



**Australian Government**

**Australian Transport Safety Bureau**



**ATSB TRANSPORT SAFETY REPORT**  
Occurrence Investigation Report AO-2007-029  
Final

**In-flight breakup – Clonbinane, Vic.**

**31 July 2007**

**VH-YJB**

**Rockwell International Aero Commander 500-S**





**Australian Government**  

---

**Australian Transport Safety Bureau**

**ATSB TRANSPORT SAFETY REPORT**

Aviation Occurrence Investigation

AO-2007-029

Final

**In-flight breakup  
Clonbinane, Vic.  
31 July 2007  
VH-YJB  
Rockwell International Aero Commander  
500-S**

*Published by:* Australian Transport Safety Bureau  
*Postal address:* PO Box 967, Civic Square ACT 2608  
*Office location:* 62 Northbourne Ave., Canberra City, Australian Capital Territory  
*Telephone:* 1800 020 616; from overseas + 61 2 6257 4150  
Accident and incident notification: 1800 011 034 (24 hours)  
*Facsimile:* 02 6247 3117; from overseas + 61 2 6247 3117  
*E-mail:* [atsbinfo@atsb.gov.au](mailto:atsbinfo@atsb.gov.au)  
*Internet:* [www.atsb.gov.au](http://www.atsb.gov.au)

© Commonwealth of Australia 2009.

This work is copyright. In the interests of enhancing the value of the information contained in this publication you may copy, download, display, print, reproduce and distribute this material in unaltered form (retaining this notice). However, copyright in the material obtained from other agencies, private individuals or organisations, belongs to those agencies, individuals or organisations. Where you want to use their material you will need to contact them directly.

Subject to the provisions of the *Copyright Act 1968*, you must not make any other use of the material in this publication unless you have the permission of the Australian Transport Safety Bureau.

Please direct requests for further information or authorisation to:

Commonwealth Copyright Administration, Copyright Law Branch  
Attorney-General's Department, Robert Garran Offices, National Circuit, Barton ACT 2600  
[www.ag.gov.au/cca](http://www.ag.gov.au/cca)

ISBN and formal report title: see 'Document retrieval information' on page v.

---

# CONTENTS

---

<b>THE AUSTRALIAN TRANSPORT SAFETY BUREAU .....</b>	<b>vi</b>
<b>TERMINOLOGY USED IN THIS REPORT .....</b>	<b>vii</b>
<b>1 FACTUAL INFORMATION .....</b>	<b>1</b>
1.1 History of the flight .....	1
1.2 Pilot information .....	3
1.3 Aircraft information .....	4
1.3.1 Aircraft description .....	4
1.3.2 Aircraft history .....	5
1.3.3 Aircraft limitations .....	6
1.4 Meteorological information .....	7
1.4.1 Overview .....	7
1.4.2 Forecast conditions .....	8
1.4.3 Observed conditions .....	9
1.4.4 Turbulence modelling .....	10
1.5 Aids to navigation .....	11
1.6 Communications .....	11
1.7 Aerodrome information .....	11
1.8 Flight recorders .....	11
1.9 Wreckage and impact information .....	11
1.9.1 Wreckage examination .....	13
1.9.2 Wreckage reconstruction and fracture surface examination .....	14
1.10 Medical and pathological information .....	15
1.11 Fire .....	15
1.12 Survival aspects .....	15
1.13 Tests and research .....	16
1.13.1 Other related Aero-commander occurrences .....	16
1.14 Organisational and management information .....	19
1.15 Additional information .....	21
1.15.1 Radar data .....	21
1.15.2 Airspeed calculations .....	23
<b>2 ANALYSIS .....</b>	<b>27</b>
2.1 Introduction .....	27

