons can pose a safety risk to other members of the industry, as well as to themselves.

When assessing a person's competency, the assessment needs to ensure that the person is not only competent during the assessment, but is likely to retain that competence into the future. In guidance material provided to the vocational education industry, Foyster (1990) commented:[31]

> When we certify we are in fact predicting the future – at least to the extent that we invite anyone looking at a certificate to infer something about the future performance of the person to whom the certificate applies. The prediction can only be valid if the assessment is, in the technical sense, valid.

While Foyster may have been addressing the assessment of competence at the completion of a certificated training course, the assessment of knowledge obtained during a ground theory course forms the foundation on which future flight operations are based.

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[29] Reportedly, the minimum command under supervision requirements had not been met. This was later resolved by contacting the pilot's previous employer.

[30] Civil Aviation Safety Authority, (2009). *Civil Aviation Advisory Publication 5.59A-1(0): Competency Based Training and Assessment in the Aviation Environment*, CASA: Canberra, ACT Australia.

[31] Foyster, J., (1990). *Getting to grips with competency-based training and assessment*. Commonwealth Department of Employment, Education and Training: Canberra, ACT Australia.

Limited (or partial) panel flying

Limited or partial panel flying is known to increase the risk of spatial disorientation. The CASA day VFR syllabus defined limited panel as the availability to the pilot of a:

> Flight instrument array of at least a magnetic compass, air speed indicator (ASI), vertical speed indicator (VSI), altimeter, turn and balance indicator/turn coordinator and an engine power indicator.

In the case of an aircraft such as OZA losing both of its electrically-operated artificial horizons during over water operations under the night VFR, or while transiting through cloud, the pilot(s) would have to revert to flying the aircraft via limited panel. Limited panel flying is very demanding, and previous accident investigations have found that even highly experienced IFR-rated pilots are challenged to fly safely in such a configuration.

Spatial disorientation

Spatial disorientation can be defined as '...the inability of a pilot to correctly interpret aircraft attitude, position or motion in relation to the earth or other points of reference'.[32] More simply, it is '...the inability to tell which way is up'.[33]

There is a high risk of spatial disorientation occurring when a VFR pilot encounters cloud or an area of reduced visibility and no visible horizon. Although trained in limited (or partial) panel instrument flight, an IFR-rated pilot can still experience disorientation, especially in circumstances where the actual aircraft attitude is different to that portrayed by the flight instruments, such as a 'frozen' gyroscopic horizon. The resulting state of confusion is dangerous for the pilot, as it can lead to incorrect control inputs and a resultant loss of aircraft control.

More information about spatial disorientation can be found in the ATSB aviation research and analysis report B2007/0063, *An Overview of Spatial Disorientation as a Factor in Aviation Accidents and Incidents*. That report noted:

> There are several aircraft factors that can contribute to SD [spatial disorientation]. Single pilot operations face a more serious challenge identifying and handling disorientation, as the single pilot has no other person to check information with, or to hand over control to if disorientation occurs. It should be remembered, however, that it is possible for all crew members to experience disorientation, but in multi-crew operations there is the possibility of the non-handling pilot taking over from the disorientated handling pilot.
>
> An aircraft equipped with an autopilot system will allow a disoriented pilot to maintain safe flight even while disoriented if the autopilot is engaged appropriately. This may allow a disoriented pilot to overcome their erroneous sensations while the aircraft's fate is not threatened by inappropriate control inputs from the disoriented pilot. The lack of an autopilot system, or the presence of an autopilot that subsequently fails, can help contribute to a SD problem in the operating pilot.

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32 Previc FH & Ercoline WR (2004). *Spatial disorientation in aviation*. American Institute of Aeronautics and Astronautics: Reston, VA.

33 FAA (1983). *Pilot's spatial disorientation*. FAA Advisory Circular AC 60-4A, 1983. FAA: Washington, DC.

Somatogravic illusions

The somatogravic illusion is a subtle form of disorientation where a pilot has a strong sensation of the aircraft pitching up during aircraft acceleration, such as during takeoff. The illusion generally occurs at night and in conditions where visual cues are lacking, such as taking off over dark terrain or water. The illusion is the result of acceleration forces acting on the body's vestibular system, which translates acceleration as a pitch-up effect, generally resulting in the pilot inputting a pitch-down force on the control column to counter the perceived excessive nose-up attitude. If this illusion happens shortly after takeoff, the affected pilot may pitch down sufficiently that the aircraft is flown into the ground or water.

Single-pilot turboprop operations

The United Kingdom (UK) Civil Aviation Authority type certificate data sheet for the Metro III aircraft included a requirement for two pilots as minimum crew. The FAA type certificate data sheet for the aircraft noted the minimum required crew as:

> One Pilot except as otherwise required by the Airplane Flight Manual[34]

A report by the US National Aeronautics and Space Administration (NASA) Ames Research Center on single-pilot commercial aircraft operations noted: [35]

> In single pilot operations, there will be one fewer crewmember for the difficult task of catching errors of omission, compounded by the fact that it is one's own errors that must be caught.

The report also suggested that several technology-based improvements to an aircraft's cockpit that could relieve pilot workload and improve efficiency in a single- pilot environment. OZA had not been modified in any way to reduce pilot workload or to improve efficiency for single-pilot operations.

Previous similar accidents

Appendix E sets out the details of two previous accidents that share features with the accident involving OZA.

The first occurred in 1985 when an Israel Aircraft Industries 1124 Westwind aircraft, registered VH-IWJ, crashed into the sea off the South Head of Botany Bay, NSW. The aircraft was being operated as a cargo flight with a crew of two pilots. Both pilots received fatal injuries and the aircraft was destroyed.

The investigation report concluded that it was likely that the flight crew lost awareness of the attitude of the aircraft following a simulated instrument emergency.[36]

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34 The airplane flight manual authorised single-pilot operations in June 1992. Two pilots were required as minimum crew should the temperature limiter or single red line computer be inoperative, and for reduced power take-off operations.

35 Prepared for the NASA Ames Research Center by BBN Technologies BBN Report No. 8436, *Single Pilot Commercial Aircraft Operation,* November 2005, Moffett Field, CA, USA.

36 See Bureau of Air Safety Investigation Aircraft Accident Investigation Report at hyperlink http://www.atsb.gov.au/publications/investigation_reports/1985/aair/aair198502557.aspx.

In the second, which occurred in 2001, a Raytheon (Beechcraft) Super King Air 200, registered N81PF, sustained an in-flight electrical systems failure and loss of control near Strasburg, Colorado. The aircraft departed controlled flight and impacted the ground resulting in fatal injuries to all 10 occupants.

The subsequent investigation by the US National Transportation Safety Board (NTSB) determined that the probable cause of the accident was the pilot's spatial disorientation resulting in his failure to maintain positive control of the aircraft with the available flight instruments. Contributing to the accident was the loss of AC electrical power during flight in instrument meteorological conditions.[37]

[37] See NTSB Air Accident Report at hyperlink http://www.ntsb.gov/publictn/2003/AAR0301.pdf.

ANALYSIS

Introduction

The occurrence was consistent with the loss of control of the aircraft soon after takeoff. The condition of the available wreckage indicated a high-velocity, near vertical descent and impact with the water that was considered not survivable. The proximity of the heavier items of wreckage to each other on the seabed indicated that an in-flight breakup of the aircraft was highly unlikely. Primary radar information supported this conclusion, as no separated major sections of the aircraft, such as wing sections were observed prior to the impact with the water. Notwithstanding, the investigation could not entirely discount the possibility that part(s) of the aircraft may have separated prior to the fuselage impacting the surface of the ocean.

Due to the limited information available in the form of direct access to the aircraft wreckage, and the lack of flight information recorded on the aircraft's cockpit voice recorder (CVR) and flight data recorder (FDR), this analysis will consider the implications of the following issues on the development of the occurrence:

- the reported delays on the ground at Sydney Airport
- radio communications between the pilot and air traffic services
- air traffic control radar operation
- aircraft loss of control
- the operator's pilot endorsement and training procedures
- regulatory oversight.

Reported delays on the ground at Sydney

The investigation was unable to determine the nature of the delay of about 5 minutes from when the aircraft was loaded and the engines were started. Similarly, the reason for the pilot not taxiing immediately on being cleared to do so by air traffic control could not be established.

The pilot was able to establish and maintain what appeared on radar to be a normal initial rate of climb for the aircraft's estimated take-off weight. That would suggest that either the delay on the ground was not a result of a problem in an engine or related system or, if that had been the case, the pilot was able to resolve the problem before or during the taxi.

Radio communications between the pilot and air traffic services

The overtransmissions on the ADC's frequency, although possibly distracting for the affected pilots, were not considered to be a factor in the development of the accident.

The interference lines in the recorded transmissions from two other Metro aircraft on the night, and interference frequency spikes in the recorded transmissions from VEU and EEO at the frequencies of 397, 1,193, 1,992, 2,788 and 3,573 Hz represent harmonics of the Metro aircraft's alternating current (AC) electrical system frequency of 400 Hz. The absence of similar interference in the recorded transmissions from OZA could suggest that the aircraft's AC electrical system was inoperative at the time of those transmissions.

Air traffic control radar operation

The last four recorded primary radar returns before the pilot's report of technical difficulty corresponded with a single primary return from the aircraft each radar scan period of 3.7 seconds. If there was an in-flight breakup of the aircraft, multiple primary radar returns would have been recorded each scan period, subject to any detached components being of sufficient size to be detected by radar. The lack of such multiple returns, the recorded last primary return 1 minute 20 seconds after the pilot's indication of a technical problem, and the location of the wreckage field in the vicinity of the last primary radar return indicated that an in-flight breakup was highly unlikely.

During the final descent, the loss of secondary radar returns was probably due to aircraft manoeuvring shielding the aircraft's transponder aerial from the radar, or to a reduction in the received signal strength. An analysis of the likelihood of the loss of those returns is tabulated in Appendix A.

Aircraft loss of control

The inability to recover and examine the majority of the wreckage limited the technical investigation. However, analysis of the radar information indicated a normal rate of climb after takeoff, suggesting no anomalies of either engine, either propeller or any flight controls at that time. Additionally, radar data indicated that the pilot regained control on several occasions following the initial descent, indicating that the pilot was in control of the aircraft until immediately prior to the rapid descent.

The investigation was unable to conclusively determine the factors related to the loss of control of the aircraft that led to the collision with the water. Turbulence or wind shear was discounted as data recovered from the following aircraft showed no evidence of either. The investigation considered the following possible factors that might have resulted in the loss of control as observed from the radar information:

- a shift in the aircraft's centre of gravity (c.g), such as from the load shifting
- an in-flight emergency
- pilot incapacitation and/or fatigue
- pilot distraction
- a technical problem leading to the loss of electrical power
- spatial disorientation.

Centre of gravity shift, such as from the load shifting

The aircraft's weight and balance was considered to have been within the aircraft manufacturer's allowable limits and therefore would not have affected performance and handling unless the load shifted. A load shift, if it were to occur, would most likely be a result of acceleration forces during the takeoff, or at rotation.

A review of the radar data did not indicate any unusual aircraft motion immediately after takeoff, such as pitch oscillations, that are characteristic of a rear c.g resulting from a rearward load shift. In addition, the retrieved cargo securing straps indicated gross overstress from exposure to impact loads, indicating that they were still attached to their securing points at the time of impact. Therefore, the investigation discounted load shifting or improper loading as a possible factor.

In-flight emergency

An examination of the recovered wreckage items found no evidence of in-flight fire or dangerous goods release prior to the loss of control. However heat and/or fire damage was noted on the outer casings of both flight recorders (Appendix C).

On the basis of the investigation's understanding of the accident scenario, it was considered most likely that the discolouration of the FDR and CVR cases resulted from their short-term exposure to the effects of a flash-fire or explosion that ignited upon the impact of the aircraft with the water. If a flash-fire had occurred, this would support the conclusion that the aircraft was intact when impacting the ocean, as the fuel required for such an explosion was contained in the wings, but would have been liberated at impact.

The cargo of dry ice and acrylamide solution was reported to be correctly packaged and protected, lessening the likelihood for it to have contributed to the occurrence. Additionally, if the pilot had noted fire, smoke or irritation, he would have likely notified air traffic control of the situation and requested an immediate return to the airport. On that basis, the investigation discounted that the carriage of the dry ice and acrylamide was a factor.

Pilot incapacitation and/or fatigue

As a post-mortem examination and toxicology testing could not be completed, pilot incapacitation could not be discounted. Because of the nature of the single-pilot operation, pilot incapacitation may have led to the loss of control. However, analysis of the recorded radar information indicated that the pilot arrested the initial rate of descent during the flight, possibly in an attempt to control the trajectory of the aircraft. In that case, it is unlikely that pilot incapacitation was a factor in the loss of control.

A review of the pilot's previous work history in the days prior to the accident, the aircraft loader's report of the pilot's demeanour, and the tone of the pilot's voice during the flight did not reveal any indications that the pilot may have been experiencing fatigue.

Pilot distraction

As a result of the elevated workload during single-pilot operations, most pilots would activate their aircraft's autopilot if available. A failure in the supply of AC to the aircraft's autopilot would have rendered it unavailable to the pilot.

Analysis of the aircraft's radar track following takeoff indicated that the aircraft was drifting off track. Although several other scenarios could have explained that drift from track, it could equally have been indicative of the pilot hand-flying the aircraft, such as if the autopilot was unavailable due to a power interruption or other anomaly, or through choice.

During single-pilot operations requiring hand flying, any troubleshooting of a technical problem, such as a power failure and loss of the aircraft's autopilot, would increase the risk of pilot distraction and a consequent loss of control.

Technical problem resulting from the loss of electrical power

As the pilot communicated with air traffic control using the VHF radio, and the secondary surveillance radar transponder was operating, the investigation concluded that 28 volts direct current (VDC) power was available at that time.

The recent installation and test of the flight recorders, and availability of continuous recorded data from the previous flights, including the most recent flight up to the landing and shutdown at Sydney, would suggest that the coincident failure of both recorders on the accident flight was highly unlikely. However, both recorders were powered from a common 115 VAC power supply, and it was more likely that the lack of data was a consequence of the lack of 115 VAC power for the duration of the flight. That could explain the lack of frequency spikes in the recorded radio calls made by the pilot of OZA, as compared with those in a number of other similarly-configured Metro III aircraft.

The absence of 115 VAC power could have been the result of bus failure, an inverter failure, inverter switch failure, system relay failure or pilot mis-selection of one or more of the electrical switches. The investigation considered it unlikely that the pilot, who had access to the circuit breakers for the recorders, purposely disabled the recorders before starting the aircraft. The investigation also discounted the activation of the G switch during the previous landing, thereby isolating power to the FDR, as the data for the previous flight included following touchdown. Even if the G switch had activated during the previous landing, that would not explain the lack of data from the CVR for the accident flight.

Examination of the recovered artificial horizon (AH) showed that the internal, electrically-powered gyroscope was not rotating at the time of the impact with the ocean. That indicated that either there was no 115 VAC driving the gyroscope, or that there was some other failure of the gyroscope's motor at that time. A lack of 115 AC power to the gyroscope was consistent with the effect of such a power interruption on the unavailability of recorded flight data for the flight.

Despite the lack of recorded data from engine start for the flight, the investigation could not conclusively determine that there had been a loss of 115 VAC power for the duration of the flight. However, given that the entire flight was only about 10 minutes, and that the time needed for the gyroscope to wind down is of the order of about 20 minutes, the absence of any indication of gyroscope rotation at impact appeared to confirm that there was no 115 VAC power to the instrument for the entire flight. The means of that power failure will be discussed in the following paragraphs.

Alternating current bus failure

The investigation considered bus failure as very remote, as both buses were mechanical in nature, with in-built system redundancy. However, even if a bus failure had taken place, the aircraft's flight recorders should have recorded data until the time of the failure, and therefore interruption of 115 VAC power to whichever recorder was powered from the failed bus. On that basis, a bus failure sometime after start was discounted.

Inverter failure

The coincident failure of both static inverters was considered remote because of inverter reliability. Failure of an inverter, following the engine start and prior to taxi, should have been detected during the completion of the checklist items by the pilot.

The failure of an inverter prior to taxi that was not noted in the aircraft's documentation by the pilot was a possibility. If that had been the case, and the one operable inverter subsequently failed when selected, the aircraft's flight recorders would not have recorded any data. However, such a failure would also result in a caution advisory illumination (L or R AC BUS), indicating the loss of 115 VAC power and should have been detected by the pilot.

Inverter switch

The 3-position inverter switch on the right side of the centre console was required to be switched to either LEFT or RIGHT to provide 26 and 115 VAC electrical power to the aircraft's electrical systems. A mis-selection of the switch to the central OFF position would render all AC systems inoperative. Alternatively, it was possible that if the switch was in the correct position, an internal switch failure could prevent the supply of AC electrical power. However, such a failure or mis-selection would also result in a caution advisory illumination (L or R AC BUS), indicating the loss of 115 VAC power and should have been detected by the pilot.

System relay failure

The 115 VAC electrical power system contained several electrically-operated relays, which when energised provided power to different sections of the system. The inverter control relay supplied DC power to the inverters and the respective AC switching relay. However, any relay failure would also result in a caution advisory illumination (L or R AC BUS) indicating the loss of 115 VAC power and should have been detected by the pilot. Even if a relay failure had taken place, the aircraft's flight recorders should have recorded data until the time of the failure. On that basis, a relay failure sometime after start was discounted.

Pilot actions following an inverter failure

If the pilot had been faced with a loss of AC electrical power during the takeoff, he would have been required to manually select the other static inverter to power the electrical system. However, even if a mis-selection had taken place, the aircraft flight recorders should have recorded data until the time of the failure.

Annunciator panel globe failures

The redundancy provided by two light globes in the caution advisory capsule in the annunciator panel, and pre-flight test of the caution advisory lights by the pilot should have ensured their functionality when required. The location of the caution advisory light on the annunciator panel would make it unlikely that a pilot would not have seen the caution light if it had been illuminated.

It was unlikely that the multiple light globes failures that were rectified during the series of phase servicings occurred during the flight immediately prior to each phase maintenance, during maintenance procedures or during ground handling. A more likely scenario was that the light globes failed in service, and that pilots were either not completing the testing of the panel as required or, more probably, were accepting the cumulating discrepancies until the next phase service.

Prior to the accident, the aircraft had operated about 5 months since the last documented replacement of an annunciator panel light globe. Therefore, it was possible that one or more annunciator panel caution advisory lights were inoperative on the accident flight. The effect on the flight of any failures could not be determined.

Aircraft flight recorder electrical power supply

Despite the requirements of Civil Aviation Order 103.19, which required the use of an electrical power source that offered the maximum power supply reliability to the FDR, the need by the FDR of heading information was dependent on 115 VAC. In that case, it was logical to power the FDR from the 115 VAC power source. Similarly, the aircraft manufacturer’s Service Bulletin 227-23-001 allowed the aircraft’s CVR to be powered from either the 115 VAC or 28 VDC power source. The loss of 115 VAC power for the flight, and resulting loss of the FDR and CVR in this case, indicated the potential risk of sole reliance on 115 VAC.

The aircraft’s 28 VDC power supply represented a more reliable power source, as it encompassed the aircraft’s battery system, which had a 20-minute essential power theoretical operational requirement. Although it was not applicable at the time of the CVR installation in OZA, United States (US) Federal Aviation Administration Federal Aviation Regulation (FAR) Part 23— section 23.1457 *Cockpit voice recorders* contained power requirements for the CVR which, if implemented, may have led to the installation of the CVR on the 28 VDC power supply.

The aircraft manufacturer’s option of installing a CVR system powered by the aircraft’s 28 VDC electrical power source would provide an additional level of assurance of the continued power supply to the recorder. As a result, there would be an increased probability of obtaining useful information from at least one recorder in the event of aircraft electrical system anomalies.

Spatial disorientation

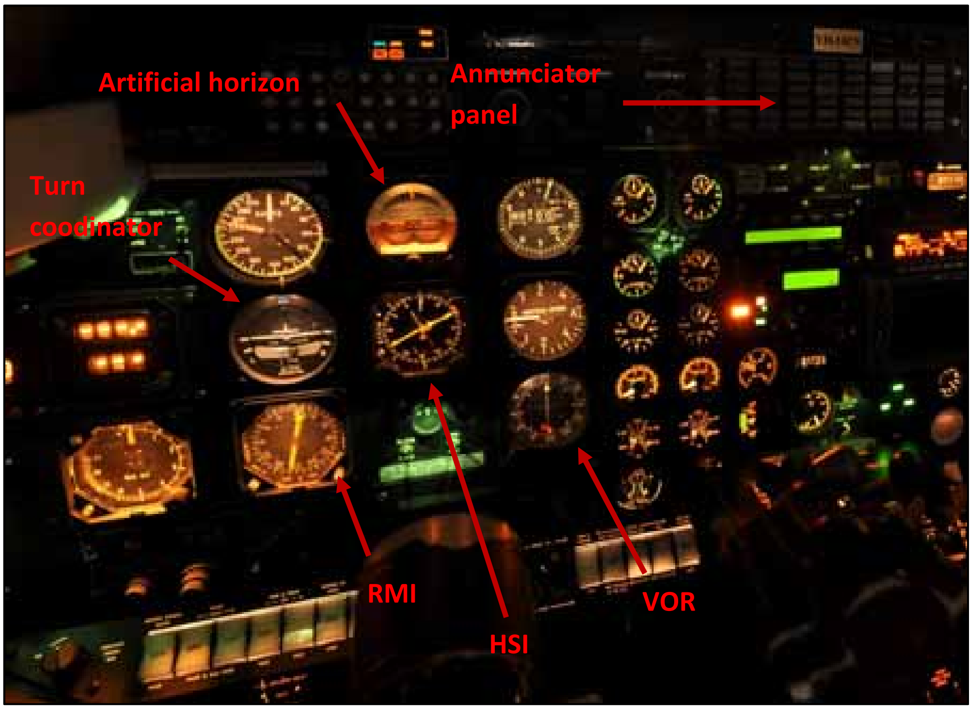
Somatogravic illusion

Although it was possible that the relative lack of lighting during the takeoff to the south could have produced a somatogravic illusion, the pilot successfully climbed to 3,000 ft more than 2-minutes after takeoff, and prior to reporting the 'slight technical fault'. That suggested that the occurrence event wasn't associated with the takeoff, making the effect of a somatogravic illusion unlikely as a factor in the occurrence.

Indications of a loss of primary attitude reference due to an AC power failure

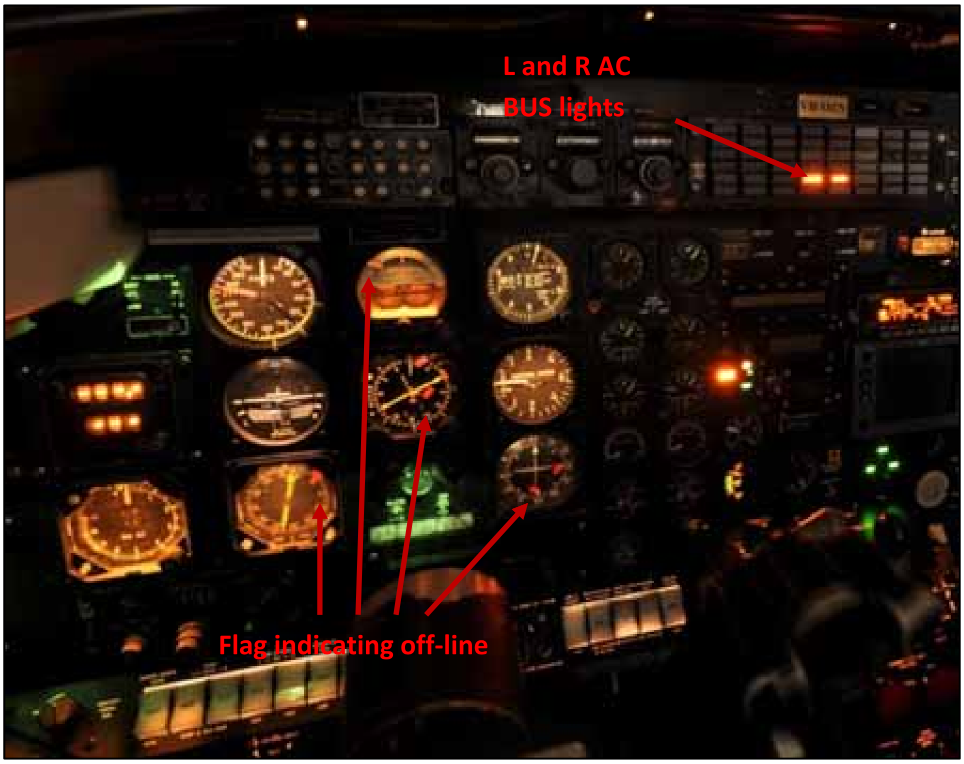
During normal night operations, the flight instruments available to a single pilot for primary attitude reference included the pilot's and copilot's AHs, one turn coordinator and one turn and bank indicator (Figure 24).

Figure 24: VH-OZN instrument panel during simulated normal night operations (pilot side) with no warning/caution lights or flags visible



A loss of AC power meant that the pilot's and copilot's AHs would have been inoperative, with the effect that the pilot would have been deprived of any primary attitude information from his instrumentation (Figure 25). The autopilot would also not have been available for use.

Figure 25: VH-OZN instrument panel during simulated night operations (pilot side) with no AC power and showing the resulting annunciator lights and instrument flags



In addition, if the pilot's AH was not powered prior to takeoff, the pilot should have been presented with an orange and white warning 'off flag' on the AH as shown in Figure 26.

Figure 26: VH-OZN, pilot's AH with off flag visible (circled)

The investigation found it improbable that the pilot might not have noticed the numerous caution lights and instrument off flags associated with an AC power failure during the pre-flight checks and taxi. Similarly, the investigation could not explain why the pilot would have continued the takeoff without primary attitude reference. To have done so markedly increased the risk of spatial disorientation and the subsequent loss of control of the aircraft.

Aircraft control in the absence of primary aircraft attitude instrumentation

The control of an aircraft's attitude at night using the turn coordinator and other secondary instrumentation, and without a visible horizon demands a very proficient instrument flight skill and absolute attention to the available instrument indications. Any distraction that interrupts a pilot's instrument scan increases the risk of the loss of control of the aircraft in a very short period of time.

In this instance, the loss of AC power and therefore availability of the aircraft's primary attitude instruments placed the pilot in a limited or partial panel situation, which is known to elevate the risk of disorientation. That was evidenced in the case of the 1985 Westwind accident near Sydney and the 2001 Super King Air accident in the US, which involved the loss of primary attitude reference during night takeoffs without any visual horizon. Combined with the effect of the lack of illumination from the moon on the night of the accident involving OZA, lack of lighting once over water, and loss of any terrestrial lighting from the built-up area had the aircraft entered the reported cloud, the simultaneous loss of the autopilot would have further increased the disorientation risk – in particular, to the single-pilot operation.