2.2	Aircraft structure and in-flight breakup .....	27
2.3	Clear air turbulence.....	27
2.4	Flight through forecast areas of severe turbulence .....	28
2.5	Application of manoeuvring speed .....	28
2.6	Conclusion.....	29
<b>3</b>	<b>FINDINGS.....</b>	<b>31</b>
3.1	Contributing safety factors .....	31
3.2	Other safety factors.....	31
3.3	Other key findings .....	31
<b>4</b>	<b>SAFETY ACTIONS .....</b>	<b>33</b>
4.1	Australian Transport Safety Bureau .....	33
4.1.1	Guidance for flight in turbulent conditions.....	33
	<b>APPENDIX A: TECHNICAL ANALYSIS REPORT .....</b>	<b>35</b>
	SUMMARY.....	37
	FACTUAL INFORMATION .....	39
	Introduction .....	39
	Investigation brief.....	39
	Wreckage recovery.....	39
	Structural examination.....	42
	Fracture detail.....	44
	Structural impact evidence .....	58
	ANALYSIS.....	67
	Structural failure and damage.....	67
	Breakup sequence .....	67
	FINDINGS.....	69
	<b>APPENDIX B: ATSB SAFETY EDUCATION MATERIAL .....</b>	<b>71</b>
	<b>APPENDIX C: SOURCES AND SUBMISSIONS.....</b>	<b>75</b>
	<b>APPENDIX D: MEDIA RELEASE .....</b>	<b>77</b>

---

## DOCUMENT RETRIEVAL INFORMATION

---

Report No.	Publication date	No. of pages	ISBN
AO-2007-029	5 November 2009	86	978-1-74251-001-9

---

### Publication title

In-flight breakup – Clonbinane, Vic. – 31 July 2007 - VH-YJB, Rockwell International Aero Commander 500-S

---

### Prepared by

Australian Transport Safety Bureau  
PO Box 967, Civic Square ACT 2608 Australia  
[www.atsb.gov.au](http://www.atsb.gov.au)

### Reference No.

Nov09/ATSB27

---

### Acknowledgements

Figure 3: Photograph courtesy of Mr Phil Vabre.

Figure 5: Synoptic chart provided by Bureau of Meteorology.

---

### Abstract

On 31 July 2007, a Rockwell International Aero Commander 500-S, registered VH-YJB, departed Essendon Airport, Vic. on a business flight to Shepparton that was conducted at night under the instrument flight rules (IFR). On board were the pilot and one passenger. At 1958 Eastern Standard Time, while in the cruise at 7,000 ft above mean sea level in Class C controlled airspace, radar and radio contact with the aircraft was lost when it was about 25 NM (46 km) north-north-east of Essendon.

The wreckage was found in the area of the last radar position and both occupants had been fatally injured. At the time, special weather reports for severe turbulence and severe mountain waves were current for that area. Wind speeds on the ground were reported to be 50 kts. Calculations made using the recorded radar data and forecast wind showed that the aircraft had been in cruise flight at speeds probably greater than its published manoeuvring speed, prior to disappearing from radar.

The wreckage and its distribution pattern were consistent with an in-flight breakup during cruise flight. The breakup most likely resulted from an encounter with localised and intense turbulence, or from an elevator control input, or from a combination of both.

As a result of its investigation, the Australian Transport Safety Bureau reissued the publication *Mountain Wave Turbulence* (available for download at [www.atsb.gov.au](http://www.atsb.gov.au)), distributed the investigation report to all Australian operators of the Aero Commander aircraft, and issued a safety advisory notice to aircraft operators and pilots. That notice encouraged aircraft operators to review their procedures to ensure an appropriate awareness amongst operating personnel of the implications for aircraft performance of the combination of aircraft weights and speed, and of the ambient conditions; in particular, when flying in, or near areas of forecast severe turbulence.

---

---

# 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 enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation, 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.



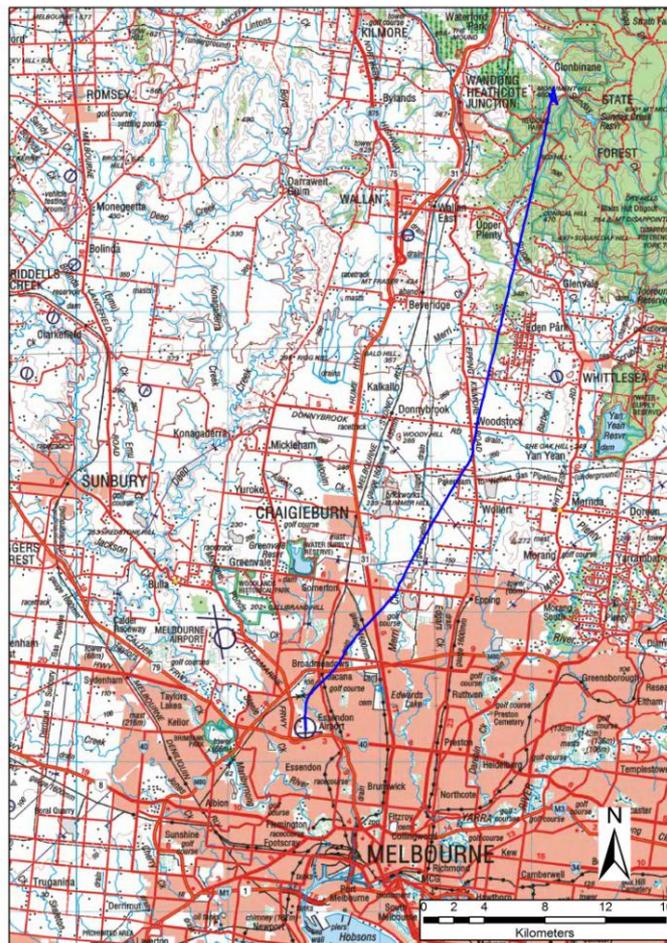
# 1

## FACTUAL INFORMATION

### 1.1 History of the flight

At 1946 Eastern Standard Time<sup>1</sup> on 31 July 2007, a Rockwell International Aero Commander 500-S, registered VH-YJB (YJB), departed Essendon Airport, Vic. on a business flight to Shepparton that was conducted at night under the instrument flight rules (IFR). On board were the pilot and one passenger. At 1958, while in the cruise at 7,000 ft above mean sea level (AMSL) in Class C controlled airspace, radar and radio contact with the aircraft was lost simultaneously by air traffic control when it was about 25 NM (46 km) north-north-east of Essendon (Figure 1).

Figure 1: Radar track of VH-YJB



<sup>1</sup> 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.

The air traffic controller declared a distress phase after a number of unsuccessful attempts to contact the pilot. At 2003, the Operations Director at Melbourne Centre declared the aircraft as probably lost and advised AusSAR<sup>2</sup>. A search was commenced using a helicopter and an aeroplane in addition to ground search parties. No emergency locator transmitter signal was reported. At 2147, aircraft wreckage was located by a searching aircraft in timbered ranges near Clonbinane, approximately 50 km north of Melbourne. At about 2200, a ground search party confirmed that the wreckage was that of YJB and that there were no survivors.

The flight was arranged to take the company owner, who was also a licensed aircraft maintenance engineer (LAME), to Shepparton to replace an unserviceable starter motor in another of the operator's aircraft. The pilot, who had landed at Essendon at 1915 from a previous flight in another of the operator's aircraft, was tasked to fly the owner to Shepparton. The pilot transferred to YJB, which had previously been prepared for flight by another company pilot.

At 1938, while taxiing for takeoff, the pilot advised the aerodrome controller of the intention to conduct the IFR flight, adding, '...and request a big favour for a submission of a flight plan, with an urgent departure Essendon [to] Shepparton [and] return'. The aerodrome controller did not have the facilities for processing flight notifications and sought the assistance of a controller in the Melbourne air traffic control centre.