Pilots are trained for limited or partial panel operations and in perhaps less demanding circumstances, and a current and competent instrument pilot could be expected to recover their aircraft. However, if at the same time, the affected pilot was presented with a problem that distracted him from the primary task of controlling the aircraft, the probability of a loss of control increases significantly. The successive left turns by the pilot when right turns were required, and pilot report that he had a 'slight technical fault here' would suggest that analysing and dealing with the technical fault had indeed distracted the pilot.

The investigation concluded that the pilot was distracted by the technical fault which, combined with the lack of a primary attitude reference and loss of the autopilot, led to spatial disorientation and a loss of aircraft control.

Single-pilot operations

Night freight operations, such as in this case, are typically conducted as single-pilot operations. In contrast, passenger-carrying operations are normally conducted using two pilots, signifying that the use of an additional pilot is a risk mitigator during passenger-carrying operations. That risk control has application in the management of increasingly complex aircraft and systems, in terms of managing in-flight workloads and in case of emergencies.

As indicated by the National Aeronautics and Space Administration study into single-pilot commercial operations, the lack of a second crew member may have impacted on the pilot's identification and correction of any errors of omission, such as not turning on or noticing the failure of aircraft items and systems, or complying with directions. That may give some understanding of the takeoff without AC power.

Without a second crew member to assist, the workload associated with the single-pilot night departure, with no ambient lighting once over water, no autopilot and involving flight with limited or partial panel would have been extremely demanding. The additional workload associated with resolving the ‘slight technical fault’ would have further impacted the pilot’s ability to manage the departure, and might explain the successive non-compliances with air traffic instructions.

Organisational issues

Civil Aviation Regulation (CAR) 217 placed a requirement on an operator of an aircraft above 5,700 kg, such as the Metro III, under the Civil Aviation Act to establish and maintain a training and checking organisation. That entailed additional investment in terms of human and other resources. The regulatory requirements and available guidance included CAR 217, Civil Aviation Order 82.1 and Civil Aviation Advisory Publication 215-1(0).

Chief pilot responsibilities

The position of chief pilot is pivotal in any operation. The acceptance by the operator’s chief pilot of the duties and responsibilities of the chief pilot, head of training and checking and check captain positions placed a large responsibility and workload on that individual. Each of those roles required attention to detail, high competency and a moderate task load. It would be unreasonable to expect one individual to successfully attend to all of those positions’ duties and responsibilities. The omissions in a number of the operator’s training and checking requirements might be explained by the excessive combined chief pilot/head of training and checking/training captain workload.

Training and checking manual

An essential part of the operator’s CAR 217 organisation was the training and checking manual. When CASA approved the operator’s manual, it certified that the level of training and checking intended by the operator would ensure that competency is obtained and maintained by the operator’s personnel.

The requirement for CASA to approve any changes to the training and checking manual was intended to maintain the integrity of an operator’s training system, and was incumbent on the operator to ensure that changes to the manual were approved by CASA. If an operator makes changes to its training and checking manual without the approval of CASA, or chooses to conduct training and checking not in accordance with the requirements of the manual, then the competence and ultimately safety of an operation cannot be assured. That was the case in respect of the unapproved changes to the operator’s training and checking manual, the non-compliance with the authorised training and checking captain requirements of that manual, and with the inconsistencies in the provision of the operator’s Metro III endorsement training.

Pilot endorsement training approvals and requirements

The overall responsibility for oversight of the operator's CASA-approved training and checking organisation rested with the chief pilot. Although there was an approved head of training and checking, his location in another state, and employment on less than a full-time basis reduced the likelihood that the duties of the head of training and checking might be carried out adequately. As a result, the chief pilot assumed those duties, thereby increasing his own workload.

The pilots who conducted the pilot's in command under supervision (ICUS) training were not approved training or supervisory pilots in accordance with the training and checking manual and at least one of those pilots did not meet the operator's minimum requirements as a training captain. When combined with the likely effect of the unapproved changes to the operator's checking and training manual and the non-compliance with the authorised checking and training requirements of that manual, the conduct of ICUS by the non-approved training/supervisory pilots meant that the effectiveness of the pilot's endorsement training could not be assured.

Operator record keeping

It may have been that a ground theory assessment was undertaken by the pilot during his endorsement training on the Metro III aircraft. However, the lack of documentary evidence to confirm that was the case meant that the pilot's level of knowledge of the aircraft's equipment and systems could not be determined. The investigation could not establish any conclusive evidence on how the pilot's level of knowledge may have influenced the flight.

The additional workload sustained by the chief pilot on assuming the duties and responsibilities of the head of training and checking meant that items of an administrative nature were more likely to be overlooked.

Civil Aviation Safety Authority surveillance of the operator

The surveillance action by the Civil Aviation Safety Authority (CASA) prior to and following the accident was based on its standard practices and undertaken in response to industry intelligence. Similarly, the reported operator action to address the requests for corrective action that resulted from that surveillance was a normal operator response.

A number of the discrepancies that were identified in the CASA risk-based audit of the operator after the accident were also identified during this investigation. That included in respect of the operator's operations manual, the training and checking requirements, and the operator's record keeping. The reported operator action to rectify those discrepancies should allow the operator to better understand and manage the safety of its operation.

Summary

In conclusion, the loss of control of the aircraft soon after takeoff was considered to be unrelated to:

- load shifting, based on the variations in pitch during the flight, suggesting that the pilot retained control of the aircraft, and the evidence within the wreckage of the security of the cargo straps
- an in-flight emergency such as dangerous goods release or sustained fire, based on there having been no emergency broadcast by the pilot
- pilot incapacitation, based on the pilot's attempts to recover the aircraft in the latter stages of the flight.

It was highly likely that the pilot report of an undefined 'slight technical fault' related to a continuing interruption in the supply of alternating current (AC) power to the aircraft's systems. That conclusion was made on the basis of the lack of:

- any data recordings of the start, taxi, takeoff and departure for the flight on either of the AC-powered FDR or CVR
- any indication at the impact with the ocean of rotation of the AC-powered AH gyroscopic rotor
- AC electrical system interference lines on the audio recordings from OZA, as compared to other similarly-configured Metro III aircraft.

It is therefore very likely that the pilot took off without a functioning primary attitude reference and that this, in conjunction with there being no AC-powered autopilot, led to pilot spatial disorientation and the subsequent loss of control of the aircraft. The conduct of the single-pilot flight in dark night conditions and probably without any terrestrial lighting once over the water increased the risk of that occurring.

The reason for the lack of AC power could not be determined.

An interruption in the supply of AC power should have illuminated the left and right AC bus caution advisory lights and caused the appearance of inoperative flags on the AH and other AC-powered flight instruments. In addition, the FDR FAIL light would also have illuminated.

The reason that the pilot commenced or continued the takeoff with any or all of those warnings displayed could not be explained. The pilot very likely recognised the electrical anomaly soon after being directed to turn left by air traffic control, and then reported the 'slight technical fault'.

FINDINGS

Context

From the evidence available, the following findings are made with respect to the loss of control after takeoff from Sydney Airport, New South Wales on 9 April 2008 involving a Fairchild Industries Metro III aircraft, registered VH-OZA, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- It was very likely that the aircraft's alternating current electrical power system was not energised at any time during the flight.
- It was very likely that the aircraft became airborne without a functioning primary attitude reference or autopilot that, combined with the added workload of managing the 'slight technical fault', led to pilot spatial disorientation and subsequent loss of control.

Other safety factors

- The pilot's Metro III endorsement training was not conducted in accordance with the operator's approved training and checking manual , with the result that the pilot's competence and ultimately, safety of the operation could not be assured. *[Significant safety issue]*
- The chief pilot was performing the duties and responsibilities of several key positions in the operator's organisational structure, increasing the risk of omissions in the operator's training and checking requirements.
- The conduct of the flight single-pilot increased the risk of errors of omission, such as not turning on or noticing the failure of aircraft items and systems, or complying with directions.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Conduct of training not in accordance with operator and regulatory requirements

Significant safety issue

The pilot's Metro III endorsement training was not conducted in accordance with the operator's operations manual and Civil Aviation Safety Authority regulations governing training and checking requirements, with the result that the pilot's competence and ultimately, safety of the operation cannot be assured.

Action by the Civil Aviation Safety Authority

On 10 July 2008, Civil Aviation Safety Authority (CASA) officers met with the aircraft operator to discuss the results of the June 2008 risk-based audit. As a result of those meetings, on 11 July 2008 CASA imposed the following conditions on the air operator's certificate:

- no passenger carrying charter or aerial work operations were to be conducted whilst the then chief pilot held that position, with such operations only to resume upon CASA approval of a new chief pilot
- the operator was required to develop multi-crew procedures in order to crew Metro aircraft with two qualified pilots when carrying passengers, with those procedures to be in place prior to such operations
- by 18 July 2008, the operator was required to implement a system that printed pilot flight and duty time records to ensure a permanent record is kept
- by 25 July 2008, the operator was to implement a confidential reporting system to provide the chief executive officer (CEO) with information relating to poor operational standards or hazards and risks within their operations
- by 31 July 2008, the operator duplicate, via a secure back-up process, all computerised operator records and keeps these back-ups in a secure place
- by 31 August 2008, the operator was to employ an appropriately-qualified independent auditor that was acceptable to CASA. The auditor was required to conduct comprehensive quality and aviation safety systems audits on a

6-monthly schedule, and provide CASA with a copy of each audit report within 3 weeks of the completion of the audit

- by 30 September 2008, the operator was required to develop a comprehensive, company-wide safety management system that was fully supported by the CEO
- by 30 September 2008, the operator was to review and where required, amended the operations manual, any amendments were to be submitted to CASA for acceptance.

Action by the aircraft operator

In response to the issues that were identified in CASA's risk-based audit of June 2008, on 30 July 2008 the operator advised CASA of the following actions to rectify those issues:

- the operations manual was being rewritten to:
  - bring the operator's training and checking into line with the regulations and address multi-crew operations
  - ensure that base and line checks accurately reflected the operator's procedures and testing requirements by reference to specific test-content forms
  - include the requirement for all inducted pilots to complete 'wet drill' training on the use of life jackets and life rafts. The results of that training would be recorded and renewed annually
  - ensure the review of ground course theory examinations and that they were corrected to 100% knowledge of the subject
  - ensure the completion of formal ground courses and that the training and syllabuses were documented
  - ensure that pilots undertook pressurisation endorsement with a minimum training criteria
- several pilots were being retrained as required to meet the operator's endorsement training requirements
- the operator's computer-based flight and duty time records were password protected and a monthly copy of each crew member's record would be printed out and placed on the individual's file
- flight crews had been informed about the importance of accurately completing paperwork
- the head of training and checking had resigned and a new individual had been approved by CASA
- one pilot who had been identified as not having sufficient in command under supervision hours had been recertified.

Subsequently, on 17 September 2008, the operator provided an amended operations manual to CASA for review. That included amendments to Part C of the manual.

On 16 December 2008, CASA issued a new Air Operators Certificate to the operator.

ATSB assessment of CASA and operator action

The ATSB is satisfied that in combination, the action taken by CASA, and response to the CASA action by the aircraft operator, adequately addresses the safety issue.

Additional safety action

Aircraft operator

Although no safety issue was identified as a result of this investigation, on 6 August 2008, the operator notified CASA that, as part of its new safety management system, a safety committee had been implemented that comprised the CEO, general manager, chief pilot, head of training and checking, safety manager and a pilot or engineering representative.

APPENDIX A: RADAR INFORMATION

ATSB TECHNICAL ANALYSIS REPORT

ATSB Aviation Safety Investigation AO-2008-026

Radar data analysis

Collision with water
VH-OZA, Fairchild SA227-AC
19 km SE Sydney, NSW
9 April 2008

Neil A. H. Campbell
Senior Transport Safety Investigator – Engineering

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

FACTUAL INFORMATION

Introduction

On 9 April 2008 at 2316 Eastern Standard Time (1316 UTC), the pilot of a Fairchild Industries Inc. SA227-AC (Metro III) aircraft, registered VH-OZA, taxied at Sydney, NSW, on a freight charter flight to Brisbane, Qld. The flight was operated under the Instrument Flight Rules (IFR) and the pilot was the sole occupant.

After takeoff, the aircraft was observed on radar to be turning contrary to air traffic control instructions. The pilot reported that he had a '...slight technical fault...'. No further radio transmissions were received from the pilot. Over the next 70 seconds, recorded radar data showed that the aircraft completed a turn to the left before turning back to the right and disappearing from radar coverage. Searchers later discovered a small amount of aircraft wreckage floating in the ocean, south of the last recorded radar position. The pilot was fatally injured and the aircraft was destroyed.

Scope of the factual examination

Following is the scope of the factual examination:

- filter recorded radar data to obtain all the returns from VH-OZA (OZA)
- identify and examine radar data from any aircraft that were operating in the vicinity of OZA
- Identify any issues with the accuracy of the radar data
- produce a sequence of events
- produce plots and data listings.

Background – radar operation and terminology

The Australian Advanced Air Traffic System (TAAATS) is the primary system for civil air traffic control in Australia. TAAATS integrates information from a range of sources, including radar, global positioning satellites, aircraft flight plans and pilot position reports. TAAATS is capable of processing radar signals from multiple sensors and combining the information to synthesise a track that is presented to the air traffic controller as the aircraft progresses along its flight path. The system records the radar information received from each sensor as local track data, and the synthesised track as system track data.

Primary radar returns are produced by radar transmissions which are passively reflected from an aircraft and received by the radar antenna. The received signal is relatively weak and provides only position information. Primary radars, which are only located near capital city airports, have a nominal range of 50 NM.

Secondary radar returns are dependent on a transponder in the aircraft to reply to an interrogation from the ground. The aircraft transmits an encoded pulse train containing the secondary surveillance radar code (Mode A) and other data. Pressure altitude (Mode C) may be encoded with these pulses. As the aircraft transponder directly transmits a reply, the signal received by the antenna is relatively strong. Consequently, an aircraft which has its transponder operating can be more easily and reliably detected by radar. Civilian secondary surveillance radars are located along the east coast of Australia to meet the operational requirement of radar coverage from 200 NM north of Cairns to 200 NM west of Adelaide. Coverage within a 200 NM radius of Perth is also required.

A radar directly senses aircraft position by measuring the range (distance) and azimuth (bearing) to the aircraft. Radar position is recorded as X and Y coordinates, with the origin at the radar site and the Y axis aligned with True North.

Terrain shielding - radar returns require a clear line-of-sight between the radar antenna and the aircraft transponder aerial. At low altitudes, intervening terrain may block this line-of-sight.

A transponder-equipped aircraft is not always detected by secondary radar. This could be due to one of the following reasons:

- secondary radar sensor failure
- aircraft is outside of the range of the radar
- aircraft transponder is not switched on
- aircraft transponder is unserviceable
- loss of aircraft power to the transponder
- terrain shielding
- aircraft transponder aerial is shielded from the radar (or received signal strength is reduced) due to aircraft manoeuvring.

Mode C pressure altitude, in units of 100 feet, is transmitted from the aircraft by the transponder. An encoding altimeter provides the altitude information to the transponder and it is referenced to 1013.2 hPa. This is a fixed reference and is independent of instrument settings by the pilot.

It is normal practice for the pilot to activate the transponder when lining up on the runway for takeoff. This involves switching the transponder from STBY (standby) to ON. If a separate switch is in the ALT (altitude) position - as is normally the case, then the transponder will reply to Mode A and Mode C interrogations.

Mode C valid parameter - A validation bit is derived by considering the history of the track, whether the Mode C altitude is coherent and the quality of the code pulses. This bit indicates that the Mode C is either ‘valid’ (i.e. high confidence that the Mode C altitude is correct) or ‘invalid’ (i.e. low confidence that the Mode C altitude is correct). An incoherent Mode C is due to one of the following:

- altitude too high
- altitude rate of change exceeds a threshold
- illegal code.

Derived parameters - Recorded *groundspeed* and *track angle* are derived from the changes in aircraft position data as detected by the radar. The recorded groundspeed data is derived from the rate of change of aircraft position between successive antenna scans. When the aircraft changes speed, there will be a time lag before this is reflected in the recorded groundspeed. The recorded groundspeed is smoothed and does not represent the instantaneous value of groundspeed.

Tracking - there are two levels of radar data: plots and tracks. A plot is the position of an aircraft at the time of interrogation. There is no history of the past position of the aircraft or prediction of its future position. A track is formed by examining a series of plots from a single radar to determine if they represent the same aircraft, thus allowing the groundspeed of the aircraft to be calculated and its future position to be predicted.

Local track - a track from a single radar sensor.

System track - the standard way of presenting information to air traffic controllers where an aircraft is under surveillance by more than one radar. TAAATS combines or 'fuses' local track information and presents it as one consolidated track. System tracks are updated every 5 seconds.

Missed returns - the radar tracker software generates missed returns when an aircraft on an established track disappears from radar coverage. If a valid return is not received before three missed returns are generated in succession, the track is cancelled.

Accuracy - the accuracy of the radar position data is proportional to the range of the aircraft from the radar site. The overall accuracy can be affected by terrain or meteorological conditions.

Aircraft equipment

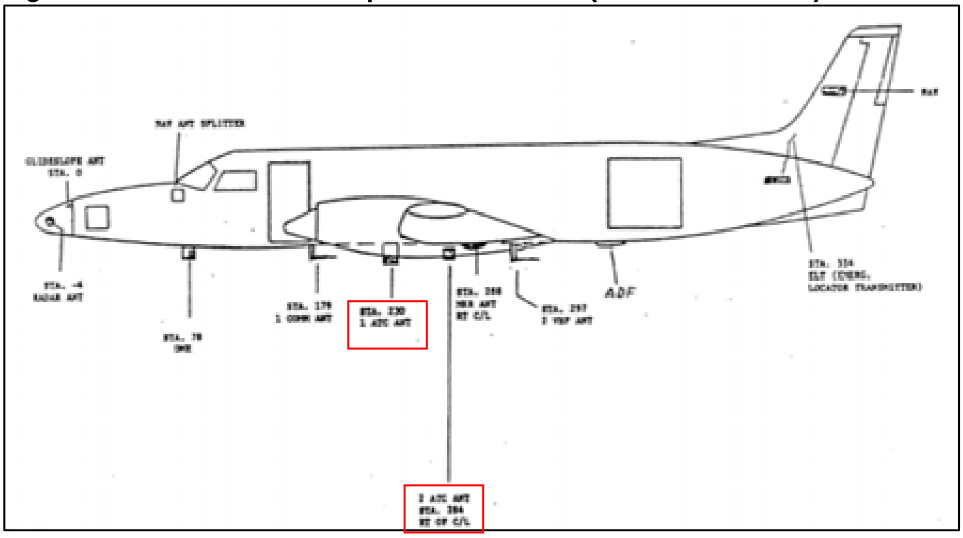
The aircraft was equipped with two transponders, an encoding altimeter, cockpit transponder control unit, transponder aerials and inter-connecting wiring as detailed in Table A-1.

Table A-1: Reported aircraft equipment details

Description:	Model:	Power supply:
Transponder #1	Garmin GTX-320	28 VDC
Transponder #2	Collins TDR-90	28 VDC
Encoding altimeter	IDC/Kollsman	28 VDC
Cockpit control unit	Gables	28 VDC

The two transponder antennas are located on the fuselage underneath the aircraft (Figure A-1).

Figure A-1: Location of transponder antennas (1 ATC and 2 ATC)



Radar coverage

Radar returns from OZA were received from the following five sensors:

- Sydney surface movement radar (SMR)
- Sydney Terminal Area Radar (TAR) - primary
- Sydney Terminal Area Radar (TAR) - secondary
- Sydney Precision Runway Monitor (PRM) - secondary
- Mount Boyce secondary surveillance radar (SSR) – secondary.

Sydney surface movement radar (SMR)

Table A-2: Sydney SMR details

Purpose:	• Airport surface surveillance • Correlation of airborne targets over the runway thresholds
Location:	On Sydney Airport control tower
Latitude:	S 33° 56’ 59.70”
Longitude:	E151° 10’ 52.65”
Nominal coverage:	5 NM
Range accuracy:	4 metres
Azimuth accuracy:	4 metres
Update interval:	3.7 seconds (antenna rotation rate 16.4 RPM)

SMR data was not recorded as part of TAAATS, but could be replayed and observed. A video, of duration 4 minute 43 seconds, was produced covering the operation of OZA during taxi and takeoff on runway 16L. The video was examined by the investigation team, but was not considered in this report as Sydney TAR secondary data included the period when the aircraft taxied onto the runway and took off.

Mount Boyce secondary surveillance radar (SSR)

Table A-3: Mount Boyce secondary surveillance radar (SSR) details

Purpose:	• Control within 40 NM of Sydney Airport • Tracking of transponder-equipped aircraft along the Eastern seaboard
Location:	Blackheath, Blue Mountains Approximately 50 NM north-west of Sydney Airport
Latitude:	S 33° 36’ 47. 61”
Longitude:	E150° 16’ 10.15”
Nominal coverage:	250 NM
Range accuracy:	±0.03 NM RMS
Azimuth accuracy:	±0.05º RMS
Update interval:	3.7 seconds (antenna rotation rate 16.4 RPM)

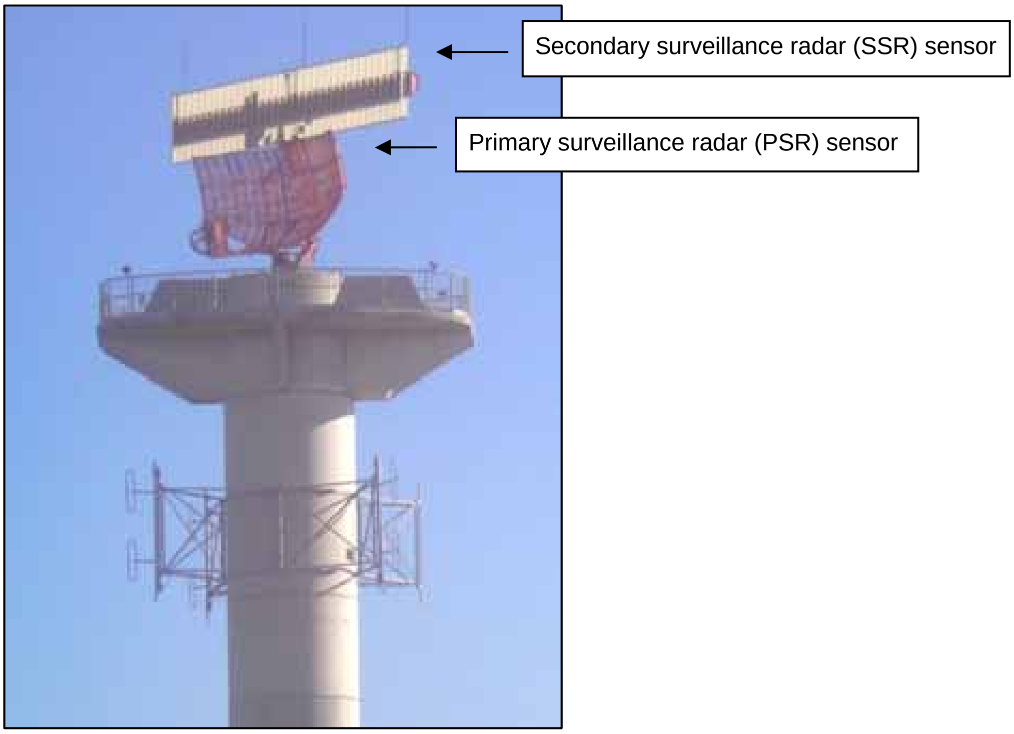
Figure A-2: Location of Mount Boyce SSR

Sydney TAR – primary surveillance radar (PSR)

Table A-4: Sydney PSR details

Purpose:	• Intruder detection within 30 NM of Sydney Airport • Tracking of non-transponder-equipped aircraft
Location:	On Sydney Airport, co-mounted with Sydney TAR – secondary surveillance radar (SSR)
Latitude:	S 33° 56’ 59.70”
Longitude:	E151° 10’ 52.65”
Nominal coverage:	50 NM
Range accuracy:	±0.03 NM RMS
Azimuth accuracy:	±0.15º RMS
Update interval:	3.7 seconds (antenna rotation rate 16.4 RPM)

Figure A-3: Sydney TAR sensors



Sydney TAR – secondary surveillance radar (SSR)

Table A-5: Sydney TAR - SSR details

Purpose:	• Approach control within 40nm of Sydney Airport

	• Tracking of transponder-equipped aircraft along Eastern Seaboard
Location:	On Sydney Airport (co-mounted with Sydney TAR – primary surveillance radar (PSR)
Latitude:	S 33° 56’ 59.70”
Longitude:	E151° 10’ 52.65”
Nominal coverage:	250 NM
Range accuracy:	±0.03 NM RMS
Azimuth accuracy:	±0.05º RMS
Update interval:	3.7 seconds (antenna rotation rate 16.4 RPM)

Figure A-4: Locations of TAR and PRM at Sydney Airport

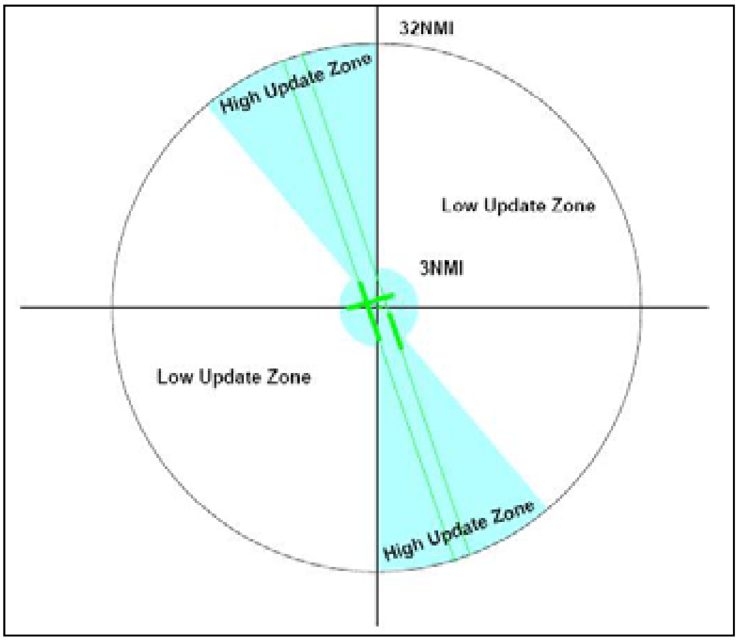
Sydney precision runway monitor (PRM)

Table A-6: Sydney PRM details

Purpose:	• Approach control within 30 NM of Sydney Airport

	• Precision radar approach control to the parallel runways
Location:	On Sydney Airport
Latitude:	S 33° 56' 37.71"
Longitude:	E151° 10' 57.34"
Nominal coverage:	32 NM
Range accuracy:	±0.01 NM RMS
Azimuth accuracy:	Better than 0.06º RMS
Update interval:	2.2 seconds - electronically scanned

Figure A-5: PRM coverage chart



Airservices Australia radar data

Following the accident, the ATSB obtained a copy of the recorded radar data from Airservices Australia. The following files were examined:

Table A-7: File details

Filename:	File size:	Comments:
2008_02004_lt.txt	7,896 KB	Text file containing all local tracks recorded between 1315:00 UTC and 1329:00 UTC on 9 April 2008 from the following radar sensors: Williamtown, Mount Majura (Canberra), Sydney TAR, Mount Boyce and Sydney PRM.
qrySortLocalTracksByTimeStamp_OZA.xls	2,163 KB	Text file containing returns corresponding to local track numbers 47 and 143.
DAF_Data_Analysis_2002.mdb	12,644 KB	Database file containing all fields for all local tracks recorded between 1315:00 UTC and 1329:00 UTC on 9 April 2008 from the following radar sensors: Williamtown, Mount Majura (Canberra), Sydney TAR, Mount Boyce and Sydney PRM.
OZA DAF system data.xls	39 KB	System track data for SSR code of 1370.