There were no eye witnesses to the accident. Residents living in the vicinity of the accident site were inside their homes and reported difficulty hearing anything above the noise made by the wind and the foliage being blown about. One of the residents reported hearing a brief, loud engine noise. Another resident thought the noise was that of a noisy vehicle on the road. The noise was described as being constant, '...not spluttering or misfiring' and lasted for only a few seconds. Some of those residents near the accident site reported hearing and feeling an impact only moments after the engine noise ceased.

The aircraft was seriously damaged<sup>3</sup> by excessive in-flight aerodynamic forces and impact with the terrain (Figure 2). The vegetation in the immediate vicinity of the main aircraft wreckage was slightly damaged as the aircraft descended, nearly vertically, through the trees.

The pilot and passenger were fatally injured.

---

2 AusSAR is the Australian search and rescue agency.

3 The Transport Safety Investigation Regulations 2003 definition of 'serious damage' includes 'destruction of the transport vehicle'.

**Figure 2: Main wreckage**



## 1.2 Pilot information

Type of licence	Air Transport Pilot (Aeroplane) Licence (ATPL) issued on 7 June 2006.
Medical certificate	Class 1, valid until 13-April 2008 Restrictions: Vision correction to be worn for distance vision and to be available for reading.
Ratings	Command instrument rating (aeroplane) multi-engine, valid until 31 March 2008
Endorsement	AERO COM Class endorsement issued 9 June 2005 (included AC 500S)
Total flying experience (hours)	2,342
Experience on type (hours)	970
Hours flown in last 90 days	190 Total / 121 On type
Instrument flight time (hours)	196
Night flying (total hours)	200
Hours on duty	7.5
Rest period (hours)	6 (before commencing second period of split shift)

The majority of the pilot's Aero Commander flight experience was accumulated during scheduled freight services for the operator since May 2005. All but 9 months of that flying was conducted from the operator's Essendon base; and the pilot was familiar with the route, the terrain and the seasonal meteorological conditions. Prior

to commencing the flight to Shepparton, the pilot had flown 4 hours that day. The flight was the first time that the pilot had flown YJB.

The pilot was off-duty for the previous 4 days and had returned to work that morning. That off-duty period was spent in the country away from Melbourne. The pilot returned to Melbourne 2 days before the accident by car, a reported 8-hour drive. The pilot's activities on the previous day were not known, but friends reported that the pilot would normally attend to domestic duties and studies during rostered days off.

Flight and duty times recorded by the pilot on company records showed that the pilot commenced duty on the morning of the accident at 0630 for a rostered, scheduled freight service from Essendon to Mildura, Vic., returning later that day. From 1030 until 1630, the pilot rested at the operator-provided motel accommodation. Motel staff reported that the pilot normally spent the time studying and sleeping until recommencing duty. They also reported that the pilot ate a hot meal during the day and appeared to be in normal good spirits. At 1630, the pilot recommenced duty for the return flight to Essendon.

The pilot was reported to have not had any illnesses, and was described as being in 'good health and with a positive outlook'.

## 1.3 Aircraft information

### 1.3.1 Aircraft description

The Aero Commander 500-S is a high-wing, multi-engine aeroplane (Figure 3) powered by two normally-aspirated Textron Lycoming IO-540 engines rated at 290 horsepower maximum. The aircraft was designed as a business and personal aircraft with seating capacity for 6 or 7 persons. As of July 2007, there were 50 of these aircraft, of various models, on the Australian aircraft register.

Manufacturer	Rockwell International
Model	Aero-commander 500-S
Serial number	3299
Registration	VH-YJB
Year of manufacture	1977
Certificate of airworthiness HJG-116	Issue date: 18/05/07
Certificate of registration	Issue date: 08/02/07
Total airframe hours	4,558.1 (97.9 hours since arrival in Australia)
Maintenance release A72904 was valid at the time of the accident and certified to remain in force until:	18 May 2008, or 4,610.2 aircraft hours whichever occurred first

**Figure 3: Rockwell International Aero Commander 500-S VH-YJB**



A copy of the operator's standard flight log<sup>4</sup>, incorporating the Essendon to Shepparton sector, was found in the wreckage. It contained pre-computed time intervals and fuel figures, but no actual fuel quantity for the flight. The aircraft's previous flight log showed 294 L of aviation gasoline (Avgas) remaining, and the operator's fuel documents recorded that 191 L were added after that flight. Employees reported that the operator's aircraft were normally refuelled to a quantity of approximately 480 L in readiness for any of the scheduled freight services. They also reported that the only items the owner took with him on the flight were his tool kit and a replacement starter motor.