The file *DAF_Data_Analysis_2002.mdb* was used as the primary data source. It contained radar returns recorded between 1315 UTC and 1329 UTC for all aircraft in the Sydney area and not just OZA. The 12,789 records were filtered using the following criteria:

- all returns with an SSR code (i.e. mode A) of 1370 or
- all returns within a box with coordinates (in NM) of (-2,-6), (5,-6), (5,-11), and (-2,-11) from the Sydney TAR site.

These criteria were used as 1370 was the assigned SSR code for OZA and the 35 square mile box covered the area of the aircraft's final manoeuvres.

These returns were scrutinised and the following track numbers were observed to have been assigned to OZA by the radar trackers:

Table A-8: Local track numbers

Radar:	Local track number:
Sydney TAR	47
Sydney PRM	80 and later 143
Mount Boyce SSR	75

Results

The radar returns from OZA, obtained from the search of the Airservices Australia data files, were examined. Details of the returns were:

Table A-9: Number of returns

	UTC of the initial return: (hhmm:ss)	UTC of the final return: (hhmm:ss)	Number of returns:
Mount Boyce SSR	1323:20	1323:48	6
TAR (primary and secondary)	1321:59	1327:45	95 (includes 6 missed returns)
PRM	1323:18	1327:09	108 (includes 23 missed returns)

Only a small number of returns were received from the Mount Boyce SSR due to coverage limitations. These returns were received between 1323:20 UTC and 1323:48 UTC during the initial climb of the aircraft (300 ft to 700 ft). At this time, there was good radar coverage from both the TAR and PRM, so there was no further need to examine the Mount Boyce SSR returns in this report.

As the reported QNH was 1022 hPa, approximately 270 feet (9 hPa x 30 feet/hPa) needed to be added to the recorded Mode C values to give pressure altitude referenced to QNH. TAAATS automatically corrects Mode C values based on the QNH sensed by an automatic weather station at the airport at the time. The TAAATS correction was +243 feet, indicating that the actual QNH at the time was 1022.3 hPa[38].

Figure A-6 contains a combined track plot of TAR and PRM data. Refer to the appendices for further plots and data listings.

38 The TAAATS correction for QNH is 26.7 ft per hPa.

Figure A-6: Radar tracks (Sydney TAR – blue, PRM – red)

Table A-10: Sequence of events

UTC: (hhmm:ss)	Event:	Comment:
1321:59	Initial TAR secondary return	Aircraft was stationary on taxiway golf adjacent to runway 16R.
1323:11	Aircraft airborne	First increase in Mode C altitude.
1323:18	Initial PRM return	
1324:29	Aircraft intercepted the 168° radial	In accordance with the Standard Instrument Departure (Sydney Curfew Two Departure).
1325:28	End of continuous climb after takeoff	Aircraft reached an altitude of 3,140 ft (Mode C of 2,900 ft).
1326:18 to 1326:29	Loss of PRM secondary returns	PRM track cancelled (no. 80).
1326:20 to 1326:27	Loss of TAR secondary returns	Primary returns continued to be received.
1326:27 to 1326:29	Radar returns regained	Aircraft track changed from south-south-west to north-east. Aircraft reached a minimum altitude of 1,540 ft (Mode C of 1,300 ft). New track created for PRM (no. 143).
1326:53	Maximum recorded Mode C value	Aircraft reached a maximum altitude of 4,340 ft (Mode C of 4,100 ft)
1327:00	Final PRM return with Mode C	3,943 ft (Mode C of 3,700 ft)

1327:00	Final TAR secondary return with Mode C	3,740 ft (Mode C of 3,500 ft)
1327:04	Final TAR secondary return (Mode A only)	Aircraft was tracking south-south-west.
1327:09	Final PRM return (Mode A only)	
1327:19	Final TAR primary return	

It was observed that another Metroliner aircraft, VH-VEU (VEU), took off on runway 16R at 1324:41 UTC, approximately 1 minute and 40 seconds after OZA. VEU was a Metro 23 (SA227-DC) and was operating a freight flight from Sydney to Adelaide. Radar data from VEU (assigned SSR code of 4051) was examined for comparison with data from OZA. In addition, the flight data recorder (FDR) from VEU was downloaded and data from the takeoff at Sydney was examined.

Figure A-7: Relative positions of OZA and VEU at 1324:41 UTC

Examination of the recorded radar data for VEU showed that the TAR and PRM sensors were operating within normal tolerances. There were minimal missed returns for VEU and no indications of any problems with the performance of TAAATS.

ANALYSIS

Scope of the analysis

The following analysis of the radar data was undertaken:

- compare the recorded radar data for OZA and VEU
- identify aircraft manoeuvres that correlated with the recorded radar data
- using a transcript of recorded ATC communications, comment on whether the aircraft manoeuvres were in accordance with ATC clearances and instructions
- estimate indicated airspeed (IAS) values from the recorded radar groundspeed data
- identify and examine other accidents involving Metroliner aircraft where radar data was available
- comment on the reasonableness of the apparent aircraft manoeuvres
- comment on the serviceability of the aircraft electrical system based on the recorded radar data.

Comparison between OZA and VEU

Table A-11: Comparison between VEU and OZA

Event:	VEU:	OZA:	Comment:
Destination	Adelaide	Brisbane	
Time of takeoff roll	43 seconds	47 seconds	Time between the lowest groundspeed after lining up (runway track) and the first increase in Mode C altitude.
Initial rate of climb	1,700 fpm	1,330 fpm	VEU was a Metro 23 (SA227-DC) with a MTOW of 7,484 kg and was fitted with Garrett TPE 331-12 engines.
Groundspeed	165 kts	165 kts (average)	VEU groundspeed paused at 125 kts immediately after takeoff. FDR data showed that this corresponded to flap retraction.
Tracking along 168 radial	Intercepted radial and initially continued tracking along radial.	Intercepted radial but did not track along radial (turned left).	Annotated as R1 on Figure 8.

Rate of turn	During the right turn to the east, the rate of turn was 2.5°/second[39].	During the right turn from a SE track to a SW track, the rate of turn was 2.5°/second.	Annotated as L1 on Figure 8.

Aircraft manoeuvres

Refer to Figure 8on the following page, where the aircraft manoeuvres are shown on a track plot. Refer to Attachments 4.7 and 4.8 for altitude plot of data from TAR and PRM.

Table A-12: Aircraft manoeuvres

Start time (UTC):	Description:	Altitude:	Comment:
1323:57	Right turn onto 168 radial (R1)	1,300 ft	Consistent with controlled flight and in accordance with ATC clearance (Sydney Curfew Two departure).
1324:33	Left turn (L1)	2,000 ft	Consistent with controlled flight, but not in accordance with ATC clearance (track along 168 radial).
1325:28	Aircraft levelled at approximately 3,000 ft for about 30 seconds.	3,000 ft	Consistent with controlled flight, but not in accordance with ATC clearance (cleared to climb to FL170). The crew of VEU reported being in cloud at 3,000 ft.
1325:30	Right turn (R2)	3,140 ft	Consistent with controlled flight, but inconsistent with ATC instruction (turn left heading 090).
1326:01	Left turn (L2)	4,140 ft	The initial rate of change of track was 5.4°/second. During the period of missed returns the average rate of change of track was 5.9°/second.
1326:09	Descent (D1)	4,340 ft to 1,540 ft	Inconsistent with controlled flight. Temporary loss of transponder returns. Average rate of descent was 8,400 fpm.
1326:29	Climb (C1)	1,540 ft to 4,340 ft	Average rate of climb was 8,400 fpm.
1326:54	Right turn (R3)	4,340 ft	The average rate of change of track was 7.4°/second.
1326:56	Descent (D2)	4,340 ft to sea-level	Inconsistent with controlled flight. Permanent loss of transponder returns. The final reasonable primary return was recorded at 1327:19 UTC. The aircraft impact

39 A rate 1 turn is 3°/second (i.e. 360° in 2 minutes).

	with the water is considered to have occurred shortly after this time. This indicated an average rate of descent of approximately 10,400 fpm.

Figure A-8: Aircraft manoeuvres annotated on a track plot

Estimated indicated airspeed (IAS)

Indicated airspeed values were estimated using radar groundspeed, wind speed, wind direction and temperature information. The meteorological information was obtained from the Bureau of Meteorology (BoM)[40].

As FDR information was available for VEU, its IAS was calculated using radar groundspeed and compared with the IAS recorded by the FDR. This gave good agreement and showed that the observed wind was consistent with the wind experienced by VEU.

Reasonableness of the radar data

Aircraft position (X and Y coordinates)

The initial SSR returns showed that the OZA was located on taxiway Golf adjacent to runway 16R. Subsequent returns showed that the aircraft tracked along runway 16R during takeoff.

Within radar system tolerances, both these checks showed that the recorded positions at these times were reasonable and were evidence that TAAATS was recording position data correctly.

Mode C returns

There were two occasions when the accuracy of the Mode C returns could be checked.

The first occasion occurred when the aircraft was taxiing at Sydney airport. A Mode C value of -2 (-200 ft referenced to a QNH of 1013.2 hPa) was recorded by the TAR while the aircraft was taxiing. As the reported QNH at the time was 1022 hPa, a correction of approximately +270 ft needed to be added to the Mode C value. This gave a value of +70 ft compared to the documented aerodrome elevation of +21 ft.

At 1323:55 UTC, the pilot reported that he was 'passing 1,300 ft'. At this time a mode C value of +9 (+900 ft referenced to a QNH of 1013.2 hPa) was recorded by the TAR. With the QNH correction of +270 ft this gives an altitude value of +1,170 ft.

Within timing tolerances and the Mode C quantisation of 100 ft, both these checks showed that the recorded Mode C values at these times were reasonable and was evidence that the aircraft transponder was transmitting the correct Mode C value, and that TAAATS was recording it correctly.

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40 *Aviation Safety Investigation Meteorological Report* BoM 22 August 2008 – *Appendix 3*.

Other investigation reports examined

A search was conducted for other investigation reports, involving Metroliner aircraft, where high rates of descent were recorded. Three reports were identified:

Table A-13: Other investigations

Investigation agency:	Report number:	Synopsis:
ATSB	200403209	Date: 30 August 2004 Model: SA226-T Registration: VH-SSL Summary: Loss of control following an autopilot disconnection due to a fuel imbalance. Radar data showed that the aircraft rapidly descended from a cruise level of FL160 and 50 seconds later was levelled at 5,200 ft (an approximate rate of descent of 13,000 fpm).
NTSB[41]	FTW98FA073	Date: 19 December 1997 Model: SA226-T Registration: N950TT Summary: Aircraft stalled. Radar data indicated a rate of descent of 8,500 fpm and after a loss of altitude of 3,500 ft, control of the aircraft was recovered. Later, radar data indicated a climb rate of 7,500 fpm.
TAIC[42]	200400998	Date: 3 May 2005 Model: SA227-AC Registration: ZK-POA Summary: Loss of control associated with a fuel imbalance and subsequent steep spiral descent. FDR data showed that the aircraft rapidly descended from FL220 and that the final descent rate recorded was approximately 15,000 fpm. A maximum vertical acceleration of +4.1 g and an IAS of 295 kts were recorded near the end of the FDR recording.

41 National Transportation Safety Board (United States).

42 Transport Accident Investigation Commission (New Zealand).

Table A-14: Metro III characteristics[43]

Parameter:	Description:	Value:
V_A	Manoeuvring airspeed	179 to 185[44] at MTOW KIAS[45]
V_{MO}	Maximum operating airspeed	246 KIAS
V_C	Design cruising speed (at sea level)	248 KEAS[46]
V_D	Design dive speed (at sea level)	311 KEAS
$+n_m$	Manoeuvre limit load factor at V_C	+3.08 g
$-n_m$	Manoeuvre limit load factor at V_C	-1.21 g

While the positive limit load factor is nominally +3.08 g, the ultimate load factor is 1.5 times this value (+4.62 g). From the FDR data, there was an apparent structural failure of ZK-POA at a load factor of +4.1 g. In an actual overload failure scenario, there would be lateral and longitudinal g loadings that could be expected to lower the theoretical load factor (vertical g) failure threshold.

Descent manoeuvre (1326:09 UTC to 1326:29 UTC)

Both the TAR and PRM radar data showed an apparent rapid descent from an altitude of 4,340 ft at 1326:09 UTC to an altitude of 1,540 ft at 1326:29 UTC. This equated to an average rate of descent of 8,400 fpm and a decrease in altitude of 2,800 ft. At a groundspeed of 250 kts, a flight path angle of -45° for a period of 20 seconds would produce an altitude decrease of this magnitude. The SA227 aircraft is aerodynamically clean and could be expected to gain speed quickly with a negative flight path angle.

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43 *Development of a Supplemental Inspection Document for the Fairchild SA226 and SA227 Aircraft, Part 1*. DOT/FAA/AR-99/20, P1. September 1999.

44 From *Company Operations Manual* Section B10-0-11.

45 Knots Indicated Airspeed.

46 Knots Equivalent Airspeed (i.e. IAS adjusted for compressibility effects).

Recorded groundspeed is derived from the rate of change of aircraft position data as detected by the radar. The recorded groundspeed data is derived from the rate of change of aircraft position between successive antenna scans. When the aircraft changes speed, there will be a time lag before this is reflected in the recorded groundspeed. Once radar returns are again received after a series of missed returns, the groundspeed data may be initially unreliable until position data from several returns has been averaged. Given these constraints, the groundspeed at the end of the descent would have been in the order of 300 kts and the indicated airspeed would have been a similar value.

During a descent, typically the groundspeed would increase and the Mode C altitude would decrease. Groundspeed was derived from the rate of change of aircraft position and was independent of the Mode C altitude returns. A correlation between a change in groundspeed and Mode C altitude is evidence that an apparent descent was a real descent. This correlation existed in this case as the groundspeed had increased and the Mode C altitude had decreased.

An estimate of the load factor required to arrest the aircraft's descent and initiate a climb was calculated[47]. A load factor of approximately 2 g maintained for 15 seconds would achieve the necessary change in vertical speed to arrest the descent and initiate the climb. The estimated load factor value is sensitive to changes in the time period the positive load factor would need to have been maintained. As the aircraft would have needed to be substantially wings-level during the transition from a descent to a climb, the chance of the TAR and PRM successfully receiving SSR returns would have increased. The TAAATS data shows that SSR returns were regained before the aircraft began to climb.

Climb manoeuvre (1326:29 UTC to 1326:49 UTC)

Both the TAR and PRM radar data showed an apparent rapid climb from an altitude of 1,540 ft at 1326:29 UTC to an altitude of 4,340 ft at 1326:49 UTC. This equated to an average rate of climb of 8,400 fpm and an increase in altitude of 2,800 ft. This rate of climb exceeded the aircraft's sustained rate of climb capability, but was possible with a zoom climb where kinetic energy (groundspeed) is exchanged for potential energy (i.e. altitude) [48]. A reduction in groundspeed of approximately 125 kts could provide an altitude gain, by itself, of 700 ft. In addition, while the airspeed remained at a larger than normal value, the wings would have been capable of providing more lift and therefore a greater than normal climb capability[49].

During a climb, typically the groundspeed would decrease and the Mode C altitude would increase. Groundspeed was derived from the rate of change of aircraft position and was independent of the Mode C altitude returns. A correlation between

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47 $acceleration = \Delta v / \Delta t$ where Δv is the change in velocity (metres/sec) and Δt is the time interval (*seconds*) over which the change in velocity takes place. The vertical component of the change in velocity was estimated using Mode C altitude values, while the horizontal component was estimated using groundspeed.

48 $\Delta h = (\Delta v)^2 / 2g$ where Δh is the change in altitude (metres), Δv is the change in speed (metres/sec) and g is the acceleration due to gravity (9.81 metres/sec^2). This technique ignores the effects of aerodynamic drag and engine thrust. The resultant effect of these forces may be positive (net thrust) or negative (net drag).

49 Lift is proportional to the square of the airspeed.

a change in groundspeed and Mode C altitude is evidence that an apparent climb was a real climb. This correlation existed in this case as the recorded groundspeed at the end of the climb had decreased to 178 kts (approximately 175 KIAS).

Descent manoeuvre (1326:56 UTC to 1327:19 UTC)

Both the TAR and PRM radar data showed an apparent rapid descent from an altitude of 4,340 ft at 1326:56 UTC, until Mode C returns were lost at 1327:00 UTC at an altitude of 3,740 ft. The final reasonable primary return was recorded at 1327:19 UTC. The aircraft impact with the water is considered to have occurred shortly after this time. This indicated an average rate of descent of approximately 10,400 fpm.

During salvage operations, the wreckage field was found at a central location of 34º 5.76’ S and 151º 14.12’ E. This was close to the position of the final primary return recorded at 1327:19 UTC. The orientation of the wreckage field was noted to be in a similar direction as the final series of reasonable radar returns.

Loss of secondary radar returns

Examination of the radar returns showed that there were two periods where secondary radar returns were lost from both the PRM and TAR; 1326:20 UTC until 1326:27 UTC and from 1327:09 UTC onwards.

Table A-15: Loss of secondary returns from 1326:20 UTC until 1326:27 UTC

Possible reason for loss of secondary returns:	Likelihood:
Secondary radar sensor failure	Unlikely, as returns from VEU were successfully recorded during this period and the PRM and TAR are independent radar sensors.
Aircraft was outside of the range of the radar	Nil, as OZA was well within the range of both the PRM and TAR.
Aircraft transponder was not switched on	Unlikely, as the transponder was operating satisfactorily before and after the period of the temporary loss of returns.
Aircraft transponder was unserviceable	Unlikely, as the transponder was operating satisfactorily before and after the period of the temporary loss of returns.
Loss of aircraft power to the transponder	Unlikely, as the transponder was operating satisfactorily before and after the period of the temporary loss of returns.

Terrain shielding	Nil, as there was line-of-sight between the aircraft and PRM and TAR antennas.
Aircraft transponder aerial was shielded from the radar (or received signal strength was reduced) due to aircraft manoeuvring	Probable, as the aircraft underwent a rapid descending manoeuvre during the period of the loss of secondary returns.

Table A-16: Loss of secondary returns from 1327:09 UTC onwards

Possible reason for loss of secondary returns:	Likelihood:
Secondary radar sensor failure	Unlikely, as returns from VEU were successfully recorded during this period and the PRM and TAR are independent radar sensors.
Aircraft was outside of the range of the radar	Nil, as OZA was well within the range of both the PRM and TAR.
Aircraft transponder was not switched on	Unlikely, as it is normal practice to leave a transponder switched on throughout a flight.
Aircraft transponder was unserviceable	Unlikely, as the transponder was operating satisfactorily before the loss of returns.
Loss of aircraft power to the transponder	Possible.
Terrain shielding	Nil, as there was line-of-sight between the aircraft and the PRM and TAR antennas.
Aircraft transponder aerial was shielded from the radar (or received signal strength was reduced) due to aircraft manoeuvring	Probable, as the final few secondary (Mode C) returns showed that the aircraft had entered a rapid descent. Several further primary returns were received before they were lost as well. The loss of primary returns (after 1327:19 UTC) is consistent with the aircraft having impacted the water. The wreckage survey showed that the wreckage field was in the vicinity of the last reasonable primary return.

Aircraft electrical system

For a ground-based secondary radar sensor (i.e. TAR or PRM) to successfully receive a return, the aircraft's transponder system must be powered, switched on and serviceable.

The transponder system comprises:

- transponder No.1 or No. 2 (only one unit is active at any time)
- encoding altimeter and
- cockpit control unit.

Transponder No.1 was powered from the 28 VDC Left Hand Essential bus. Transponder No.2 was powered from the 28 VDC Right Hand Essential bus. It was not possible from the radar data to determine which transponder was selected. The last secondary return from OZA was received at 1327:09 UTC. This is evidence that the transponder system was powered, switched on and serviceable until at least that time.

The pilot successfully communicated with ATC using VHF radio until 1325:59 UTC. OZA was equipped with two VHF radios. This is evidence that at least one VHF radio was powered and serviceable until at least 1325:59 UTC.

At 1327:05 UTC, a pilot of VEU reported sighting OZA. This is evidence that the navigation lights of OZA were powered and serviceable until at least that time.

CONCLUSIONS

3.1 Data files containing recorded TAAATS radar returns were obtained from Airservices Australia. Recorded radar returns for OZA were extracted from the data files.

3.2 Examination of the data showed that returns from OZA had been received from four radar sensors: Sydney TAR (primary and secondary), PRM (secondary) and Mount Boyce (secondary).

3.3 The initial return was recorded at 1321:59 UTC when the aircraft was stationary on taxiway golf adjacent to runway 16R. The final (primary) return was recorded at 1327:19 UTC and corresponded to a position near where the wreckage field was discovered during salvage operations.

3.4 At 1324:33 UTC, OZA intercepted the 168 radial, but then turned left. This was not in accordance with its ATC clearance (Sydney curfew two departure - track along the 168 radial).

3.5 At 1325:28 UTC, OZA was levelled at around 3,000 ft for 30 seconds; however, it had earlier been cleared by ATC to climb to FL170.

3.6 The radar data subsequently showed evidence of a right turn, then a left turn, followed by a descent, a climb, a right turn and a second descent. The apparent rates of descent, climb and turn during these manoeuvres showed that controlled flight was not continuously maintained.

3.7 During both descents there were missing transponder (secondary) radar returns. The most likely reason for the loss of returns was shielding of the aircraft's transponder aerial from the ground-based SSR sensor (or significantly reduced received signal strength), due to aircraft manoeuvring.

3.8 The last secondary return from OZA was received by TAAATS at 1327:09 UTC. This was evidence that the aircraft transponder system (the selected transponder i.e. either No.1 or No.2, the encoding altimeter and the control unit) was powered, switched on and serviceable until at least that time.

3.9 It is likely that the aircraft impacted the water shortly after the last reasonable primary return was recorded at 1327:19 UTC.

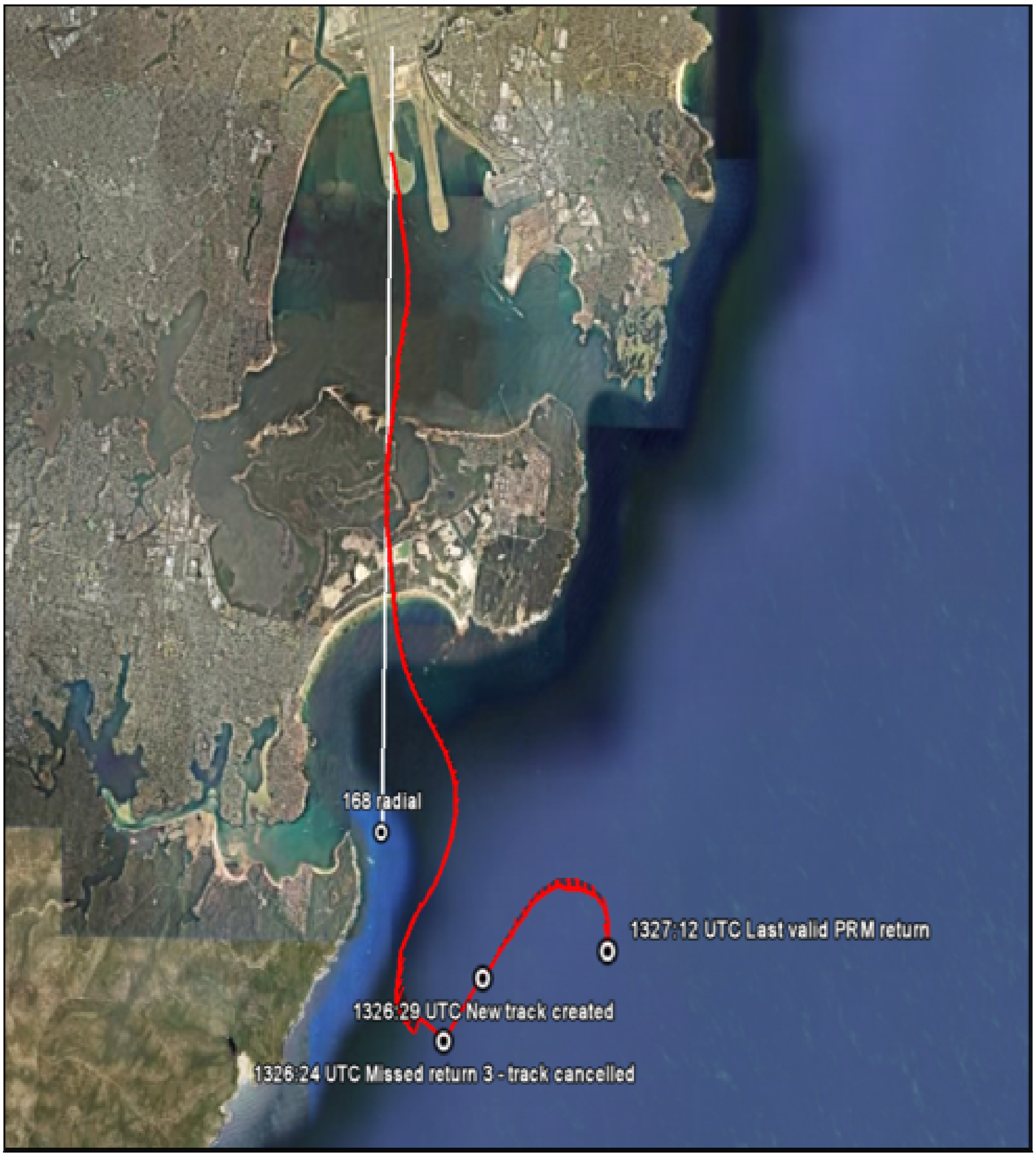
3.10 No evidence was found of any problems with the performance of TAAATS, in particular the performance of the Sydney TAR and PRM.

3.11 The manoeuvres recorded by TAAATS for OZA were unusual, but the aircraft performance was not unprecedented. No reason was found to discount the radar evidence.