The aircraft was configured as a '2-seat freighter' and was equipped with cargo nets immediately behind the front seats and toward the rear of the cabin. Calculations were made using the pilot and passenger weights and the estimated cargo and fuel load. It was determined that the aircraft was operating within its centre of gravity and weight limits for flight under the IFR and was nearly 400 kg below its original certified maximum take-off weight (see Section 1.6.3 Aircraft limitations).

The aircraft was approved for flight under the IFR and was equipped with an EDO AIRE Mitchell Century III autopilot. It was not equipped for flight in known icing conditions.

### **1.3.2 Aircraft history**

The aircraft was manufactured in the US in 1977 and was registered there until February 2007, when it was imported into Australia by the operator and issued with an Australian certificate of registration. All relevant Australian Airworthiness

---

<sup>4</sup> Flight logs were produced for each of the operator's routes, and incorporated the relevant route's pre-computed flight plan, a fuel log, duty times, flying times and maintenance times. The flight log used for the flight to Shepparton was for the scheduled route from Essendon to Shepparton, Swan Hill, Bendigo and Essendon.

Directives and mandatory maintenance requirements were certified as being complied with at that time.

An examination of the US maintenance documentation and log books showed that the aircraft was previously involved in a landing accident in the US on 6 January 1999. At that time, the aircraft had 1,239.2 hours total time in service (TTIS). A US National Transportation Safety Board (NTSB) report (ID number CHID99LA059) advised that the accident occurred during a landing on runway 10, at Plymouth municipal airport, Indiana USA in heavy snow. The NTSB report further advised that the aircraft sustained significant damage to the left outer wing and main spar section, which broke at approximately 1/3 of its length inboard from the tip. The left main landing gear separated and the nose landing gear collapsed. The aircraft was subsequently repaired and returned to airworthy condition.

The current maintenance release was recovered from the wreckage. It was issued on 18 May 2007 and, under the operator's approved system of maintenance, was valid for a period of 12 months or 150 flight hours, whichever came first. The daily inspection certificate recorded 4,557.8 hours TTIS at the time of the accident, not including the accident flight time of approximately 20 minutes.

The aircraft was maintained in accordance with regulatory requirements for a Class B aircraft. There were no defects recorded on the maintenance release, and the pilot who flew the aircraft on the previous day reported there were no unserviceable items.

### 1.3.3 Aircraft limitations

In 1968, the Aero Commander 500-S was certified as a utility category aircraft complying with the standards of US Civil Air Regulations Part 3 (CAR 3) that applied to that aircraft category. Those standards required the aircraft design to sustain ultimate<sup>5</sup> flight loads of +6.6 g and -2.7 g.

Subsequently, the then Australian Department of Civil Aviation issued Supplemental Type Certificate (STC) No. 68-1, dated 10 February 1972. That STC permitted an increase in the aircraft's gross weight in the normal category from the original 3,068 kg to 3,357 kg for VFR<sup>6</sup> operation, and 3,243 kg<sup>7</sup> for IFR operation. The ultimate flight loads in the normal category were +5.7 g and -2.28 g.

The Aero-Commander 500-S flight manual specified a maximum 'published maneuvering speed'<sup>8</sup> ( $V_p$ ) of 141 kts calibrated airspeed<sup>9</sup> (CAS). That speed

---

<sup>5</sup> Ultimate load was the greatest load that any structural component was required to carry without breaking. It could be permanently deformed at the ultimate load. Exceeding ultimate loads can cause catastrophic airframe failure.