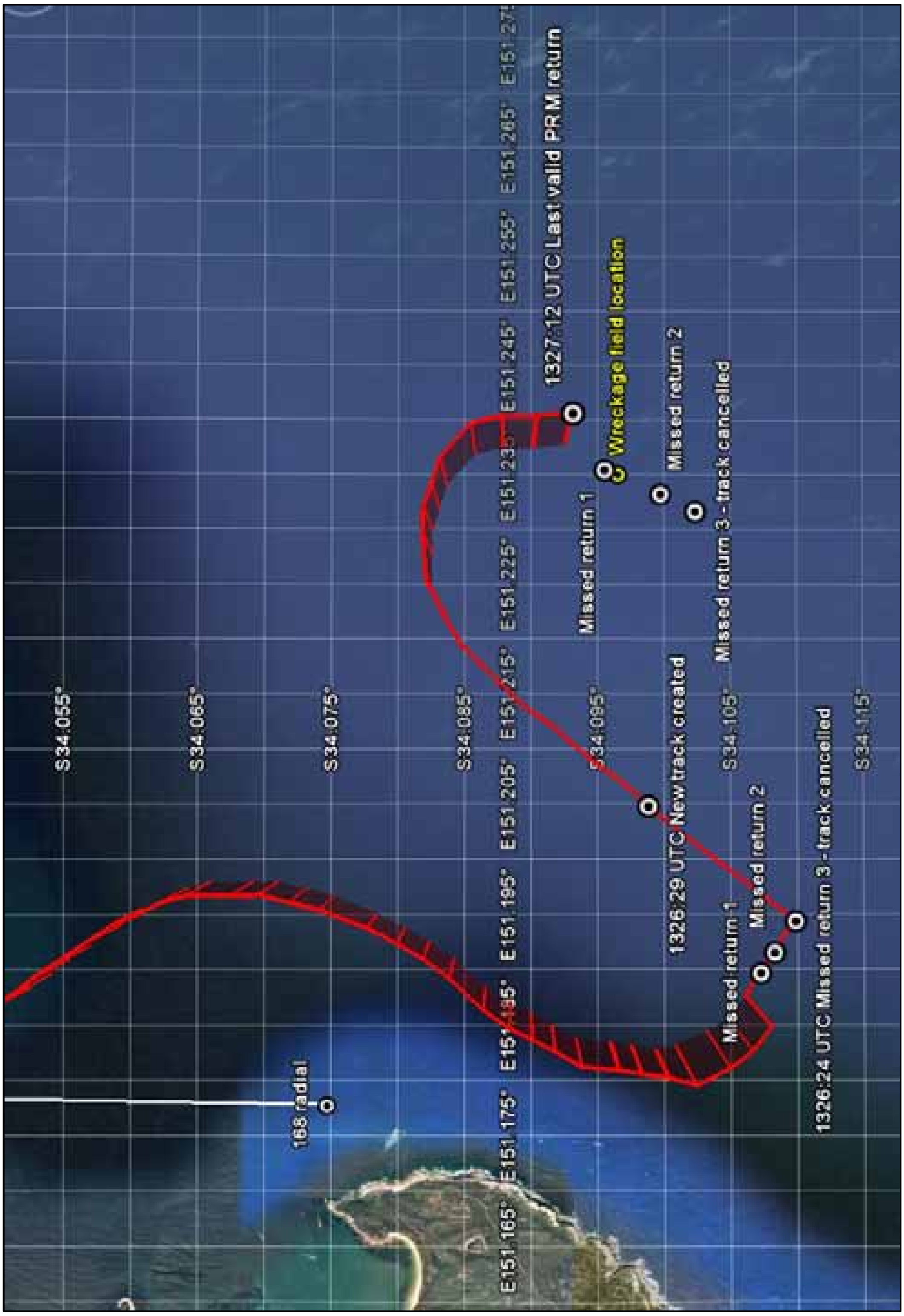
ATTACHMENTS

Attachment A-4.1	PRM track plot_entire period.bmp
Attachment A-4.2	PRM track plot_final period.bmp
Attachment A-4.3	TAR track plot_entire period.bmp
Attachment A-4.4	TAR track plot_final period.bmp
Attachment A-4.5	Combined PRM and TAR track plot_entire period.bmp
Attachment A-4.6	Combined PRM and TAR track plot including VEU_final period.bmp
Attachment A-4.7	Data Plot_TAR.bmp
Attachment A-4.8	Data Plot_PRM.bmp
Attachment A-4.9	Radar Data Listing.xlsx

Attachment A-4.1: PRM track plot entire period



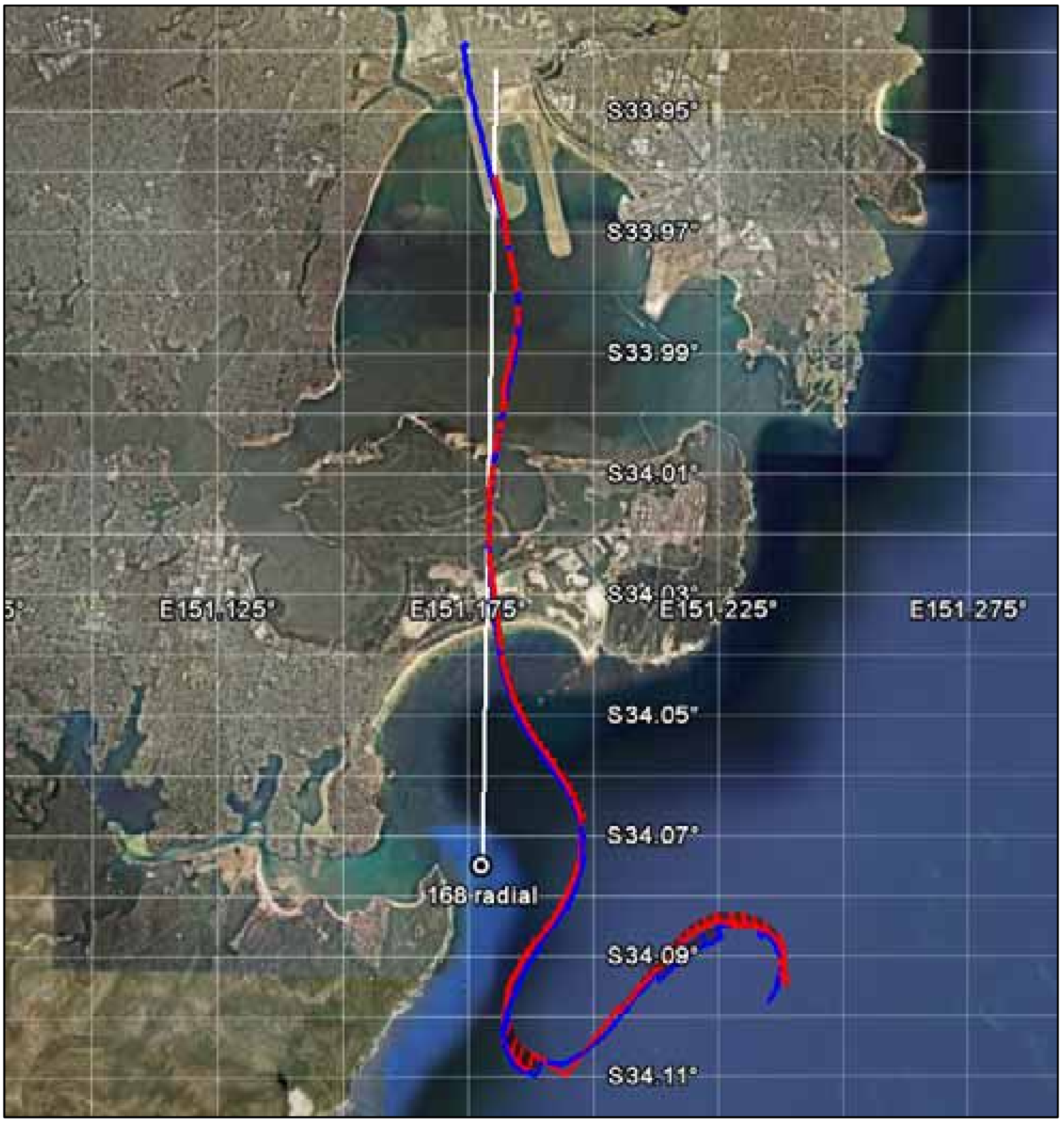
Attachment A-4.2: PRM track plot_final period



Attachment A-4.3: TAR track plot entire period

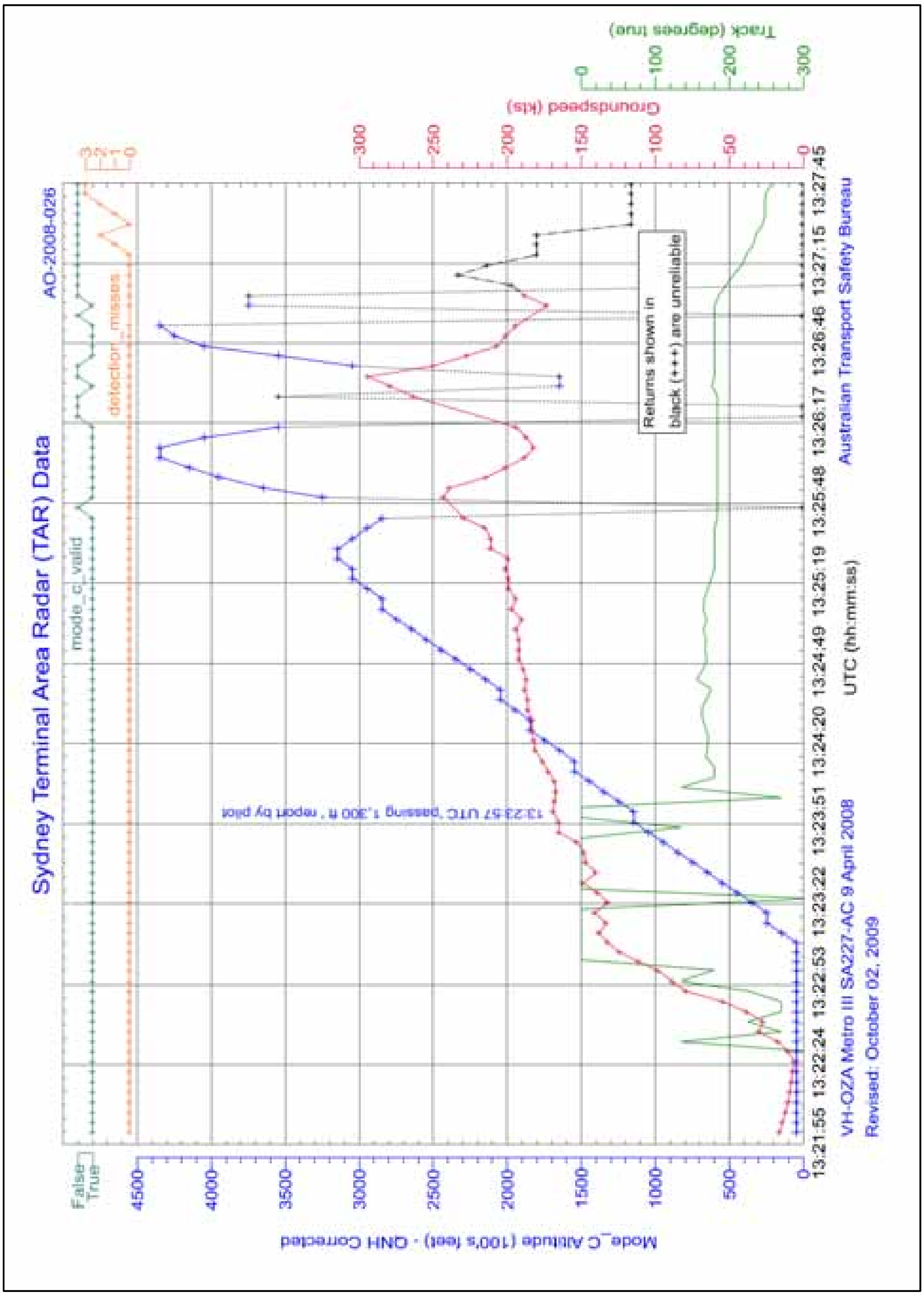
Attachment A-4.4: TAR track plot_final period

Attachment A-4.5: Combined PRM and TAR track plot entire period

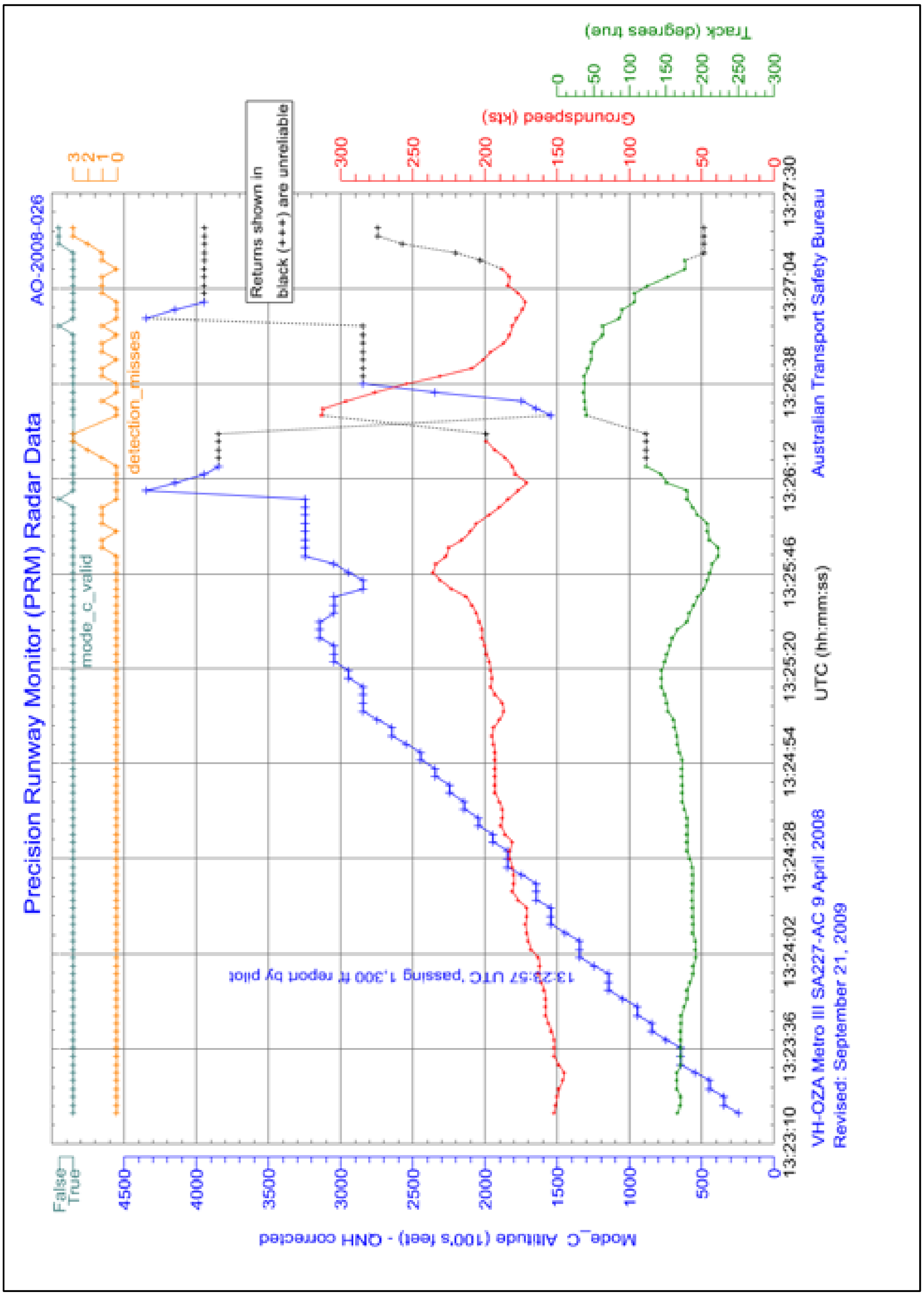


Attachment A-4.6: Combined PRM and TAR track plot including VEU_final period

Attachment A-4.7: Data Plot_TAR



Attachment A-4.8: Data Plot_PRM



APPENDIX B: FLIGHT RECORDER INFORMATION

ATSB TECHNICAL ANALYSIS
AO-2008-026

Collision with water – 19km SE of Sydney Airport – 09 April 2008

Fairchild SA227-AC, VH-OZA

Flight Recorder Download & Analysis

Duncan Bosworth
Senior Transport Safety Investigator – Engineering

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

SUMMARY

On 09 April 2008, a Fairchild Metro III aircraft, registered VH-OZA, crashed into the ocean shortly after takeoff from Sydney (Kingsford-Smith) Airport. The Australian Transport Safety Bureau (ATSB) recovered the flight recorders fitted to VH-OZA from the ocean floor on 27 and 29 June 2008. The flight recorders comprised a flight data recorder (FDR) and a cockpit voice recorder (CVR).

The data and audio from the FDR and CVR were able to be recovered in their entirety from the respective recorders following their underwater retrieval. The FDR recorded the last 25 hours of flight data leading up to (but not including) the accident flight, with no BITE[50] faults recorded. Similarly, the CVR recorded the last 30 minutes of audio data to a high quality prior to (but not including) the accident flight. The recorders powered down normally at the time of the last engine shutdown and not as a result of 'G' switch activation.

Neither of the recorders had been powered up at any time during the accident flight.

[50] Built-in Test Equipment.

INTRODUCTION

This report details the disassembly and download of the flight recorders recovered from the underwater wreckage field of VH-OZA. The flight recorders fitted to VH-OZA were a flight data recorder (FDR) and Cockpit Voice Recorder (CVR). This report describes the data recovered from the FDR and CVR and provides an analysis of its contents.

Scope of the examination

The FDR and CVR were recovered during underwater salvage operations on 27 and 29 June 2008. The recorders were transported (immersed in fresh water) to the Australian Transport Safety Bureau's (ATSB's) Technical Analysis facilities in Canberra on 30 June 2008. The scope of the examination was to download and analyse the data contained on the flight recorders.

Recorder requirements

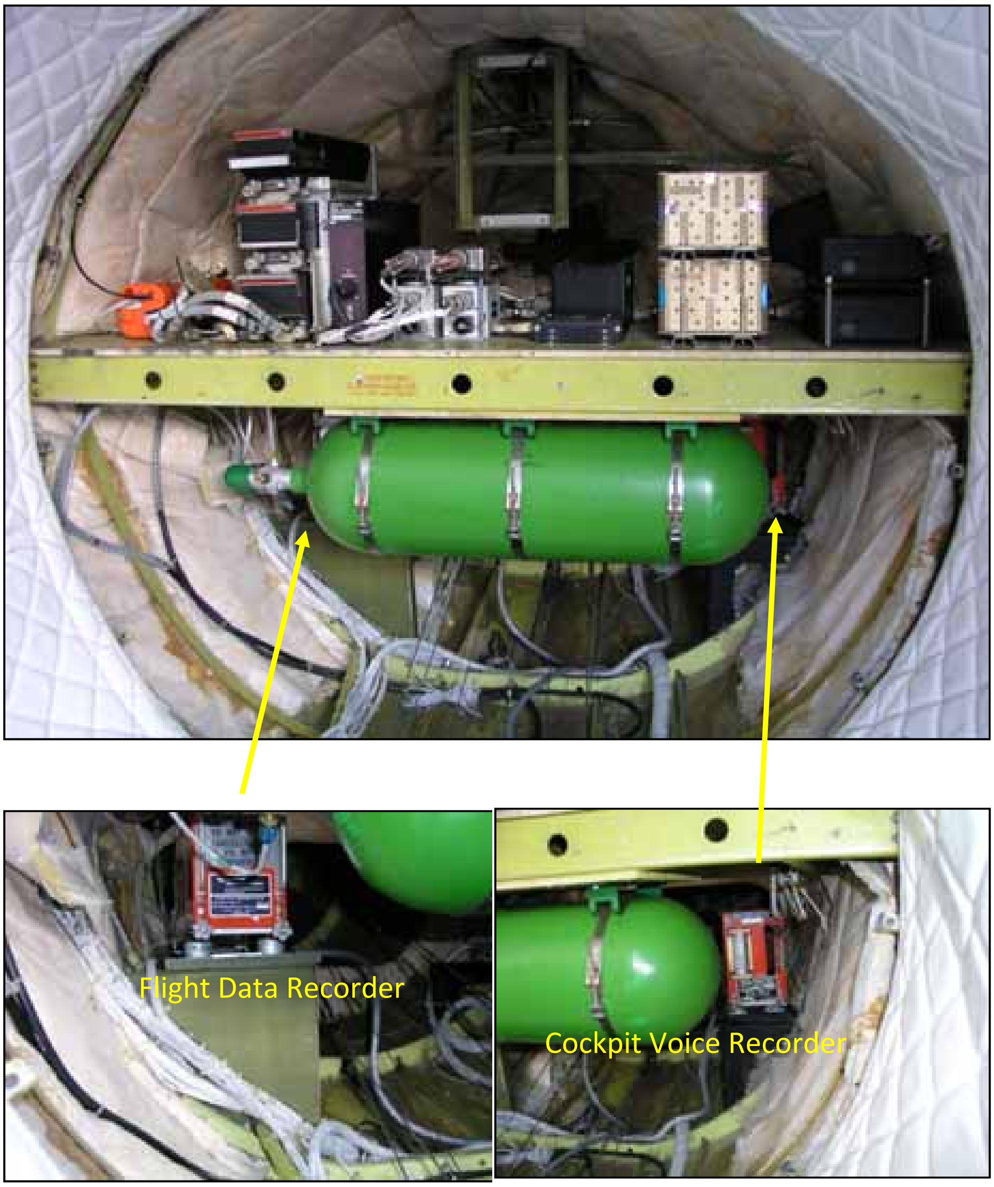
Flight recorder carriage requirements for Australian-registered aircraft were specified in Civil Aviation Safety Authority (CASA) Civil Aviation Order (CAO) 20.18. Since the maximum take-off weight of VH-OZA was greater than 5,700 kg, the aircraft was required to carry an approved FDR and CVR. The FDR and CVR fitted to VH-OZA were approved units. The FDR parameters that were required to be recorded (i.e. mandatory parameters) were specified in Appendix I of CAO 103.19. The FDR fitted to VH-OZA 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) for a duration of 25 hours. The CVR was required to record voice transmissions for a minimum duration of 30 minutes. The flight recorders fitted to VH-OZA met these minimum requirements.

Aircraft installation of recorders

On 4 September 1991, the CVR was installed while the aircraft was registered and being operated in the United States (US). On 3 March 1998, the FDR was installed following the importation of the aircraft into Australia. The installation authorisation was done citing an approved engineering facility drawing and an approved avionics facility wiring diagram.

In Metro III aircraft, the flight recorders were installed in the rear fuselage, behind a removable panel at the rear of the baggage compartment (Figure B-1).

Figure B-1: Metro III rear fuselage behind removable panel looking aft showing the typical location of the flight recorders



The recorders were located aft of the rear cargo bulkhead. Two separate ‘G’ switches (inertia switches) were fitted to the aircraft, most likely mounted on the rear avionics shelf near the flight recorders. The G switches were designed to interrupt power to the FDR and CVR to preserve the recording should the aircraft experience excessive G-force. Both recorders were powered by 115 VAC via two circuit breakers; the CVR on the left bus and the FDR on the right bus.

Flight data recorder receipt

The FDR was received at the ATSB's Technical Analysis facilities on 30 June 2008, securely sealed within a waterproof container (Figures B-2 and B-3).

Figure B-2: FDR sealed in container prior to opening, as received at the ATSB

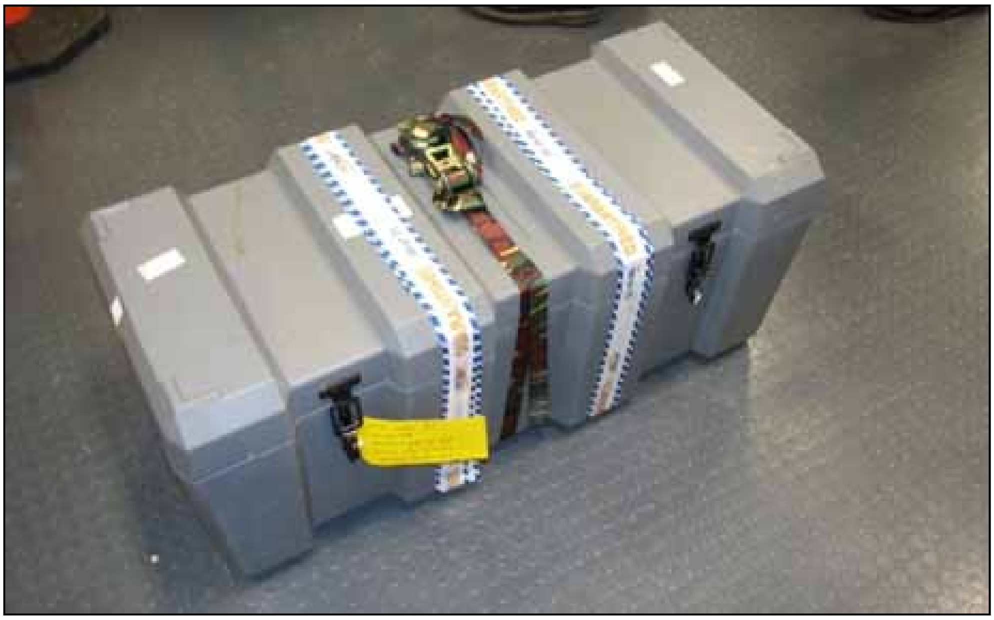
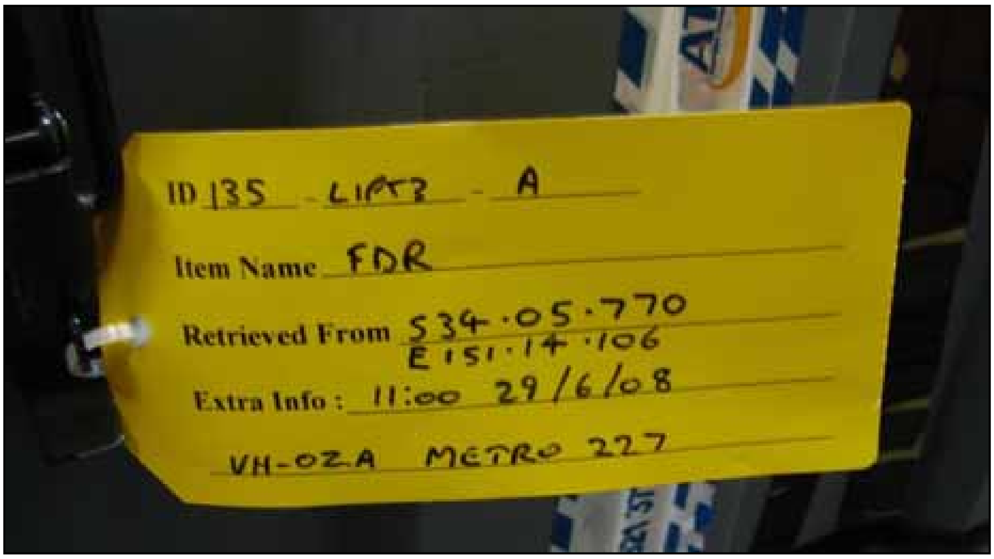


Figure B-3: FDR container security

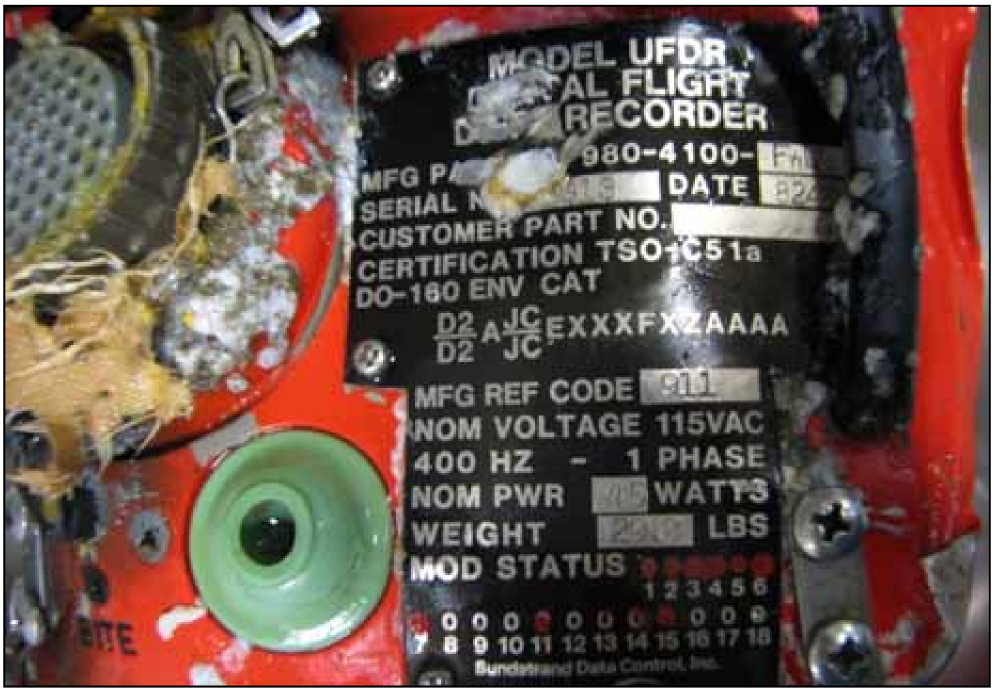


Upon opening of the container, the FDR was found to be immersed in water, as-packed (Figure B-4).

Flight data recorder identification

On 2 July 2008, the FDR was removed from the shipping container and examined. The recovered FDR was identified from the manufacturer's data plate as a Sundstrand Data Control (now Honeywell Aerospace) model Universal Flight Data Recorder (UFDR), part number 980-4100-FWUS, serial number 1313 (Figure B-5). The maintenance records for VH-OZA confirmed that this FDR was fitted to VH-OZA at the time of the accident.

Figure B-5: FDR data plate



Flight data recorder disassembly

The FDR had been subjected to substantial impact forces and saltwater immersion, which had resulted in extensive damage to the recorder, including a fracture of the crash-protected enclosure and wiring damage. Some discolouration of the external paint was observed. Analysis of the paint discolouration was the subject of a separate materials examination (see Appendix C). The recorder was dismantled (Figures B-6 to B-12) and the recording tape was extracted from the crash protected enclosure for replay.

Figure B-6: VH-OZA's FDR during disassembly showing the crash protected enclosure and associated electronics

Figure B-7: FDR crash protected enclosure showing fracture damage (arrowed)

Figure B-8: Removed crash protected enclosure

Figure B-9: Crash protected module opened

Figure B-10: Tape assembly within crash protected enclosure

Figure B-11: Tape adhesion to tape transport heads

Figure B-12: Tape removed from FDR rinsed and cleaned and on spools

The tape was in reasonable condition and, after cleaning, was replayed using the ATSB's FDR analysis workstation. No evidence of heat or fire damage was found during disassembly of the crash protected module.

Flight data recorder aircraft installation

The Honeywell UFDR had been installed in the SA227-AC aircraft to record six mandatory flight parameters – magnetic heading, airspeed, altitude, normal acceleration, microphone keying and elapsed time (Table B-1) – and was capable of recording at least 25 hours of aircraft operation in a digital format.

Table B-1: Recorded parameters information

Parameter	Sensor
Mandated flight parameters	
Magnetic heading	5-wire synchro
Airspeed	Pneumatic input from copilot's pitot and static pressure lines
Altitude	Pneumatic input from copilot's static pressure line. Scaling of this parameter is dependent on the transducer type fitted to the UFDR.[51]

[51] The altitude transducer fitted to the UFDR was 3000-0424-001/002/003. The recorded transducer P/N was 3000-0424-001/002/003.

Normal acceleration	Accelerometer
Microphone keying	VHF1 and VHF 2 keying from co-pilots audio panel
Elapsed time	Internal clock
Recorder operation information	
Altitude transducer type	Used for altitude scaling
Ambient temperature	Sensor mounted on altitude transducer to calculate barometric pressure
Built-in-test-equipment (BITE)	Internal recorder

The UFDR incorporates built-in-test equipment and results of faults are stored each second in word 63 of the FDR, which contains a check-word. The individual bits of the check-word are set and reset to indicate the results of the built-in test routines.

Recovered flight data

The tape recovered from the FDR contained over 25 hours of good quality digital signals recorded across all eight channels/ tracks (Figure B-13 and Table B-2).

Figure B-13: UFDR tape configuration

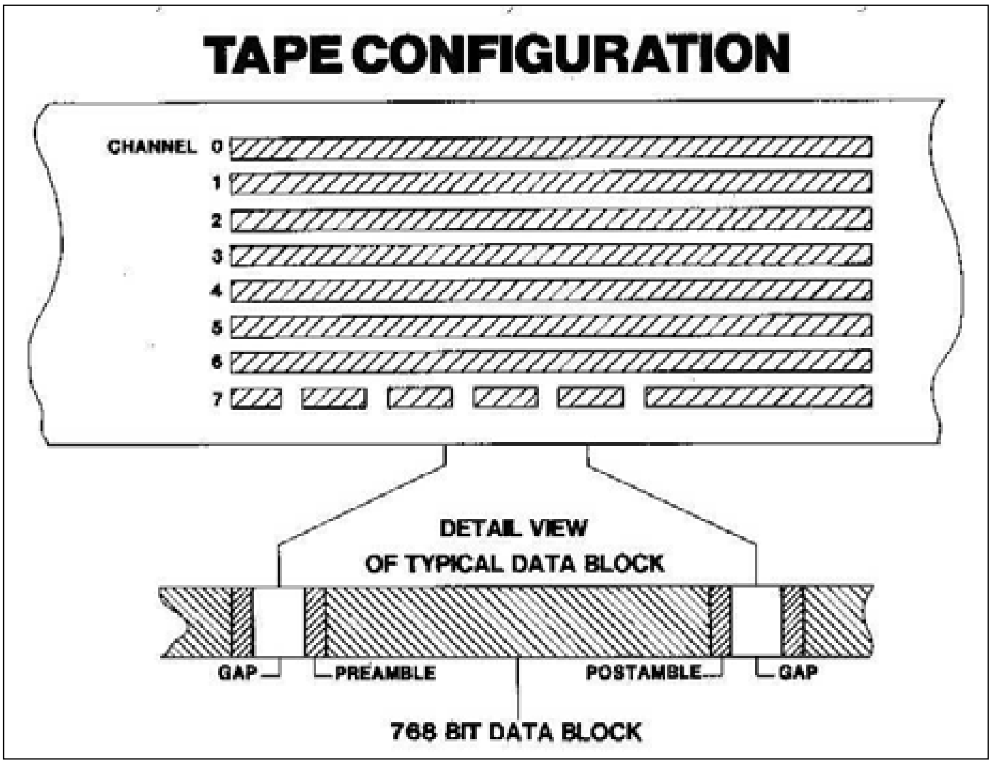


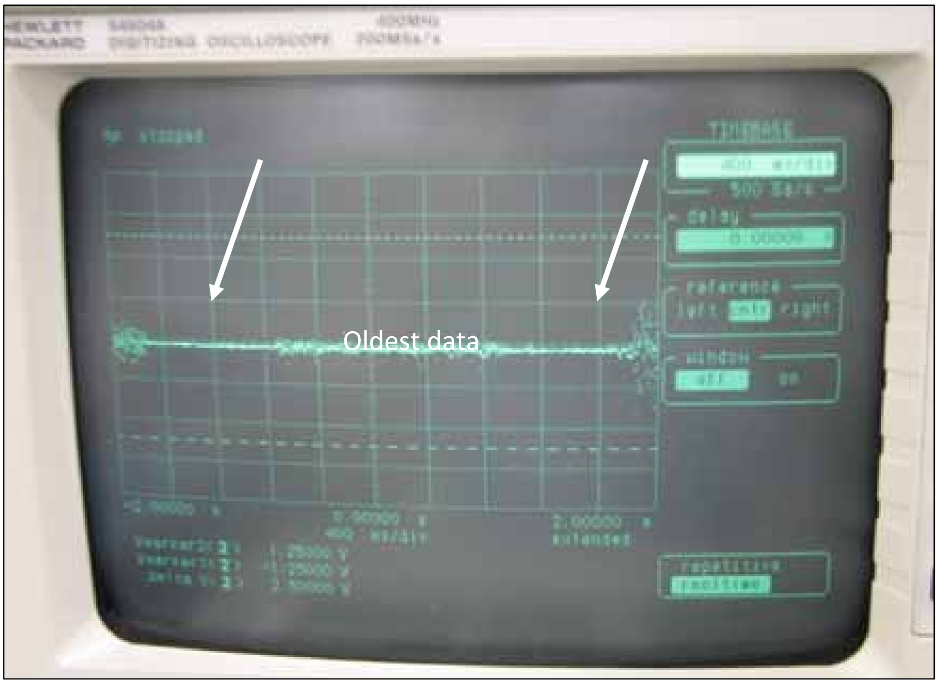
Table B-2: UFDR Channel and HP Recorder mapping

UFDR Channel	HP3968A Instrumentation Recorder Track
0	8
1	7
2	6
3	5
4	4
5	3
6	2
7	1

At the location where the tape had stopped and the tape had adhered to the heads (at about 3,900 secs from one end of the tape and 7,400 secs from the other) the tape signal strength was reduced across all tracks (Figure B-14). During the analogue to digital conversion, the recovery stalled and had to be restarted. The recovery was restarted after the reduced signal strength location, resulting in approximately 33 seconds of data[52] per track not being recovered at this point. The damage to the tape at this location was considered to be a consequence of magnetic tape and head corrosion damage due to water immersion for over 2 months.

[52] Period not recovered was approximately 3.6s of tape on HP3968A recorder with tape speed of 3.75 inches-per-second (ips), equating to 13.5 inches of tape. The UFDR records at 0.41 inches per second of data so this equated to an actual time period of 32.93 seconds of data per track.

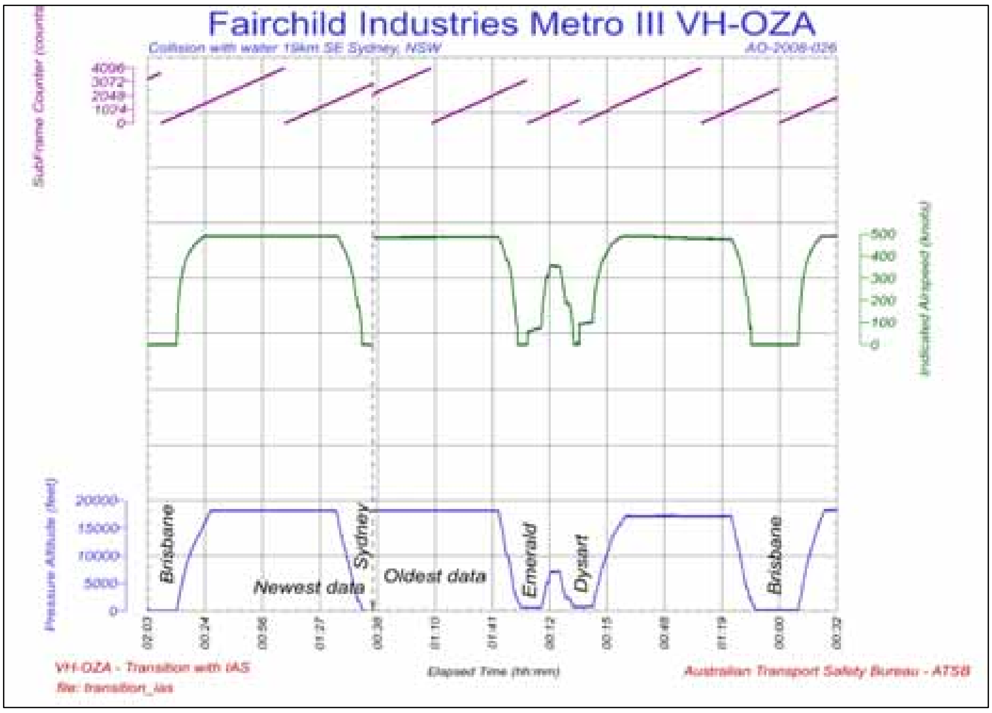
Figure B-14: Oscilloscope screenshot of Track 6 at location of tape stoppage (i.e. transition from newest to oldest data). Reduced signal strength arrowed. This was typical across all eight tracks



Additional work was undertaken on track 6 only to recover as much data as possible. There is a gap of approximately 1 inch between the erase and read/write heads on the FDR tape transport, and only about 3.75 inches of tape could not be recovered (denoted by the arrows above). Therefore, since the tape between the heads had been erased, only 2.75 inches of tape was not recovered, which equated to 6.7 seconds of recorded data. Typically a 3-second distance between data blocks occurs between the end of one flight and the start of another. Therefore, in reality only about 3.7 seconds of data were potentially not available from the final flight. It was considered unlikely that this would include a period of FDR activation.

All parameters recorded on the FDR were serviceable, with the exception of indicated airspeed (IAS). The IAS was recorded at an unreasonably high value, and increased as the aircraft climbed until the top of climb, where it remained steady during the cruise. The IAS reduced during descent. The IAS therefore changed in conjunction with altitude or static air pressure only. This characteristic was evident across the entire FDR recording.

Figure B-15: Plot of airspeed and IAS over a number of flights



The transition from oldest to newest recorded information was confirmed by examination of all tracks and found to have occurred on Track 6[53] (Figure B-16).

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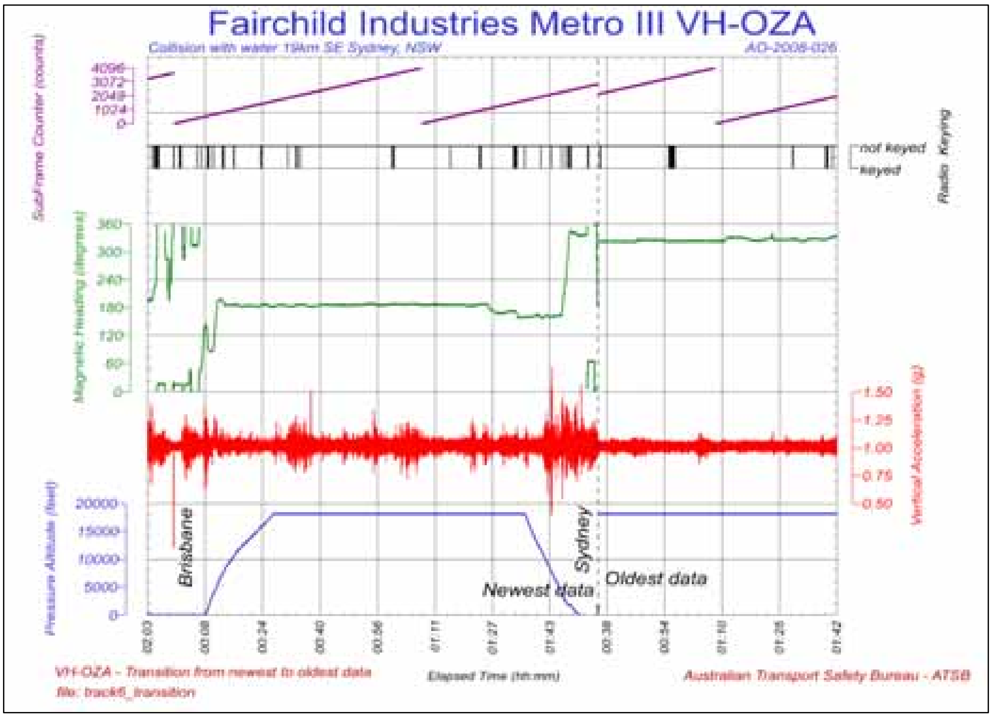
53 Track 6 of the ATSB's HP3968A Instrumentation Recorder equates to UFDR track 2 (see Table B-2)

Figure B-16: FDR parameters showing entire Track 6 containing transition from newest to oldest data



The last flight recorded on the FDR was examined. The timing, track and runway headings indicated this was a flight from Brisbane Airport to Sydney Airport. The aircraft cruised at an altitude of 18,000 ft, made an approach and landed on runway 34 at Sydney, then taxied to the north-east and parked. The recording then stopped as would occur during a normal engine shutdown. The data then recommenced (oldest data) with the aircraft in a 18,000 ft cruise approximately 37 minutes into a flight tracking towards the north-west.

Comparison of recorded flights with the aircraft trip record

Since the FDR recorded only elapsed time (since FDR power-up) and not absolute (UTC[54]) date and time, the aircraft trip logs were examined (Table B-3 and B-4) and compared with data from the other seven tracks of the FDR, to ascertain exactly when the last recorded flight occurred.

54 Universal Time Coordinated.

Table B-3: Information regarding previous flights obtained from VH-OZA aircraft log

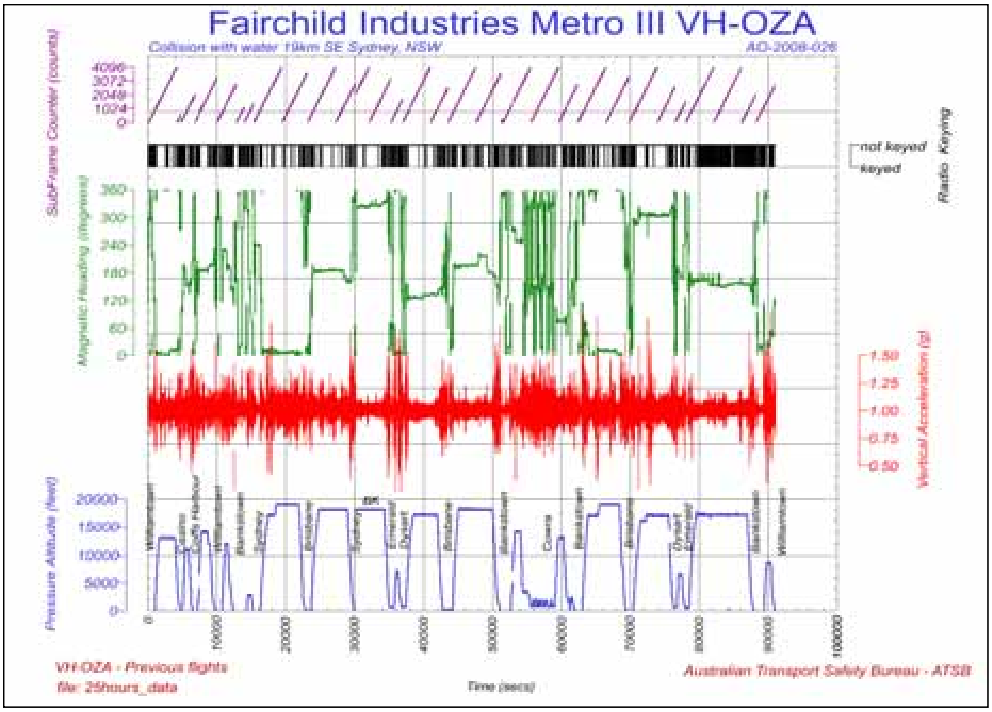
Log Book page	Date	Departure	Time (hh:mm)	Arrival	Time (hh:mm)	Flight Time (hh:mm)	Total log book page time	Trend Data	IAS
8963	9/04/2008	BN	03:21	SY	05:05	01:44	03:47	FL170	200
	9/04/2008	SY	00:18	BN	02:06	01:48			
	8/04/2008	BK	22:40	SY	22:55	00:15			
8962	8/04/2008	WLM	18:26	BK	18:50	00:24	02:57	FL130	198
	8/04/2008	CFS	17:07	WLM	17:47	00:40			
	8/04/2008	CAS	10:12	CFS	10:36	00:24			
	8/04/2008	WLM	08:51	CAS	09:50	00:59			
	8/04/2008	BK	07:20	WLM	07:50	00:30			
8961	7/04/2008	EML	19:10	BK	21:47	02:37	06:22	FL170	200
	7/04/2008	DYS	18:00	EML	18:20	00:20			
	7/04/2008	BN	15:50	DYS	17:30	01:40			
	7/04/2008	BK	13:20	BN	15:05	01:45			
8960	5/04/2008	CWR	19:24	BK	20:15	00:51	02:09	FL140	200
	5/04/2008	BK	17:35	CWR	18:53	01:18			
8959	3/04/2008	BN	16:46	BK	18:40	01:54	06:42	FL180	190
	3/04/2008	DYS	14:28	BN	16:00	01:32			
	3/04/2008	EML	13:40	DYS	13:56	00:16			
	3/04/2008	SBK	09:49	EML	12:49	03:00			
						TOTAL	**21:57**	hours	

Table B-4: Aircraft codes with runway headings

Aircraft Code	Location	State	Rwy headings	Runways
B(BN)	Brisbane	Qld	016/196 & 134/314	01/19 & 14/32
S(SY)	Sydney	NSW	155/335 & 062/242	16/34 & 07/25
S(BK)	Bankstown	NSW	111/291	11/29
WLM	Williamtown	NSW	118/298	12/30
CFS	Coffs Harbour	NSW	029/209	03/21
EML	Emerald	Qld	062/242	06/24
DYS	Dysart	Qld	137/317	14/32
CWR	Cowra	NSW	150/330	15/33
CAS	Casino	NSW	094/274	10/28

The runway heading for takeoff and landing were examined as well as flight duration and cruise headings. The data matched exactly the sectors noted in the trip log and it was therefore confirmed that the last recorded flight was the Brisbane to Sydney flight on the morning of 9 April 2008 (Figure B-17) immediately preceding the accident flight.

Figure B-17: Entire 25 hours VH-OZA FDR data showing destinations



The sectors detailed in the aircraft log book for the previous 25 hours prior to the accident flight were confirmed as being recorded continuously on the FDR (Figure B-18). The eight FDR tracks contained 25.28 hours of data. This elapsed time data comprised time when the recorder was powered up, and was consequently greater than the aircraft log recorded flight time (wheels off – wheels on) (Table B-5). Calculations from the FDR power-up elapsed time gave a total of 25.42 hours, which equated to approximately 65 seconds per track in missing/bad data (0.55%).

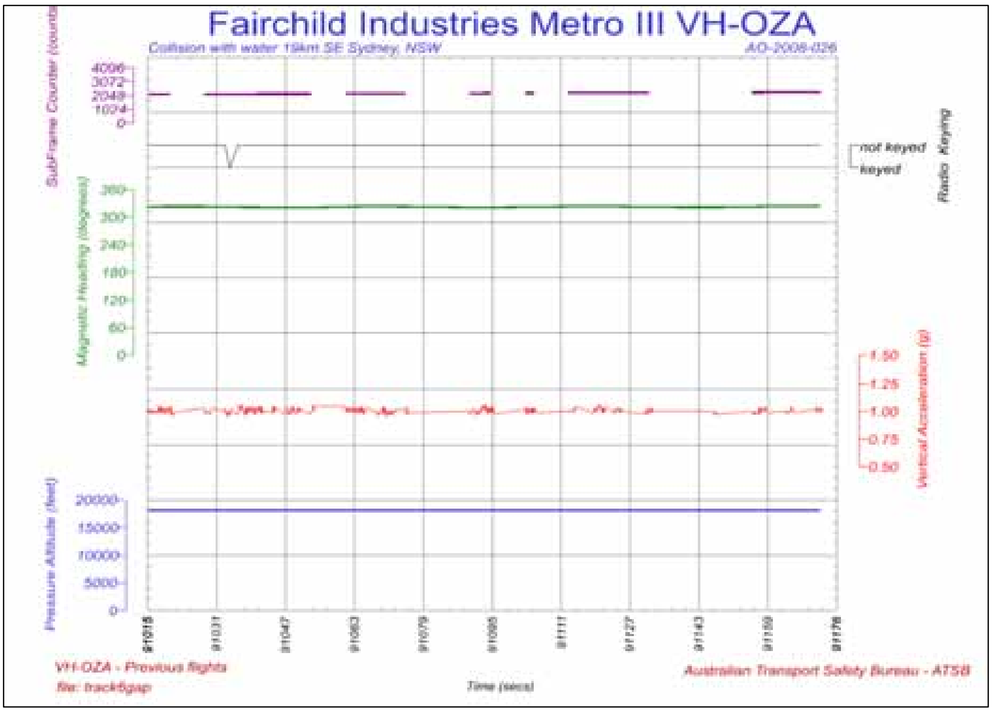
Approximately 33 seconds of this was accounted for at the tape stoppage location, which was skipped during the recovery on all tracks except track 6.