<sup>6</sup> Visual Flight Rules (VFR).

<sup>7</sup> The aeroplane weight and performance limitations of Civil Aviation Order (CAO) 20.7.4 required IFR multi-engine aeroplanes to achieve a climb gradient of 1% at all altitudes up to 5,000 ft in the standard atmosphere with the critical engine inoperative.

<sup>8</sup> US-spelling used when quoting US terminology.

<sup>9</sup> The calibrated airspeed for this type of aircraft could be considered as the indicated airspeed corrected for instrument error and position error.

represented the maximum speed at which, in symmetrical flight, a pilot could apply full up elevator control deflection without exceeding the aircraft's maximum positive limit<sup>10</sup> load, before the aerodynamic stall occurred and 'unloads' the wing. Similarly, when the elevator control is deflected fully down, there was a corresponding speed at which the negative limit load for the aircraft was reached at the negative stalling angle of the wing. That speed was not published, however, it is usually lower than the 'published maneuvering speed' due to the lower negative limit load.

The US Federal Aviation Regulations Part 23 (FAR 23) superseded the CAR 3 certification standards. In aircraft that were certified to FAR 23, the 'published maneuvering speed' ( $V_P$ ) became the 'design maneuvering speed' ( $V_A$ ). Although the use of the word manoeuvring implied that a pilot was performing a manoeuvre in an aircraft such as a sharp pull-up, a steep turn or aerobatics, the manoeuvring speed limitation applied at any time the aircraft's elevator was fully deflected. For example, in level flight, when a pilot used full elevator control input to counteract an aircraft upset, such as a sudden nose-up or nose-down pitching movement due to turbulence.

There was no published maximum turbulence penetration speed for the aircraft, nor was one required for certification to CAR 3 or FAR 23 standards. Instead, the manoeuvring speed was used as a guide to the maximum speed that the aircraft could be safely flown in turbulent conditions. Flight in turbulent air at speeds above the manoeuvring speed could result in flight loads exceeding the aircraft's design limit loads, even in circumstances that involved less than maximum control deflection.

The  $V_P$  or  $V_A$  published in most aircraft flight manuals is derived from an aircraft's stalling speed at its maximum take-off weight. Manoeuvring speed varies according to the stalling speed. At lighter aircraft weights such as in this instance, where the stalling speed is slower, manoeuvring speed is correspondingly slower. In simple terms, a lightly-laden aircraft is accelerated more readily than at heavier weights; the transient nature of the acceleration, and the inertial response of the aircraft, producing greater g-loadings for a given gust strength. Some aircraft manufacturers publish several manoeuvring speeds for varying aircraft gross weights. There was only one published manoeuvring speed for the Aero-Commander 500-S. Calculations made using the estimated weight of the aircraft at breakup indicated that the weight-adjusted manoeuvring speed at that time was approximately 131 kts; 10 kts less than the 'published maneuvering speed'.

## **1.4 Meteorological information**

### **1.4.1 Overview**

The area where the accident occurred was experiencing strong and gusty northerly winds ahead of a cold front that was approaching from the west and was expected