Table B-5: Comparison of flight information from log book and FDR (highlighted)

Log Book page	Date	Departure	t/o dirn	Time (hh:mm)	Arrival	ldg dirn	Time (hh:mm)	Flight Time (mm:ss)	Total log book page time	Trend Data	IAS	Cruise Level	Cruise Heading	HP3968A track number	FDR Elapsed Time (secs)	FDR Elapsed Time (hrs)	Track	Recovered Track time (secs)	
8963	9/04/2008	BN	134	03:21	SY	335	05:05	01:44	03:47	FL170	200	FL180	South	6	7003	1.95	6	11377	
	9/04/2008	SY	155	00:18	BN	196	02:06	01:48				FL170/ FL190	North	7	7812	2.17	7	11374	
	8/04/2008	BK	110	22:40	SY	62	22:55	00:15				FL027	SE	7	2602	0.72	8	11346	
8962	8/04/2008	WLM	118	18:26	BK	111	18:50	00:24	02:57	FL130	198	FL120	SW	8 & 7	2781	0.77	1	11406	
	8/04/2008	CFS	209	17:07	WLM	118	17:47	00:40				FL140	South	8	3292	0.91	2	11382	
	8/04/2008	CAS	94	10:12	CFS	209	10:36	00:24				FL110	South	8	2021	0.56	3	11375	
	8/04/2008	WLM	118	08:51	CAS	274	09:50	00:59				FL130	North	8	4688	1.30	4	11380	
	8/04/2008	BK	111	07:20	WLM	118	07:50	00:30				FL087	NNE	1 & 8	2909	0.81	5	11375	
8961	7/04/2008	EML	62	19:10	BK	111	21:47	02:37	06:22	FL170	200	FL170	SSE	2 & 1	10264	2.85	TOTALS	91015	secs
	7/04/2008	DYS	137	18:00	EML	242	18:20	00:20				FL065	South	2	1552	0.43		25.28	hrs
	7/04/2008	BN	196	15:50	DYS	137	17:30	01:40				FL160/ FL170	NW	2	6744	1.87			
	7/04/2008	BK	111	13:20	BN	196	15:05	01:45				FL170/ FL190	North	3 & 2	7468	2.07			
8960	5/04/2008	CWR	330	19:24	BK	111	20:15	00:51	02:09	FL140	200	FL130	NE	3	3618	1.01			
	5/04/2008	BK	111	17:35	CWR	330	18:53	01:18				FL140	SW	4 & 3	7397	2.05			
8959	3/04/2008	BN	16	16:46	BK	291	18:40	01:54	06:42	FL180	190	FL180	SW	5 & 4	7750	2.15			
	3/04/2008	DYS	137	14:28	BN	133	16:00	01:32				FL170	SE	5	6744	1.87			
	3/04/2008	EML	62	13:40	DYS	137	13:56	00:16				FL070	North	5	1726	0.48			
	3/04/2008	BK	?	09:49	EML	242	12:49	03:00				FL180	330	6 & 5 (partial flight)	5134				
								TOTAL	21:57	hrs				TOTALS	91505	secs			
															25.42	hrs			

The transition from oldest to newest recorded information was confirmed by examination of all tracks, and found to be on Track 6 (Figure B-18). The transition period was closely examined for any brief period of recording after the shutdown at the end of the previous flight; none was found. The 33 second area of reduced signal strength at the tape stoppage point was examined on Track 6, with extra data recovered being from the oldest data during cruise at 18,000 ft.

Figure B-18: Data recovered from Track 6 in gap shown in Fig B-14



The last flight recorded indicated VH-OZA flew from Brisbane Airport to Sydney Airport. The aircraft cruised at an altitude of 18,000 ft, made an approach and landed on runway 34 at Sydney, then taxied to the north-east and parked.

Cockpit voice recorder receipt

The Cockpit Voice Recorder (CVR) was received at the ATSB's Technical Analysis facilities on 30 June 2008, securely sealed within in a waterproof container (Figures B-19 and B-20).

Figure B-19: CVR sealed in container prior to opening, as received at the ATSB's Technical Analysis facilities

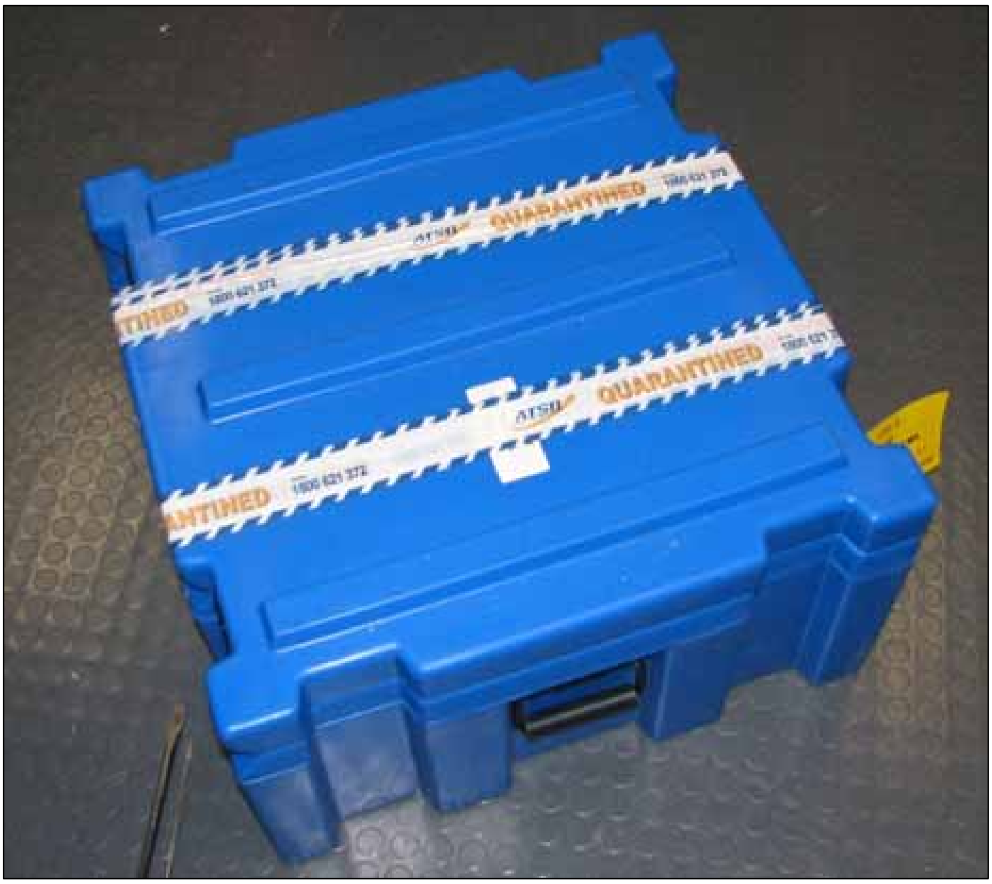
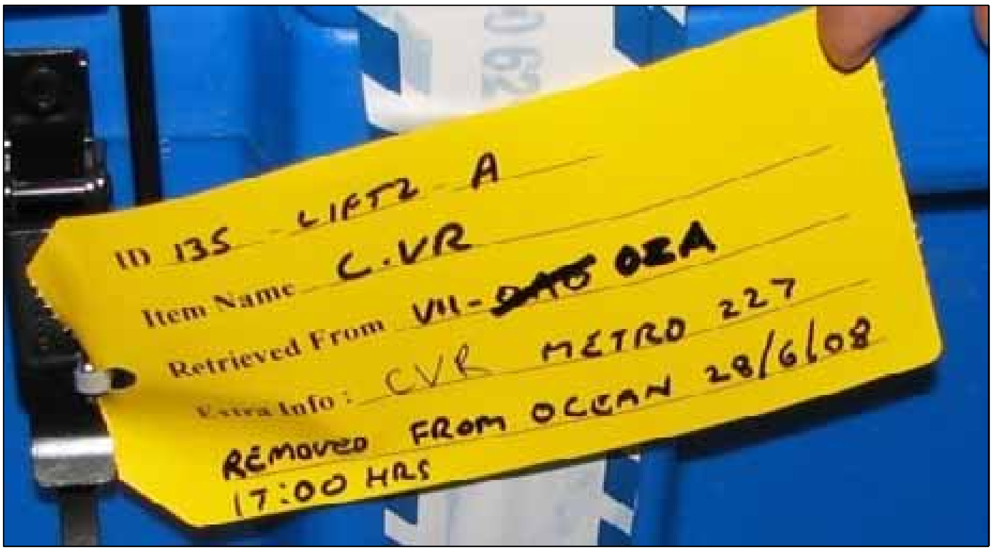


Figure B-20: CVR container security



Cockpit voice recorder identification

Upon opening of the container on 1 July 2008, the CVR was found to be immersed in water as packed. The CVR was removed from the shipping container and was washed and inspected, and the impact damage was assessed (Figure B-21). Some discolouration of the external paint was observed. Analysis of the paint discolouration was the subject of a separate materials examination (see Appendix C).

Figure B-21: Fairchild model A100A Cockpit Voice Recorder from VH-OZA following removal from shipping container on 1 July 2008

The CVR had been subjected to substantial impact forces and saltwater immersion, which had resulted in extensive damage to the recorder. The recovered CVR was identified from the manufacturer's data plate as a Fairchild model A100A CVR, part number 93-A100-80, serial number 55650 (Figure B-22). The maintenance records for VH-OZA confirmed that this CVR was fitted to VH-OZA at the time of the accident.

Figure B-2: CVR data plate

Cockpit voice recorder disassembly

The recorder was dismantled (Figures B-23 to B-27) and the recording tape was extracted from the crash protected enclosure for replay.

Figure B-23: VH-OZA Cockpit voice Recorder during disassembly showing the crash protected enclosure and associated electronics

Figure B-24: Crash protected module opened

Figure B-35: Tape assembly within crash protected enclosure

Figure B-26: Tape transport assembly during disassembly

Figure B-27: CVR tape across erase and recording heads

The CVR tape was in reasonable physical condition and, after cleaning, was replayed using the ATSB's CVR replay equipment. No evidence of heat or fire damage was found during disassembly of the crash protected module.

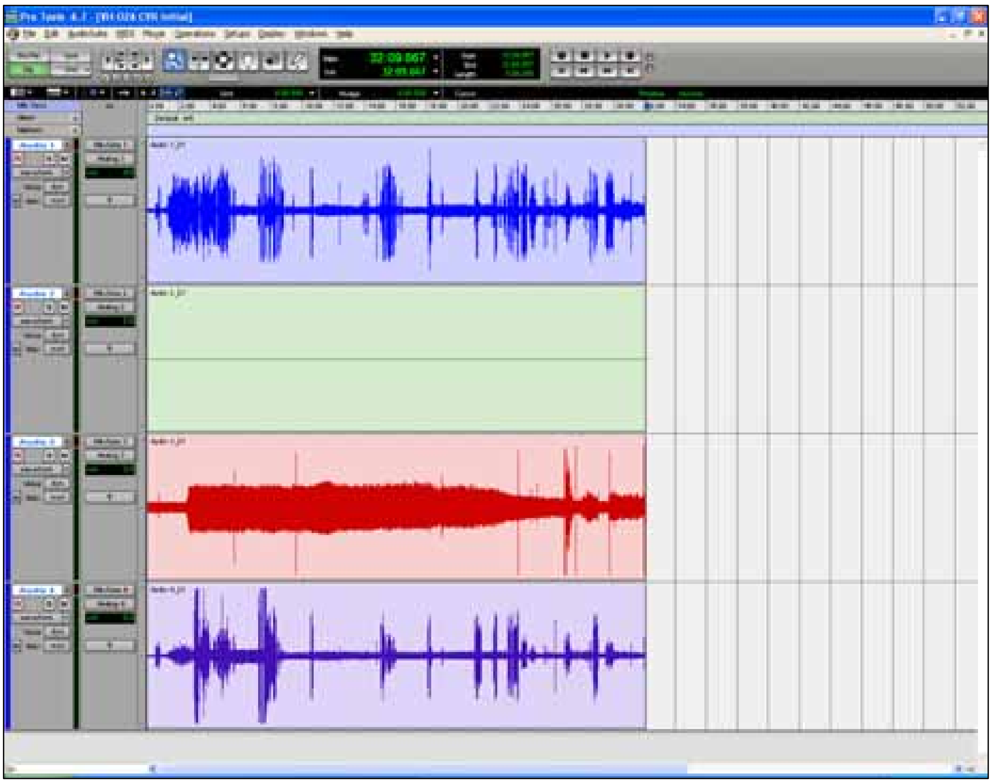
Cockpit voice recorder aircraft installation

The Fairchild model A100A CVR was capable of recording four channels of audio signals for a nominal duration of 30 minutes. The four channels comprised signals from the pilot's, copilot's and passenger-address audio systems, and a remote mounted cockpit area microphone.

Recovered audio

The recovered recording on the tape contained good quality audio signals on three channels (two flight crew positions and the area microphone) with a duration of over 30 minutes (Figure B-28).

Figure B-28: **Screenshot of audio channels recovered from CVR showing over 30 minutes continuous duration. Audio 1 is the pilot channel, Audio 2 is PA/Spare, Audio 3 is Cockpit Area Microphone and Audio 4 is the co-pilot channel**



The last recorded audio indicated the aircraft was being operated by a single pilot, and was conducting an approach and landing to Sydney (Kingsford Smith) Airport, NSW. The recorded conversations related to the operation of the aircraft and radio conversations with Air Traffic Control (ATC) and concluded with the aircraft being parked. The audio recording recovered was not that of the occurrence flight.

The final period of recording was examined for any brief period of recording after the shutdown at the end of the previous flight; none was found.

Correlation of CVR and FDR data

No speed adjustments were used in the CVR replay that would alter the duration of the CVR audio. Microphone keying recorded by the FDR was compared with the timing of radio conversation between VH-OZA and ATC recorded on the CVR. The elapsed time between conversations recorded on the CVR closely correlated with the microphone keying recorded on the FDR. In addition, conversations regarding runway and taxiway direction recorded on the CVR correlated with FDR data. It was therefore confirmed that the CVR recording was of the flight and landing at Sydney Airport on the morning of 9 April 2008 (the flight preceding the accident flight). Both the CVR and FDR recordings ended with what appeared to be a normal aircraft shutdown.

ANALYSIS

Flight Data Recorder analysis

The flight data recorder (FDR) recorded the last 25 hours of flight data prior to the beginning of the accident flight. The data stopped following a normal shutdown of the engines on the previous flight. The recorded data during this 25 hours was continuous and of a high quality. The indicated airspeed (IAS) parameter, which is sourced from a pneumatic input, was however not functioning correctly. Indicated airspeed is derived from both pitot and static air inputs provided to the Universal Flight Data Recorder (UFDR) through pneumatic lines from the copilot's instruments. The IAS characteristic of an increase during climb and decrease during descent, and of being constant during cruise, was consistent with a pitot line being blocked by water or other material, while the static line operated correctly. In this blocked condition, the pitot pressure remains at sea level pressure, while the actual static pressure changes with altitude. The fact that the altitude parameter functioned correctly, indicated that the static line was not blocked. The derivation of IAS from the static and pitot pneumatic sources is performed within the UFDR. The pitot line blockage was considered to be between the copilot's airspeed indicator (ASI) and the UFDR, since such an unreasonable IAS displayed on the cockpit ASI over such a long period (at least 25 hours) would very likely have been noted and reported by flight crew. Consequently, it is probable that the incorrect IAS information would not have been evident on the copilot's instrument, but only affected the UFDR. This particular scenario would not provide a fault indication to the UFDR BITE.

The UFDR recorder fitted to VH-OZA is a reliable tape recorder that incorporates the UFDR check-stroke built-in test equipment concept. Comprehensive test functions continuously check the recorder. When a fault is detected, a BITE light illuminates and relevant error information recorded in the check-word. Details of faults that are checked are contained in Table B-6. During the entire 25-hour recording, the recorder functioned normally, with the BITE light not illuminating and word 63 containing the '0060' code, indicating no faults found.

Table B-6: Check-word details

AlliedSignal Commercial Avionics Systems

COMPONENT MAINTENANCE MANUAL
PART NO. 980-4100

CHECKWORD BIT #			EXPANDED INTERFACE CARD (722-2532) A7	BASIC INTERFACE CARD (722-2452) A6	DAS CONTROLLER CARD (722-2451) A5	ACTIVATE BITE LIGHT	(980-4100-E---) OCTAL WORD	(980-4100-F---) OCTAL WORD
1	1	Prom test routine has detected incorrect program instructions (A5 card).			X	Yes	0001	0061
	0	Program memory functioning.			X	No	0000	0060
2[1]	1	RAM test routine has detected a failed data memory cell (A5 card).			X	Yes	0002	0062
	0	Data memory functioning.			X	No	0000	0060
3[2]	1	Interface diagnostic routine has detected an incomplete analog-to-digital conversion on basic interface card, A6.		X		Yes	0004	0064
	0	Conversion functioning.		X		No	0000	0060
4	1	Test routine has detected a power supply fault on basic interface card, A6.		X		Yes	0010	0070
	0	Power supplies functioning.		X		No	0000	0060
5	1	Interface diagnostic routine has detected an incomplete analog-to-digital conversion on expanded interface card, A7.	X			No	0020	0060
	0	Conversion functioning.	X			No	0000	0060
6	1	Interface diagnostics has detected a power supply fault on expanded interface card, A7.	X			No	0040	0060
	0	Power supplies functioning.	X			No	0000	0060

Checkword Bit Meanings
Figure 118 (Sheet 1)

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Table B-7 (continued): Check-word details

AlliedSignal Commercial Avionics Systems

COMPONENT MAINTENANCE MANUAL
PART NO. 980-4100

CHECKWORD BIT #			A7	A6	A5	ACTIVATE BITE LIGHT	(980-4100-E----) OCTAL WORD	(980-4100-F----) OCTAL WORD
7[3]	1	Accelerometer diagnostic routine has detected loss of accelerometer signal.	Accelerometer signal wires broken.			Yes	0100	0160
	0	Accelerometer connected.				No	0000	0060
8	1	Pneumatic diagnostic routine has detected a failure of the pneumatic sensors.	Pneumatic sensor out of range.			Yes	0200	0260
	0	Pneumatic sensors functioning				No	0000	0060
9	1	Interface diagnostic routine has detected a mismatch between data channels on basic interface card, A6.		X		Yes	0400	0460
	0	Data channels functioning.		X		No	0000	0060
10	1	Interface diagnostic routine has detected a mismatch between data channels on expanded interface card, A7.	X			No	1000	1060
	0	Data channels functioning.	X			No	0000	0000
11	0							
12	0							

DAS CONTROLLER CARD (722-2451) ____; BASIC INTERFACE CARD (722-2452) ____; EXPANDED INTERFACE CARD (722-2532) ____

[1] Tests the ability of the DAS to write changing data.

[2] A logic 1 in this bit indicates that the A-D converter, A6U11, is faulty.

[3] On the aircraft, this is a test of the accelerometer system. The fault could be in accelerometer aircraft wiring or the accelerometer itself. In a shop test setup, the fault is in the UFDR accelerometer circuitry.

Checkword Bit Meanings
Figure 118 (Sheet 2)

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Oct 31/96

During the last flight recorded on the FDR, the recorder was serviceable. During this flight, the magnetic heading information was valid, indicating that the copilot's compass was serviceable with electrical power available. The FDR data finished normally with the loss of aircraft power at engine shutdown, and was not as a result of the inertia switch activation.

It was considered that the FDR had been serviceable, but unpowered, during the accident flight.

Cockpit Voice Recorder analysis

The Cockpit Voice Recorder (CVR) recorded the last thirty minutes of audio prior to the beginning of the accident flight. The data stopped following a normal shutdown of the engines on the previous flight. The recorded audio during this 30 minutes was continuous and of a high quality. The A100A CVR fitted to VH-OZA was a reliable and common tape-based audio recorder. During the entire 30-minute recording, the recorder had functioned normally.

During the last flight recorded on the CVR, the recorder was serviceable. The CVR audio finished normally with the loss of aircraft power at engine shutdown, and not as a result of 'G' switch activation.

It was considered that the CVR had been serviceable, but unpowered, during the accident flight.

FINDINGS

- VH-OZA was fitted with an approved FDR and CVR at the time of the accident.
- The data and audio from the FDR and CVR were able to be recovered in their entirety from the respective recorders following their underwater retrieval.
- The FDR recorded the last 25 hours of flight data prior to the accident flight with no BITE faults recorded.
- The indicated airspeed parameter was not recorded correctly across the entire FDR and was considered a consequence of a blockage in the pneumatic pitot line between the copilot's airspeed indicator and the FDR.
- The CVR recorded the last 30-minutes of audio data prior to the accident flight.
- The recorders powered down normally at the time of engine shutdown and not as a result of 'G' switch activation.
- Neither the FDR nor CVR were powered up during the accident flight.

ATSB TECHNICAL ANALYSIS
AO-2008-026

Examination of flight recorder casing discolouration

Collision with water
19km SE of Sydney, New South Wales
9 April 2008 - Fairchild Industries Inc. SA227-AC Metro III, VH-OZA

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

FACTUAL INFORMATION

Introduction

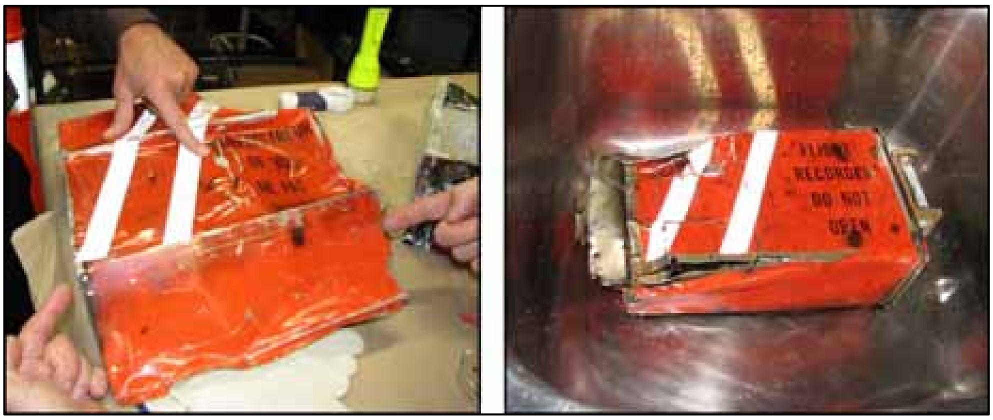
On 9 April 2008, shortly after departing from Sydney, New South Wales, a Fairchild Industries Metro III aircraft, registered VH-OZA, impacted coastal waters approximately 19 km south-east of the airport. During the subsequent search effort, wreckage from the aircraft was located on the ocean floor at a depth of approximately 110m. On 24 June 2008, salvage of the wreckage was initiated by the Australian Transport Safety Bureau (ATSB) and on 27 June, the aircraft's cockpit voice recorder (CVR) and flight data recorder (FDR) were recovered.

Both recorder units were transported to the ATSB's Canberra engineering facilities for download and analysis of the recorded data. During the initial physical disassembly of the recorders, it was noted that the external casings of both displayed unusual, localised areas of darkening and discolouration of the external paint coating. As a result, specialists from the ATSB's Technical Analysis branch were consulted and a technical investigation of the discolouration was undertaken.

Scope of the examination

To assess the nature and possible causes of the paint discolouration, the CVR casing was selected for examination and further testing. Both recorders are shown in Figure C-1.

Figure C-1: FDR (left) and CVR (right) as received by the ATSB



Physical examination

While the unit displayed obvious damage resulting from the accident impact, it was noted that isolated and localised areas over the external surfaces of the CVR outer case were also discoloured; the regions ranging from dark brown to black in discrete patches (Figure C-2). The FDR casing displayed similar effects. Manufacturing data for the CVR indicated the unit to have been painted with an enamel based compound, formulated to the *International Orange* paint code #12197.

Figure C-2: Disassembled CVR external case

Fittings that had been attached to the front panel of the CVR (including the modification status plate, audio cap and the grab handle) were removed for the examination. The front panel of the unit was of particular interest because the majority of the surface displayed significant discolouration; having changed from orange to dark grey or black. In some areas, the painted surface underneath the fittings had also discoloured. However, in other regions, notably below the underwater locator beacon (ULB), the surfaces remained essentially unaffected (Figure C-3).

Figure C-3: CVR face plate showing the location of various front attachments

Manufacturing details of the CVR are provided in Table C-1.

Table C-1: CVR details

Item	Manufacturer	Model	Part number	Serial number	Paint code
Cockpit Voice Recorder (CVR)	Fairchild	A100A	93-A100-80	55650	International Orange #12197

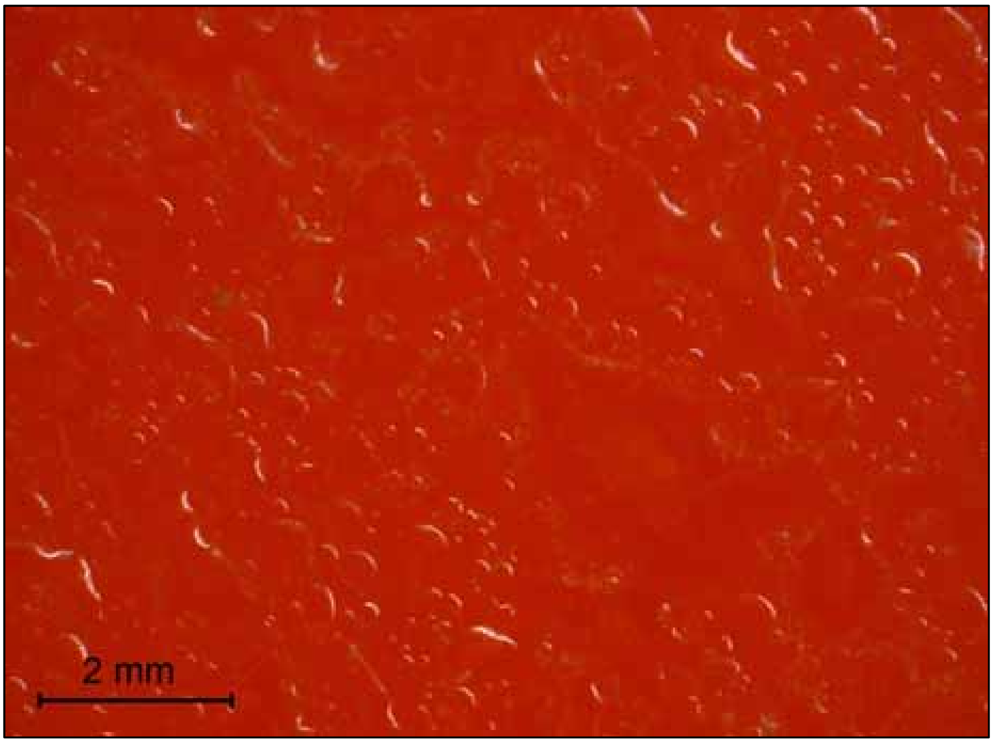
Using the stereomicroscope at moderate to high magnifications, a complete visual examination of the discoloured surfaces of both the CVR and FDR was performed. In general, the lustre and sheen of the paint did not vary noticeably between the orange and brown/grey/black areas. No blisters, bubbles or paint flaking were observed in the discoloured areas, nor was there any evidence of combustion products, soot deposits, or the characteristic odours that would normally be associated with fire damaged components. No evidence of heat damage was observed on the internal surfaces or components of either the FDR or CVR.

No evidence was found of paint degradation or changes that might have suggested exposure to chemical attack in the affected areas, and it was noted that the mottled paint surface texture remained consistent between both the discoloured and unaffected areas.

A comparison of the paint surface texture and appearance of the accident aircraft CVR (Figure C-4), against that of a new Fairchild CVR (Figure C-5) revealed no notable differences (with the exception of the discolouration and the mechanical effects of the accident).

Figure C-4: Magnified view of the discolouration observed on the CVR face plate

Figure C-5: Close view of the undamaged painted surface from an exemplar Fairchild CVR



Thermal testing

A coupon test program was undertaken to assess the effects of heat exposure on the CVR painted surfaces. The program was designed to assess paint colour change against temperatures and time of exposure. Coupons containing undamaged paint were cut from the outer case of the CVR and placed in a calibrated oven. The two test programs performed were:

(A) minimum 100°C, maximum 1,000°C, time of exposure 60 seconds

(B) constant temperature 1,000°C, time of exposure 1to 10 seconds.