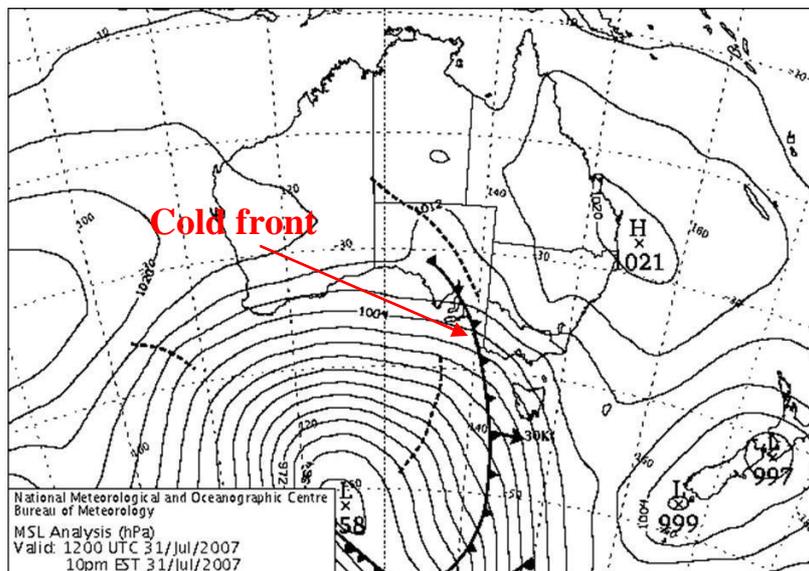
---

<sup>10</sup> Limit load is the greatest load that any structural component is required to carry without detrimental, permanent deformation. At any loads up to limit loads, any deformation must not interfere with safe operation.

to reach the area early the following morning (Figure 4). Surface wind gusts to 50 kts were reported on the ranges during the afternoon.

The planned track to Shepparton lay just east of an area in the Great Dividing Range, known as the Kilmore Gap. The Kilmore Gap is a broad saddle in the ranges where the terrain is generally lower and undulating.

**Figure 4: Mean Sea Level Pressure Analysis, 2200 (1200 UTC) on 31 July 2007**



## 1.4.2 Forecast conditions

The Bureau of Meteorology (BoM) forecast for Areas (ARFOR)<sup>11</sup> 30 and 32, which was valid for a 12-hour period from 1500 on the day of the accident, predicted strong and gusty northerly winds to prevail ahead of the passage of a cold front. North to north-westerly winds in excess of 40 kts, up to an altitude of 10,000 ft, were forecast. Severe turbulence and mountain wave activity were expected as a result of the vigorous northerly flow. The front was not forecast to pass through the area until 0300 the next morning. Isolated thunderstorms associated with the passage of the front were forecast over the sea in the southern part of the forecast area. The freezing level was 6,500 ft in the south-west, grading to 8,000 ft in the north-east.

A special weather report (SIGMET)<sup>12</sup> (ML02) that was issued at 1710 and became valid from 1800, extended the validity of an earlier SIGMET (ML01) that forecast severe turbulence below 8,000 ft near and south of the ranges. Another SIGMET (ML03) was issued at 1727 and became valid from 1800, warning of occasional

<sup>11</sup> ARFOR - For the purposes of providing aviation weather forecasts to pilots, Australia is subdivided into a number of forecast areas. The occurrence flight was contained in Area 30.

<sup>12</sup> A SIGMET, was a weather advisory service to warn of potentially hazardous (significant) or extreme meteorological conditions that were dangerous to most aircraft, eg extreme turbulence.

severe<sup>13</sup> mountain waves in the same area between 5,000 ft and FL140 (14,000 ft), with intensity increasing.

The BoM forecasters advised that the existence of concurrent SIGMET information in the same area resulted from different meteorological phenomena associated with the strong wind. The first (ML02) warned of mechanical turbulence over and in the lee of the ranges and the second (ML03) warned of mountain wave activity within the affected air mass and covered a similar broadly defined area. The BoM advised that the existence of concurrent SIGMET warnings could not necessarily be interpreted as having a cumulative affect on turbulence in the overlapping areas and altitudes.

The operator's pilots reported that, before making the return flight from Mildura, it was normal practice to obtain the latest NOTAM<sup>14</sup> and weather information by having the briefing office forward that information to the motel facsimile. The investigation was unable to establish, from motel facsimile records, if the pilot had received a weather briefing before the flight to Essendon.