Results from the testing under program (A) showed that the paint readily changed colour and darkened from the original *International Orange*, to a brown/black shade after exposure to elevated temperatures. At temperatures around 350 to 375°C, a marked change in the paint colour was observed; by 400°C the paint had blistered and turned completely black.

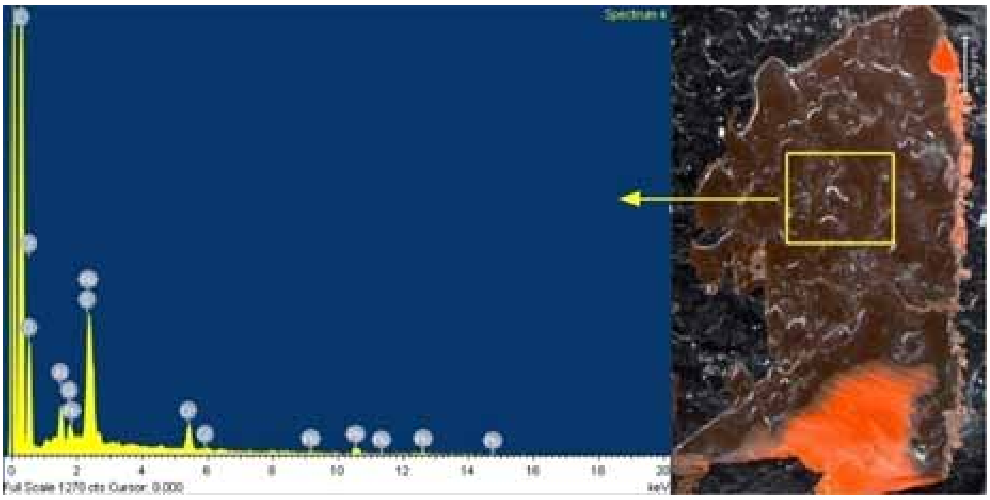
Results from the testing at 1,000°C under program (B) found that the paint changed in appearance after 7 seconds of exposure. Obvious blistering and lifting of the paint followed rapidly.

See Attachment C at the end of this Appendix for the results relating to each test program.

Chemical analysis

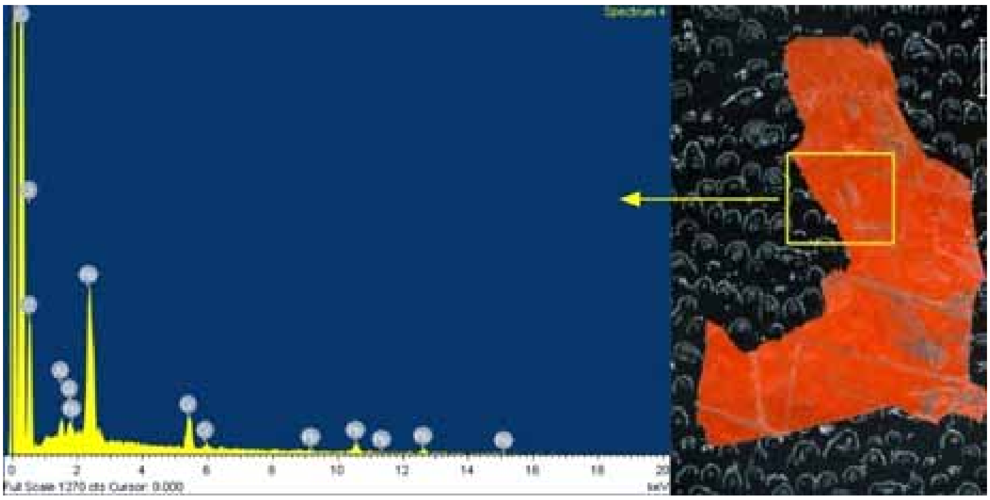
Paint scrapings were removed from both undamaged orange areas as well as discoloured areas. The chemical composition of the paint scrapings were analysed using Energy Dispersive Spectroscopy (EDS) techniques under the scanning electron microscope (SEM). Semi-quantitative chemical analysis of the paint samples revealed its primary constituents to be lead (Pb), chromium (Cr) and silicon (Si). No differences were noted in the chemistry between the discoloured and undamaged regions as shown in Figure C-6 and C-7.

Figure C-6: Damaged paint sample from CVR and its chemistry



Note: A discoloured paint chip from CVR. Original colour can be seen on the lower right of the image where the paint has been sectioned with a scalpel blade.

Figure C-7: Undamaged paint sample from CVR and its chemistry



ANALYSIS

Examination of both the flight data recorder (FDR) and the cockpit voice recorder (CVR) from the aircraft showed that both units had been exposed to conditions that produced an irregular change in colour of the external orange paint coating.

Possible explanations for the changes sustained by the painted surfaces included:

- chemical exposure from sources such as hydraulic fluid, fuel or some combination thereof
- marine water immersion allowing leaching of some constituents from the paint
- thermal effects from exposure to heat and/or fire during the development of the accident or upon impact of the aircraft with the water.

Chemical damage

Chemical analysis of the damaged and undamaged painted finish revealed no detectable chemical differences between the respective areas. In addition, the paint in all areas remained intact on the metal subsurface, with no loss of adhesion, wrinkling or degradation. Enamel based coatings and paints of the type applied to the CVR and FDR units are typically resistant to chemical effects – in particular to those chemicals (fuels, oils) that are encountered in the operating environment.

On the basis that no foreign chemicals were found or detected on the surfaces of the recorders, and in view of the sound (albeit discoloured) condition of the paintwork, it was concluded that chemical exposure was unlikely to have produced the observed discolouration effects.

Water immersion

The CVR manufacturer was consulted, together with investigators from the United States National Transportation Safety Board (NTSB) and the United Kingdom Air Accidents Investigations Branch (AAIB), regarding their knowledge and understanding of the effects of marine water immersion on flight recorder paint colour stability. All parties reported that chemical leaching and colour change effects have not been observed from water immersion. An anecdotal report from the NTSB indicated that a recorder that had been immersed underwater for 9 years, when eventually recovered:

> The unit was as bright orange as the day it was made.

On this basis, it was concluded that water immersion was unlikely to have resulted in the observed paint discolouration effects.

Heat and fire

Painted coupon testing indicated that visible changes begin to occur at temperatures around 350°C. Testing at 400°C and above for extended times showed that blistering and blackening of the paint finish will occur. Short duration testing at 1,000ºC showed that paint discolouration effects are rapid, with observable effects in as little as 7 seconds, with blackening/blistering shortly thereafter.

Based on these observations, it was likely that the localised regions of colour change were associated with exposure to localised heating to temperatures in excess of 350°C, but only for very short durations. There was no evidence to suggest that the recorders had been exposed to a period of continuous heating, such as may have been produced during a fire on board the aircraft during flight.

On the basis of the ATSB's knowledge and understanding of the accident scenario, it was considered most likely that the discolouration of the FDR and CVR cases resulted from the short-term exposure of the units to the effects of a flash-fire or explosion that ignited upon impact of the aircraft with the water. The physical violence of the impact would have produced ideal conditions for such an event, with any spray of atomised fuel from ruptured fuel tanks being ignited from exposure to damaged electrical systems or hot engine components.

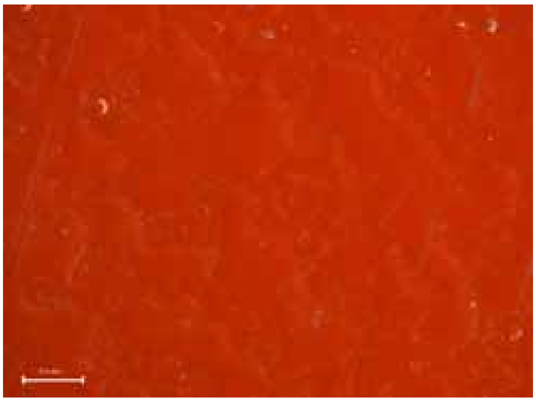
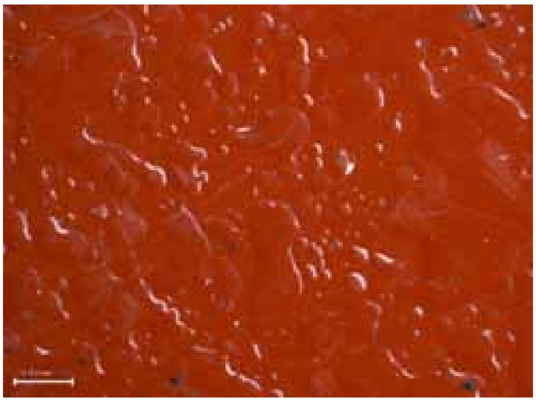
CONCLUSIONS

The following conclusions were made with respect to the presence of localised discoloured areas over the external surfaces of the cockpit voice (CVR) and flight data recorder (FDR) that were recovered from a Fairchild SA-227-AC aircraft that impacted the water near Sydney, New South Wales, on 9 April 2008:

- The enamel-based paint used for protection of the CVR and FDR external cases exhibits a pronounced and characteristic colour change when exposed to temperatures typically exceeding 350ºC.
- The localised colour changes sustained by the surface paint on both flight recorders were probably produced during a short-term exposure to high temperature conditions that were a result of a flash fire or explosion; ignited upon impact of the aircraft with the water.
- The discolouration effects were inconsistent with the more prolonged, continuous heating conditions that would be expected if the aircraft had sustained an in-flight fire.

ATTACHMENT

Table C-2: Test program (A) for CVR panel coupon testing

Temperature	Exposure	Observed paint change
150 °C	60 sec	
250 °C	60 sec	
350 °C	60 sec	

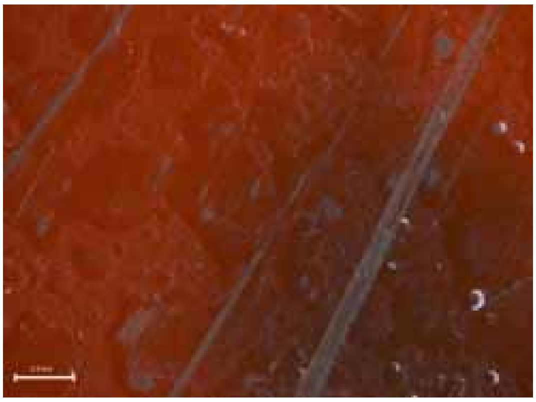
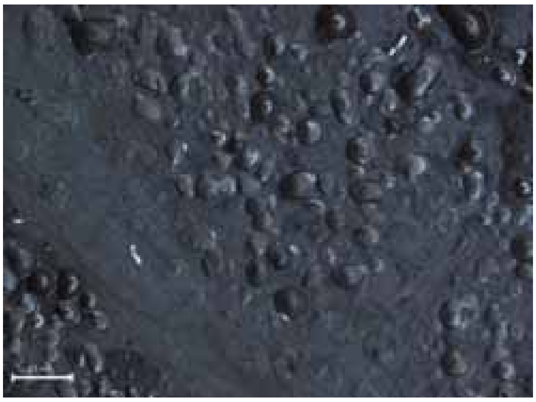
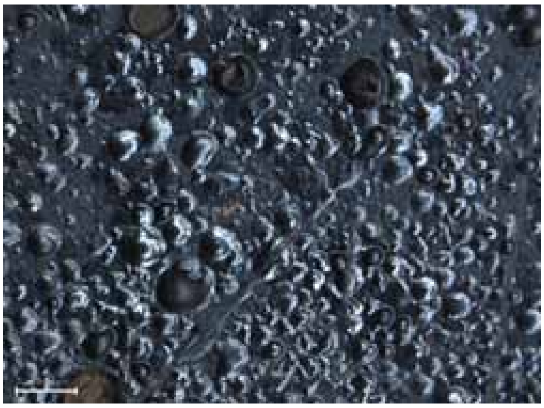
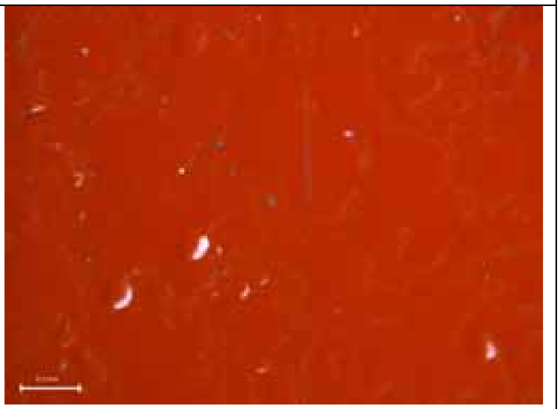
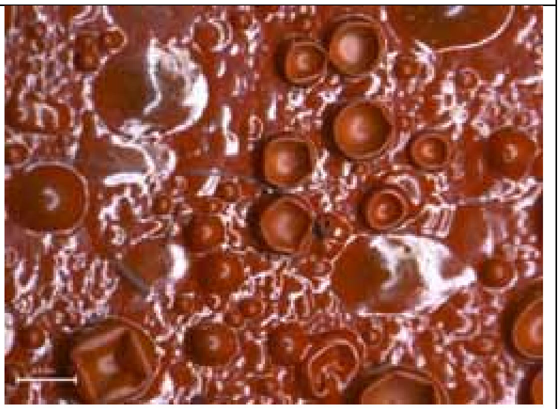
Temperature	Exposure	Observed paint change
375 °C	60 sec	
400 °C	60 sec	
450 °C	60 sec	

Table C-3: Test program (B) for CVR panel coupon testing

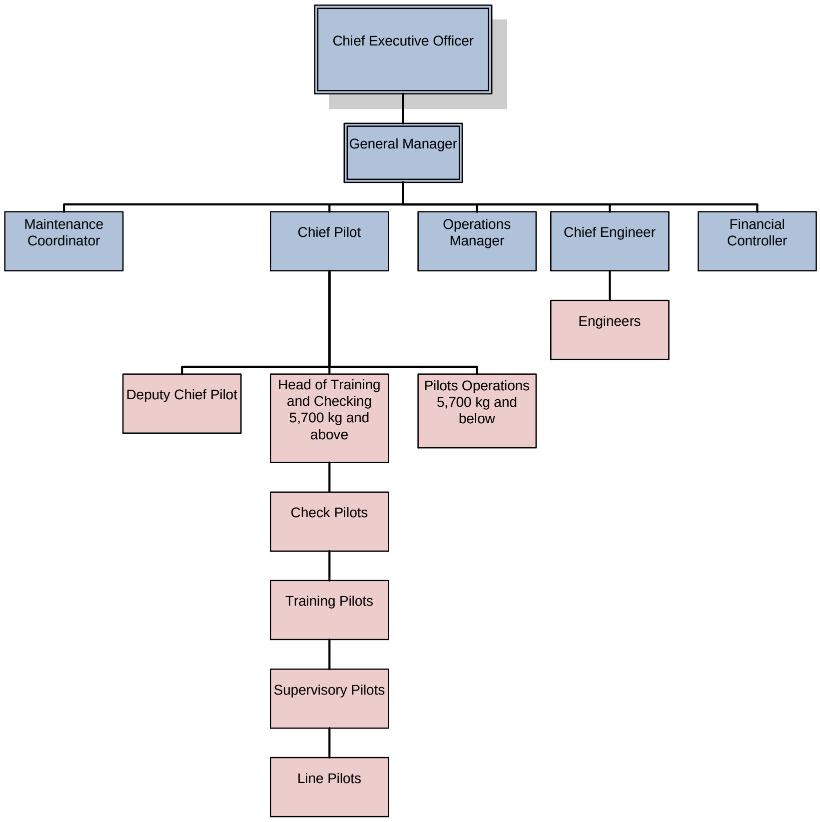
Temperature	Exposure	Observed paint change
1,000 °C	5 sec	
1,000 °C	7 sec	
1,000 °C	10 sec	

APPENDIX D: ORGANISATION AND MANAGEMENT INFORMATION

Organisation and management information

The aircraft operator was certified to operate under the instrument flight rules (IFR) and visual flight rules (VFR) on charter and aerial work operations, with the aircraft used meeting the requirements of Civil Aviation Regulation (CAR) 207 *Requirements according to operations on which Australian aircraft used*. They were also authorised to conduct maintenance on Class A and B aircraft. The operator's organisational chart is at Figure 23.

Figure D-1: Operator organisational chart



Air operator certificate requirements

In order for an aircraft operator to conduct commercial activities, including charter operations, permission was required from the Civil Aviation Safety Authority (CASA) and an Air Operator's Certificate (AOC) was required to be issued under the provisions of Section 27 of the Civil Aviation Act 1988 (the CA Act). The operator had held an AOC since the mid-1980s and the most recent AOC was issued on 31 October 2006. That AOC authorised charter and aerial work operations in aircraft above and below a maximum take-off weight of 5,700 kg.

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

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

Section 28BE of the CA Act included the following provisions:

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

Section 28BF of the CA Act stated that:

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

Operations manual requirements

Under CAR 215 *Operations manual*, an operator was required to provide an operations manual for the use and guidance of its personnel. CAR 215 (9) required that:

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

An operations manual was to contain information, procedures and instructions in relation to the flight operations of all the types of aircraft operated by the operator. This included any information pertaining to the training and checking of the operator's personnel.

The CASA *Air Operators Certification Manual* (AOCM) noted that an operations manual must be satisfactory at the time of issue of an AOC, and that:

> The manual must address the methodology in relation to each individual AOC activity to ensure that the operation can be conducted safely.

CAR 215 noted that, although the regulation gave power to CASA to direct material to be included in an operations manual, it did not require that the manual be approved by CASA. Although approval of the operations manual was not required, Section 28(1) (b) (vi) of the CA Act stated that the CASA delegate must be satisfied that:

> The organisation has suitable procedures and practices to ensure that...operations can be conducted...safely.

In addition, CAR 215 stated that:

> (5) The operator shall revise the Operations Manual from time to time where necessary as the result of changes in the operators operations, aircraft or equipment, or in the light of experience.

and that:

> (8) The operator shall ensure that all amendments to the operations manual made in accordance with this regulation are incorporated in all copies of the operations manual kept within the operator's organisation and that copies of those amendments are forwarded to all persons to whom copies of the operations manual have been furnished in accordance with this regulation.

Normal aircraft take-off operations

The operator's pilots and the chief pilot reported that it was normal practice for pilots to engage the autopilot in the climb by 1,000 ft above ground level. That procedure was not specified in the operations manual but was preferred by the chief pilot.

In addition, those pilots noted that the takeoff was normally completed with ¼ flap and that the landing gear was retracted after achieving a positive rate of climb.

Training and checking requirements

The Metro III aircraft was heavier than 5,700 kg, with the result that the operator was required under CAR 217 to establish a training and checking organisation. In that respect, CAR 217 stated:

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

On 11 February 2004, the operator applied to CASA for approval of its proposed a CAR 217 training and checking organisation. In addition to the requirements of CAR 217, Appendix 2 to Civil Aviation Order (CAO) 82.1 also required the operator to provide a training and checking manual. That manual was to contain the following:

- the duties, responsibilities and proficiency requirements of training and checking personnel
- course outlines and syllabuses and completion standards for each of the operator’s flight or simulator training programs
- an outline of the required training and checking of an operator’s flight crew
- an outline of the structure of the training organisation
- records and certificates associated with each training program and proficiency check.

On 13 May 2004, CASA approved the operator’s Training and Checking Organisation under CAR 217. That included approval of the contents of the Training and Checking Manual that the operator had included as Part C of its operations manual. Once that approval was granted, any changes or amendments to that particular part of the manual required additional CASA approval. That was explained further in the AOCM, which indicated that any changes to procedures that were approved under CAR 217 could not be used in operations until they were approved by CASA. A review of the CASA surveillance files for the operator indicated that after the original approval of the manual was granted, the operator had amended the manual without informing CASA, in particular, in respect of the authorised training and checking captains.

Any amendments to the remainder of the operations manual were the responsibility of the operator and did not require specific approval from CASA (refer to the section titled *CASA oversight operational manual amendments*).

The training and checking organisation requirements affecting an aircraft charter operator were also outlined in CAO 82.1. It stated that:

- the training and checking organisation was required to be wholly contained within the operator’s operational structure
- the chief pilot was responsible for the effective management of the training organisation
- the operator was responsible for appointing sufficient personnel to ensure that all training programs, examinations and proficiency checks were undertaken to an appropriate standard
- the operator was required to maintain up-to-date records showing the recent experience status of each flight crew member, the currency of licences and the ratings and endorsements held by each crew member.
- one of the obligations in relation to an aircraft operator’s training and checking organisation was that:

> 3.3 Persons must not be nominated to supervisory positions within the training and checking organisation without the approval of CASA.

CASA Civil Aviation Advisory Publication (CAAP) 215-1 (0) *Guide to the preparation of operations manuals* that was issued in September 1997 suggested that, pursuant to the requirements of CAR 217, a typical training and checking organisation could be expected to include the positions of:

- chief pilot or head of training and checking
- senior check pilot
- training pilot
- supervisory pilot.

Personnel and requirements affecting the operator's training and checking organisation

Generally reflective of the training and checking positions that were suggested in CAAP 215-1(0), the operator also established the position of deputy chief pilot. Whereas the operator chose to not identify a senior check pilot, a head of check of training was established in addition to the position of chief pilot.

The responsibilities of the chief and deputy chief pilots, the head of training and checking and of the check, training and supervisory captains are discussed in the following paragraphs.

Chief pilot

According to the CASA Chief Pilot Guide that was issued in March 1999, the chief pilot is one of the key personnel positions for holding an AOC. To become a chief pilot required CASA approval. Without an approved chief pilot, an organisation cannot exercise the privileges of an AOC. The guide noted that, although management skills were not a minimum requirement to be a chief pilot, depending on the size of the organisation, some formal training may be required. It also said that it was useful for a chief pilot candidate to be an understudy to a chief pilot before taking up the position.

The Chief Pilot Guide further noted that:

> Chief pilots are responsible for holding and carrying out the duties of one, and in many cases two, of the four "key positions" listed in the Act [the Civil Aviation Act] namely, the "head of the flying operations part of the organisation" and the "head of training and checking part (if any) of the organisation".

The guide noted that, when assessing an application for a chief pilot position, CASA personnel must be confident that the applicant has a satisfactory record in the conduct and management of flight operations. It further stated:

> If this cannot be established, the candidate will be generally considered unsuitable for the position. Such an applicant would unlikely to become suitable in the short term and in such circumstances, the company would need to find an alternative applicant.

A chief pilot was required to ensure that procedures were in place to deal with situations when he or she was on leave. That could include nominating a point of contact to CASA or an acting chief pilot in their absence. A nominee acting chief pilot required CASA approval.

The operator's chief pilot nominee, who also held a Grade 3 (Aeroplane) Flight Instructor Rating, was originally nominated for the position on 29 June 2004. However, on 9 September 2004, CASA informed the operator that the nominee did not to meet the minimum standards of the CAOs. The reasons given for not approving the nomination included:

- insufficient experience as required in the CAOs[55]
- inability to substantiate periods of employment in commercial operations
- poor knowledge relating to operational matters under CAO 20.7.1B
- poor preparation
- unfamiliarity with the operator's operations manual
- attending the interview with an out-of-date operations manual.

Ultimately, CASA approved the appointment of the operator's chief pilot, on 21 November 2005.

The duties of the chief pilot were annotated in the operator's operations manual Part C *Duties and Responsibilities,* which stated:

> The Chief Pilot shall, in addition to those duties listed in Part A of the Company Operations Manual, have overall responsibility for monitoring the operational standards and supervising the training and checking of all Company Pilots. In addition he shall be responsible for the following specific training and checking tasks:
>
> - Scheduling all training and checking requirements for Company flight crew
> - Managing the effective and efficient utilisation of all check and training pilots under the training and checking organisation
> - Monitoring the individual progress and performance of flight crew undergoing air and ground training
> - Taking timely remedial action in cases of unsatisfactory progress by flight crew during air and ground training
> - The safety standards of all flight crew
> - Arranging the initial, upgrade, and recurrent training and checking requirements for all flight crew
> - Ensuring the security of all examination material
> - Liaison with CASA on all CAR 217 training programs

On 27 July 2007, the chief pilot was approved by CASA under CAR 5.21 to give conversion training on the Metro III aircraft. That approval was subject to a number of conditions, including:

> 1. The requirements of CAO 40.1.0 are to be complied with; and
> 2. The endorsement training syllabus contained in the training and checking manual approved for [the operator] is to be adhered to.

---

55 The chief pilot joined the operator in 2004. His prior experience included mainly charter flights, flight instruction and skydiving operations.

Deputy chief pilot

The operator advised that at the time of the accident, a deputy chief pilot position existed, whose duties included assisting the chief pilot with the administration of the training and checking organisation. An examination of the operations manual distribution index did not include a deputy chief pilot, and there was no evidence to indicate that a staff member was approved in that position by CASA.

The operations manual Part C *Duties and Responsibilities* stated the deputy chief pilot responsibilities as follows:

> The Deputy Chief Pilot (if appointed), is to work under the direction of the Chief Pilot and, when directed by the General Manager, may assume the duties of the Chief Pilot whilst the Chief Pilot is on leave and/or through sickness.

Head of training and checking

On 13 May 2004, the operator's nominated head of training and checking was approved by CASA. That person was not employed full-time by the operator, and was located in another state of Australia.

Part C *Duties and Responsibilities* of the operations manual listed the duties of the head of training and checking as:

> The Head of Training and Checking is responsible to the Chief Pilot.
>
> He/She is responsible for the effective management of the Training and Checking Organisation.
>
> The Head of Training and Checking is subject to the prior approval of CASA, and that appointment may not be varied without CASA's consent.
>
> The Head of Training and Checking shall:
>
> - Maintain a record of qualifications and proficiencies held by each crew member. This includes validity, recency, type of endorsements, and licenses restrictions (if any).
> - Monitor operational standards, maintain records, and supervise the training and checking of flight crew.
> - Schedule endorsement training, license and instrument rating renewals, and other required training and proficiency tests.
> - The conduct of proficiency tests in the execution of emergency procedures and the issuance of certifications of proficiency.
> - The supervision of company training pilots, check pilots, and the maintenance of standards.

Additional positions within the operator's training and checking organisation were responsible for the operating standards and competency assessment of flight crew. Those included check, training and supervisory captains, the responsibilities of which are outlined in the following paragraphs.

Check captains

A check captain was a person approved by CASA under CAO 82.1 to conduct proficiency checks within a CAR 217 organisation. According to the operator's training and checking manual, prior to conducting duties as check captains, the designated pilot shall have completed:

- the right seat conversion syllabus
- a ground briefing session
- a sufficient number of supervised base checks on company pilots to achieve a pass on all elements of the check captain assessment form
- a check ride with another company-approved check pilot in accordance with the operator's proficiency check requirements.

The operations manual listed two pilots as holding check pilot approval (check captains). That included the previously-mentioned head of training and checking, and a second pilot who was also based interstate and was the chief pilot of another organisation.[56] Both of those pilots were approved by CASA on 13 May 2004.

Whereas the operator's chief pilot held a check pilot approval from CASA, he was not listed in the operations manual as an approved check pilot.

Training captains

A training captain was a person who was approved by CASA under CAO 82.1 to conduct endorsement and other flight training within a CAR 217 organisation. According to the operator's training and checking manual, prior to conducting duties as training captains, the designated pilot shall have completed the following:

- a flight proficiency base check that was flown from the right seat over a minimum of two sectors
- a ground briefing session
- a right seat conversion syllabus

In addition, the candidate was to have been recommended to, and approved by the chief pilot in accordance with the training and checking manual.

The operator's training and checking manual defined the responsibilities of a training captain as being limited to line training. The training and checking manual also listed the requirements for appointment as a training captain, which were similar to those affecting the appointment of a check captain.

According to the training and checking manual, training captains were required to have 2,000 hours total flying experience, 1,500 hours command flying experience, 1,000 hours multi-engine flying experience, a commercial pilot license, a command instrument rating, and 100 hours in command on type (which could be waived by the chief pilot).

On 4 January 2005, the operator notified CASA that the chief pilot was a nominated training captain and requested an amendment to Part C1 of the training and

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56 For more information on the roles and workload of that chief pilot in the other organisation, refer to ATSB report 200501977 available at http://www.atsb.gov.au/publications/investigation_reports/2005/AAIR/aair200501977.aspx

checking manual to amend the minimum experience, duties and requirements of training captains (see the section titled *CASA oversight – operations manual amendments*).

The chief pilot's name was not listed in the operations manual as an approved check pilot.

Supervisory captains

CASA Air Operators Certification Manual[57] Section 7.12 *Approval of the Training and Checking Organisation and Training and Checking Pilots* stated that:

> A supervisory pilot's role is to conduct the line training required for pilots (captains, first officers or second officers) to achieve "checked to line" status. It is limited to the conduct of normal operations, and the consideration of en-route emergency/abnormal operations. Persons are formally appointed to the position by the operator under the Regulations covering AICUS [acting in command under supervision] operations (CAR 5.01 (3) and CAR 5.40). Unlike the appointment of training pilots or check pilots, the appointment of supervisory pilots does not (and cannot) involve CASA.

An accompanying note to that paragraph highlighted that:

> 1. Operators that require a training and checking organisation under CAO 82.1 paragraph 3 that elect to have a supervisory pilot positions will require the approval of the person/s nominated.

The operator's training and checking manual outlined the responsibilities of its supervisory captains. The duties of the operator's supervisory captains were listed in the operations manual Part C *Duties and Responsibilities* as follows:

> Supervisory Captains shall be appointed by the Chief Pilot, and shall be responsible to the Chief Pilot for:
>
> - The supervision of endorsed pilots acting in command under supervision (ICUS)
> - Making recommendations to the Chief Pilot on areas of crew standards, SOP's, and Aviation Safety.
> - Maintaining accurate records of all training and checking carried out.

According to the operator's training and checking manual, supervisory captains were required to have 1,500 hours command flying experience, 1,000 hours multi-engine flying experience, at least 100 hours flying experience on type and 12 months experience with the operator (which could be waived by the chief pilot).

According to CAO 82.1.3, pilots that were nominated to supervisory positions within the training and checking organisation had to be approved by CASA.

Endorsement training

CAR 5.23 *Aircraft endorsement: issue and refusal* related to aircraft endorsements and directed that further requirements relating to aircraft endorsements were contained in the CAOs. The CAO that covered aircraft endorsements was CAO

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[57] Version 5.0 dated October 2005.

40.1.0. In addition to the requirements for aircraft endorsements, CAO 40.1.0 section 8A.1 and 8A.2 required that, for a pilot to operate as pilot in command of an aircraft with a weight greater than 5,700 kg that was engaged in charter operations under the instrument flight rules (IFR), additional aeronautical experience requirements were to be satisfied. Those additional requirements included that the pilot had to either:

- accrue at least 50 hours of flight time ICUS, or
- complete at least 25 hours of ICUS in the aircraft type, and successfully complete an approved training course conducted in an approved aircraft type synthetic flight trainer.

The operator's training and checking manual indicated that the operator's Metro III endorsement training was designed to meet the requirements of CAO 40.1.0 and CAR 5.23.

Advice on the conduct of multi-engine aircraft endorsements was contained in CAAP 5.23-1 (1). That document was amended in July 2007 to include consideration of the competency standards for multi-engine aircraft operations. It also contained a section relating to 'abridged' training courses when adding an endorsement for an aircraft that was powered by a turbojet engine. The abridged course allowed for a minimum of 4 hours of ground school and 3 hours of flight training (which was to be increased to 5 hours for aircraft affected by CAO 40.1.0 appendices III and IV. The Metro III aircraft was one of the aircraft affected by appendix III to CAO 40.1.0). The ground school was suggested to include five briefings as outlined in the CAAP.

The operator's training and checking manual contained no ground theory training syllabus suggesting an abridged training course between similar aircraft types such as the Metro II and Metro III, even though both aircraft were flown by the operator.

The training and checking manual noted that the operator's endorsement training on the Metro III was divided into two components; a ground theory course and airborne conversion training. The ground theory course syllabus was contained in Part C5.2 of that manual, and culminated in a ground theory examination. Part A of the examination contained 104 technical-related questions, and Part B contained 24 technical and performance-related questions about the aircraft. According to Part C5.1 *Aircraft Technical knowledge and tests*:

> The examinations are published in Appendix 1 & 3 of this manual, and:
>
> - Shall be an open book exam.
> - The pass mark shall be 100%, with open book corrections being made after the test to achieve that mark.
> - The exam paper shall indicate the corrections required to achieve 100%.

There was no specified period in the manual within which the ground theory course component was expected to be completed. Other operators of the Metro III indicated that the expected time for their crew to complete their endorsement ground training was 4 to 5 days.

The operator's training and checking manual Part C6 also dealt with Metro III endorsement training, detailing the prerequisites for the course and the syllabus of training. That included a pass in the Metro III ground theory course and a written examination to be completed by the candidate. CAO 82.1 Appendix 1 required each operator to maintain a training file in respect of each flight crew member that recorded each ground training course completed or attempted by the crew member, including the results for each phase or subject, and the final assessment of the standard achieved. The requirement was similar for endorsement training and flight or simulator proficiency checks.

An initial examination of the operator's pilot file did not reveal any documentary evidence of a completed ground theory course or written examination by the pilot on the Metro III aircraft. However, operator personnel later provided a copy of a ground theory course examination dated 17 December 2007, which was reported to have been discovered at the pilot's home. There was no indication that the examination had been presented to the operator for assessment, and it was evident that the version of the examination provided was different to that in the operator's training and checking manual.

The operator's pilot file did contain a completed ground theory course examination dated 1 October 2005 for the PA31 Mojave aircraft, and one dated 28 February 2005 for the PA31 Chieftain aircraft.

The flying component of the pilot's endorsement training was carried out by the chief pilot and the appropriate forms from the training and checking manual were included in the pilot's file. Training and checking manual Part C6 *Endorsement syllabus* indicated that the only persons authorised to carry out the endorsement training were approved check captains.

Several of the operator's pilots who underwent Metro III endorsement training with the operator's chief pilot reported that they were not given a formal ground theory course as part of that training.

Check to line

Following endorsement on the Metro III, the pilot was required to undergo a period of line training, with either an approved training captain or a check captain. That training was to consist of a period of at least 50 hours ICUS.

Following line training, the pilot was to undergo a 'check to line' in accordance with the applicable section of the operator's training and checking manual. That section of the manual indicated that the check was to consist of a 'base check' and a 'line check' over at least 2 sectors.

According to CASA:

> a base check incorporated emergency procedures checking and could not be conducted while carrying passengers
>
> a line check was used to check that a pilot was operating the aircraft in accordance with all operator procedures and was usually conducted while on a line flight which can be with passengers on board on a revenue flight.

The persons that were authorised by the operator to conduct the check were listed as 'check captains listed in the Approved Persons List', which was contained in the training and checking manual.

The head of training and checking reported that he was not contacted regarding on-going endorsement or check to line training for the pilot or of the role of supervisory pilots. However, the operator later reported that the head of training and checking was aware of the pilot 'flying the aircraft'.

According to the pilot's logbook and file, he completed a base check with the chief pilot on 11 February 2008. The operations manual required that a 'check to line form' be completed following the check to line. There was no documentary evidence in the operator's pilot file of a completed check to line form in the Metro III aircraft.

CASA oversight

Operations manual amendments

A review of the CASA surveillance files for the operator indicated that on:

- on 17 February 2005, an amendment to the operators training and checking manual was approved that revised the Metro III checklist
- on 18 February 2005, the operator was directed to amend the operations manual to include further guidance on passenger weights
- on 10 March 2006, the operator advised CASA that the operations manual had been amended to include permission to carry live animals such as police dogs on charter flights
- 6 October 2006, the operator advised CASA that the operations manual had been amended to include clarification on de-icing procedures.

There was no record of the reported 4 January 2005 request by the operator for an amendment to the minimum experience, duties and requirements of its training captains.

The operator reported that:

> The operations manual had been fully amended, but CASA were yet to incorporate the changes.

Previous CASA surveillance activity

General

The previous CASA surveillance of the operator is summarised at Table D-1.

Table D-1: Previous CASA operator audits/reviews

Date	Type of audit/review	Comments
June 2006	AOC Safety Trend Indicator review	Nil significant issues.
August 2006	Aircraft ramp inspection Bankstown, NSW	Nil significant issues.
August 2006	AOC Safety Trend Indicator review	Nil significant issues.
August 2006	COA Audit	Noted one RCA and 3 observations.
August 2006	AOC Scheduled Audit	Noted nine RCAs and

Date	Type of audit/review	Comments
		seven observations.
August 2006	Aircraft ramp inspection Cairns, Qld	Nil significant issues.
December 2006	COA Fatigue Risk Management System (FRMS)	Noted one RCA (that was unacquitted and for which an exemption was issued) and 13 observations.
January 2007	AOC Safety Trend Indicator review	Nil significant issues.
June 2007	COA Field Activity Report	Follow up on RCAs from the last audit.
July 2007	COA Field Activity Report	Conducted after a complaint to the Industrial Complaints Commissioner (ICC) about the operator.[58] Noted one RCA.
August 2007	COA Risk Based Audit	Noted four RCAs[59] and 10 observations[60], along with engine overhaul issues.
January 2008	COA[61] Safety Trend Indicator review	An identified improvement in the organisation.

In addition, in October 2007, CASA did not reissue the operator's previous exemption to the fatigue risk management system (FRMS) requirements of CAO 48, citing that flight and duty limits had not been included in the operations manual as required. The requirements of CAO 48.1 included pilot flight and duty limitations. The operator reported instead being afforded 'a standard industry CAO 48 exemption.'

OZA ramp inspections

The last recorded ramp inspection of the aircraft took place on 10 January 2005. A number of aircraft discrepancies were noted, including that:

- the left main landing gear tyre was worn
- there was erosion damage to the upper surface of the aircraft's radome[62]
- the left engine compressor blades exhibited impact damage
- there was excessive aileron free play
- there was a fuel leak from the right wing tank.

The previous ramp inspection was on 17 September 2003.

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[58] The date of the complaint was 18 July 2007. Several complaints were lodged against the operator and were believed related to commercial disputes.

[59] Requests for corrective action.

[60] Observations did not require any action to be taken to resolve the identified issue.

[61] Certificate of Approval.

[62] The operator advised that the return flight had no passengers on board.

Surveillance and regulatory actions following the accident

Following the accident involving OZA, from 11 to 28 June 2008 CASA undertook a risk-based audit of the operator and, as part of that audit, issued a number of requests for corrective action to address a number of deficiencies discovered during the audit.

Results of the CASA audit

Of the deficiencies that were identified by CASA, one related to the use of pilots in training or supervisory roles on ICUS flights, without a number of the supervising pilots having been trained and approved for that role in accordance with the operator’s training and checking manual. One of these ICUS flight involved an international passenger charter operation, in which the supervising pilot did not meet the operator’s minimum requirements for holding a supervisory position, and had only just completed the 50-hour ICUS requirement himself, before commencing the international flight as the supervising pilot.

The CASA audit report also noted that the three ‘training captains’ who carried out the ICUS flights with the pilot of OZA had not been approved as training captains, either by the operator in accordance with its training and checking manual, or by CASA as required by CAO 82.1 Section 3.3. Those ‘training captains’ also had no formal supervisory training. One had not completed a line check himself prior to flying as pilot in command, and had 884.3 hours multi-engine experience when commencing ICUS supervisory duties. That contrasted with the requirements of the operator’s training manual, which required training captains to have 1,000 hours multi-engine flying experience.

In respect of the provision by the operator of the ground component of its endorsement training, the audit found that ground school theory examinations were not being consistently corrected to 100%. That was, after marking the examination, the person conducting the training had not discussed any incorrect answers with the person attempting the exam, such that a correct understanding of each question was demonstrated, and the correct answer or reason for the answer being incorrect was explained.

The audit report included the comment that ‘by not training persons for safety critical positions and having them independently approved by CASA, they could not be taken to be able to properly supervise and train another pilot’, and that this compromised safety. In addition, it was noted that, since the initial approval by CASA in May 2004 of the operator’s training and checking organisation, two amendments had been made by the operator to that manual without CASA being notified, and therefore having the opportunity to approve the amendments.

In respect of the training provided to the pilot of OZA, the report noted that the pilot’s ‘check to line’ was not completed in accordance with the operator’s training and checking manual Part C, which required a base check followed by a line check of at least two sectors.

The audit resulted in CASA issuing two Safety Alerts[63] and 16 RCA's. In the conclusions section of the audit report, the CASA inspectors directed that the operator:

- institute comprehensive internal audits on a regular basis
- conduct an in-depth compliance audit of weight limitations, training requirements, training standards, flight and duty records affecting the carriage of more than 15 passengers
- develop multi-crew procedures and crew the operator's aircraft with two qualified pilots when carrying greater than 15 passengers
- review the entire operations manual
- immediately implement a confidential reporting system
- institute a Safety Management System
- duplicate (back up) records and keep them in a secure place
- regularly print flight and duty records and maintain them as a permanent record.

In addition, the report commented on a number of discrepancies in the chief pilot's logbook. Notably, a period of 39 days was identified where flights were not logged in the logbook, or where there were fewer hours noted than annotated in the operator's duty time records. The base check that was noted in the training documentation for the pilot of OZA as being completed on 11 February 2008 was not recorded in the chief pilot's logbook.

Operator's response to the CASA audit

In respect of the approval by the operator of training captains, on 30 July 2008 the chief pilot commented that:

> Pilots were appointed in accordance with company operations manual Part C Section 1.5.5 – "Supervisory Captains shall be appointed by the chief pilot". Company documentation failed to reflect correct procedure in particular relevance to CAO 82.1.3. However, company operations manual was inherited unchanged in this section since 2005. Inadequate referencing led to the breakdown of this section of pilot administration.

and that, to address the CASA finding, the:

> Company operations manual is being changed to bring training and checking in line with CAO's and CAR's. Operations manual will soon also reflect multi-crew operations.

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[63] A Safety Alert is defined by CASA as a request for corrective action that must be addressed immediately. The action outlined in the alert must be taken before continuing any activity carried out under an operator's certificate/licence/approval/authority.

In an effort to address CASA's finding in reference to the marking of ground school theory examinations, the chief pilot advised that the:

> Exams were corrected in accordance with pass/fail adopted. Wrong answers were discussed orally but were not documented in accordance with [the] operations manual to reflect correction or any subsequent discussions.

and that the:

> Exams will be marked to 100% and identified with a colour pen and notes on exam made accordingly operations manual will incorporate any required changes.

Administrative action by CASA after the audit

As a result of the audit, CASA determined that the operator posed a 'Serious and Imminent Risk' to safety in its present form. One of the options to address that risk was to vary the operator's AOC. Following discussions with CASA, the operator agreed to have the following conditions applied to its AOC:

> No passenger carrying charter or aerial work operations are to be conducted whilst [name] is the Chief Pilot. Such operations are only permitted to resume upon CASA approval of a new Chief Pilot;
>
> The company must develop multi-crew procedures for, and crew Metro aircraft, with two qualified pilots when carrying passengers. These procedures to be in place prior to such operations;
>
> Implements, by 25 July 2008, a confidential reporting system to provide the Chief Executive Officer (CEO) with information relating to poor operational standards or hazards and risks within the company's operations;
>
> Develops a comprehensive, company-wide, safety management system, which is fully supported by the CEO, to be implemented by 30 September 2008;
>
> Duplicates, via a secure back-up process, all computerised company records and keeps these back-ups in a secure place, such a system to be in place by 31 July 2008;
>
> Implements a system of printing pilot flight and duty time records to ensure a permanent record is kept, such process to be in place by 18 July 2008;
>
> Employ an appropriately qualified, independent auditor acceptable to CASA. The auditor must conduct comprehensive quality and aviation system audits on a six monthly schedule, commencing no later than 31 August 2008. The company is to provide CASA with a copy of each audit report within 3 weeks of the completion of the audit; and
>
> Reviews and where required, amend the company operations manual with such amendments submitted to CASA for acceptance by 30 September 2008.

Following the CASA audit, administrative action was also taken in relation to the then chief pilot's approvals as follows:

- the chief pilot's check pilot delegation was revoked on the grounds that he was not a fit and proper person to exercise the duties and responsibilities of that delegation
- the chief pilot's instrument of delegation relating to the conduct of flight tests and endorsements was revoked

- the chief pilot's instructor rating was suspended on the grounds that he was not a fit and proper person to hold the rating
- specific requirements were imposed on the chief pilot if he wanted to reapply for his instructor rating.

The chief pilot resigned from his position shortly after the CASA audit.[64]

As part of the CASA audit, the audit team contacted the operator's head of training and checking to discuss the identified training issues. The head of training and checking advised CASA that, although he still officially held that position, his assumption was that the then chief pilot had assumed responsibility for that role, even though it had not been formalised.

On 20 June 2008, the head of training and checking notified CASA that his role after the CASA appointment of the chief pilot on 26 July 2007 had been to supplement the chief pilot, and that his understanding was that the chief pilot was the new head of training and checking.[65] He reported that he was unaware of any of the endorsements that had been issued, or of the pilots that had been made supervisory/training captains in the intervening period. The CASA audit concluded that 'the standards, particularly in training and checking are far below what is an acceptable standard for any operator'.

On 1 July 2008, CASA issued two Safety Alerts to the operator as a result of the findings of the audit. One addressed the endorsement of the operator's pilots by the then chief pilot and the other addressed the need for the provision of additional ICUS flying to another pilot as required by CAO 40.1.0 8A.[66]

CASA also conducted an AOC Safety Trend Indicator review, which was completed on 11 July 2008 and noted that 75% of the operator's operations were passenger-carrying charter operations. The overall judgement by the CASA review team of the performance of the organisation relative to other organisations carrying out similar work was that the organisation was 'much worse'.

Independent audit

From 28 August 2008 to 1 September 2008, an independent external audit was commissioned by the operator as required by CASA. The objective of the audit was to establish if the operator's management structure assigned accountability at the highest levels of corporate management, permitted safe and secure operations, and defined lines of authority and responsibility throughout the organisation. The audit report found that:

- the operations manual had been rewritten
- the Chief Executive Officer (CEO) had signed a copy of a safety policy , but that policy appeared to have its origins in occupational safety and did not reflect the needs of an aviation safety policy

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64 The chief pilot at the time of the accident resigned on 9 September 2008 and a replacement chief pilot was approved that day.

65 Following the accident and subsequent audit by CASA, the head of training and checking resigned and a replacement head of training and checking was approved by CASA on 29 August 2008.

66 Reportedly, the minimum command under supervision requirements had not been met. This was later resolved by contacting the pilot's previous employer.

- there was no job description in the operations manual for the CEO
- communications to flight crews and staff were not 'robust'
- no document and records control system was in place
- improvements were needed to risk management awareness and training
- a formal quality assurance/internal audit program involving operations, maintenance and security should be implemented
- a formal audit plan should be implemented
- a flight safety officer should be assigned
- the currency of the manuals that were kept in the pilot's ready room should be audited and kept up to date.

The audit report suggested that a formal management review committee comprising senior management be formed, and concluded by suggesting that a safety management system should be implemented by the operator.

CASA definition of supervisory captains

The CASA surveillance files for the operator included an instruction dated 9 August 2006 to CASA Field Office inspectors to address ICUS flying. That instruction noted that:

> A common interpretation of PAICUS [pilot acting in command under supervision] requires the accumulation of command time, while under supervision of a "training captain". The "training captain", for the purposes of acting in this supervisory role, has not been defined by CASA, nor does it require CASA approval. The "training captain" position is usually associated with an increase in pay and is often the first step towards becoming a check pilot.

and that:

> Nothing in this instruction absolves the operator from the responsibility of ensuring sound governance in assigning "supervisory" captains to oversee PAICUS activity. It would be expected that assigned captains of PAICUS flights are trained and assessed by the operator as competent to operate with an inexperienced crew member.

CASA noted that the instruction applied to CAO 82.3, relating to regular fare-paying passenger operators using aircraft weighing above 5,700 kg, and was therefore not applicable to the operator. However, in their response to the CASA risk-based audit of June 2008, a number of the operator's personnel expressed the belief that the instruction did apply to them. CASA personnel later corrected that misconception.

APPENDIX E: PREVIOUS SIMILAR INCIDENTS

Westwind aircraft, registered VH-IWJ, near Sydney on 10 October 1985

At about 0059 Eastern Standard Time on 10 October 1985, an Israel Aircraft Industries 1124 Westwind aircraft, registered VH-IWJ, crashed into the sea off the South Head of Botany Bay, New South Wales. The wreckage came to rest in 92 m of water. The aircraft was being operated as a cargo flight with a crew of two pilots. Both pilots received fatal injuries and the aircraft was destroyed.

The aircraft took off from Sydney Airport runway 16R and was to maintain heading until reaching 500 ft, when a left turn was to be made to intercept the 126 Sydney VHF omni-directional radio range radial. At 0056, following an evidently normal takeoff, the crew contacted Sydney Departures Control. The pilot in command requested a climb to FL370 and a direct track to Brisbane, Queensland.

At 0059, the departures controller cleared the pilot to track direct to Brisbane but received no response, although the aircraft was still visible on radar. Shortly after, the radar returns faded and a distress phase was initiated. Several witnesses later reported what appeared to be the lights of an aircraft descending rapidly towards the sea. The last valid radar return showed the aircraft about 11 km south-east of Sydney Airport.

At 0245, aircraft wreckage was located on the surface of the sea by a search and rescue helicopter.

On 20 January 1986, the main wreckage was located. In February 1986, portions of the wreckage were recovered, along with the aircraft's CVR and FDR. The recovered wreckage indicated a high speed impact with the water.

The flight crew included the operator's chief pilot, who was also the head of training and checking and had a total of 9,881 hours flying experience. The copilot had 8,091 hours flying experience. At the time of the accident, the aircraft had a deferred technical discrepancy related to the operation of the rate of turn indicator that was known to be operating in reverse sense with replacement parts on order.[67]

The significant meteorological conditions on the night included:

- visibility of 30 km
- no celestial illumination (moonrise at 0315)
- one okta of cloud at 2,500 ft.

Downloaded data from the aircraft's FDR indicated that about 2 minutes after takeoff, the aircraft reached a maximum pressure altitude of 4,700 ft before it entered a rapid descent in excess of (on average) 20,000 ft/min. The data further indicated excessive bank angles and other data consistent with the loss of control of the aircraft before the descent.

The CVR recorded 30 minutes of aircraft operation and crew conversations noting a normal departure and simulated limited panel exercise. No sounds were recorded that could be associated with an in-flight structural failure, nor was there any comment from the crew to indicate a sudden control problem.

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[67] When the aircraft turned right the indicator indicated a left turn and vice versa.

The report concluded that it was likely that the flight crew lost awareness of the attitude of the aircraft following a simulated instrument emergency.[68]

Beechcraft Super King Air 200, US-registered N81PF, near Strasburg, Colorado US on 27 January 2001

At 1737 on 27 January 2001, a Raytheon (Beechcraft) Super King Air 200 registered N81PF sustained an in-flight electrical systems failure and loss of control near Strasburg, Colorado. The aircraft departed controlled flight and impacted the ground resulting in fatal injuries to all 10 occupants. The subsequent investigation by the US National Transportation Safety Board (NTSB) determined that the probable cause of the accident was the pilot's spatial disorientation resulting in his failure to maintain positive control of the aircraft with the available flight instruments. Contributing to the accident was the loss of AC electrical power during flight in instrument meteorological conditions.[69]

The flight crew consisted of two pilots. Following air traffic control instructions, the aircraft reached an altitude of FL230 when mode C transponder returns ceased and no further transmissions were received from the pilots. About 42 seconds later, primary radar returns indicated that the aircraft deviated from its heading and turned to the right. The right turn continued until impact.

Prior to impact, the aircraft's rate of descent reached 10,000 to 15,000 ft/min. The aerodynamic loading of the aircraft caused the aircraft to breakup in flight within several hundred feet from the ground. Primary radar returns supported that conclusion, most likely the result the pilot attempting to arrest the descent.

The pilot in command had accumulated 5,117 hours total flying experience and 2,520 hours in type. The second pilot had accumulated 1,828 hours total flying experience.

The AC electrical system of the Super King Air was similar to that of the Metro III. However, the aircraft was not equipped with flight recorders. The recovered aircraft AC volt/frequency meter had a needle witness mark indicating 380-Hz/100 volts, indicating no AC power. The loss of AC power rendered most of the pilot's flight instruments inoperative along with the loss of the autopilot. The investigation could not conclusively determine the reason for the loss of AC power.

The NTSB concluded that the pilot would have had salient cues to identify the AC power failure, but did not appropriately manage the workload associated with troubleshooting the loss of AC power and the need to establish and maintain positive control of the aircraft.

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68 See Bureau of Air Safety Investigation Aircraft Accident Investigation Report at hyperlink http://www.atsb.gov.au/publications/investigation_reports/1985/aair/aair198502557.aspx.

69 See NTSB Air Accident Report at hyperlink http://www.ntsb.gov/publictn/2003/AAR0301.pdf.

APPENDIX F: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included:

- Airservices Australia
- the aircraft operator
- the Civil Aviation Safety Authority (CASA)
- the Bureau of Meteorology
- the aircraft manufacturer
- the aircraft maintenance organisation
- the aircraft loading contractor
- the New South Wales Water Police
- the pilot's next of kin
- the aircraft flight recorders.

Submissions

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

A draft of this report was provided to CASA, the aircraft manufacturer, the aircraft maintainer and the aircraft operator.

Submissions were received from the aircraft operator and maintenance organisation and CASA. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Loss of control,19 km SE Sydney Airport, New South Wales 9 April 2008
VH-OZA, Fairchild Industries SA227 AC Metro III