The latest SIGMET (ML03) was issued at 1727, two minutes after the pilot departed Mildura. Recorded audio data from air traffic control revealed that at 1759, a controller broadcast the relevant elements of SIGMET ML03 on Melbourne Centre frequency 118.9 MHz. At 1808, the pilot reported arrival at Horsham to the controller on that frequency. There was no requirement for the pilot to advise having received the broadcast SIGMET, and the investigation could not determine if the pilot received it either then or later, during the flight to Essendon.

### **1.4.3 Observed conditions**

There were no recorded pilot reports of turbulence on the air traffic services sector frequencies that afternoon. The pilots flying two of the operator's other Aero Commander aircraft through the area affected by the SIGMET, landed at Essendon within 30 minutes prior to the departure of YJB for Shepparton. Neither pilot reported encountering any significant turbulence except on final approach to Runway 35 at Essendon. Pilots arriving or departing from the Melbourne area at the time of the accident reported actual wind speeds in excess of 40 kts, but none reported experiencing any significant turbulence.

Later that night, the crew of a search aeroplane reported that, in the wreckage area, there was significant, continuous turbulence at altitudes between 5,000 and 6,400 ft during the search. They reported the cloud as broken<sup>15</sup>, between 3,500 and 6,000 ft. Bureau of Meteorology radar imagery confirmed that there was no precipitation in the area at the time of the accident. Other pilots approaching Melbourne in the 3

---

13 Mountain waves were considered severe when accompanying downdrafts of 600 ft/min or more, and/or severe turbulence, was observed or forecast.

14 NOTAM. Notice to Airmen, was disseminated to give information on the establishment, condition or change in any aeronautical facility, service, procedure, or hazard.

15 Broken meaning 5 to 7 oktas. An okta was the unit of measurement that was used to report the total sky area that was visible to the celestial horizon. One okta was equal to 1/8th of that visible sky area. The term okta was also used to forecast or report the amount of cloud in an area, along a route or at an airfield.

hours after the accident also reported encountering severe turbulence. The upper level winds at Melbourne Airport at 2100 are at Table 1.

**Table 1: Melbourne Airport Upper Level Winds at 2100**

1000ft	355/45
2000ft	350/54
3000ft	340/57
5000ft	325/55
7000ft	310/46

The Aircraft Meteorological Data Relay (AMDAR) was a meteorological observational system that utilised appropriately-equipped commercial aircraft to automatically measure meteorological parameters at predetermined intervals during flight, and transmit the data to ground stations for use by meteorological agencies. The recorded AMDAR parameters from aircraft operating in the Melbourne area that evening appear at Table 2. That data showed that the wind speed and direction in the Melbourne area was consistent over a 2-hour period prior to the occurrence.

**Table 2: AMDAR data for Melbourne Area 31 July 2007**

Local Time	Height ft	Temp. (°C)	Wind Direction (T)	Wind Speed (kts)
17:20	7513	5.3	305	43
18:20	7513	6.1	316	44.9
18:55	7513	4.1	318	49
19:45	7513	3.9	317	49
20:15	8104	3.9	313	51.9

Residents living near the accident site reported very strong wind conditions, of the kind experienced on only a few occasions each year. They reported that, at the time of the accident, there was bright moonlight, even with the fast-moving cloud frequently partly obscuring it. There was no precipitation reported.

#### 1.4.4 Turbulence modelling

Subsequent computer turbulence modelling by the BoM was unable to quantify the strength of the vertical gusts in the air mass from the available data, as it lacked sufficient resolution.

In January 2005, following a number of accidents in which mountain wave activity and associated turbulence was considered to be a factor, the ATSB released safety education material on the subject, titled *Mountain wave and associated turbulence* (available at [www.atsb.gov.au](http://www.atsb.gov.au)). A revised edition of that education material is reproduced in Appendix B of this report.

## **1.5 Aids to navigation**

Navigational equipment and their operation were not considered to have contributed to the occurrence.

## **1.6 Communications**

All communications between the aircraft and air traffic services were recorded by ground-based equipment for the duration of the flight.

The recorded communication between the Essendon tower controller and the pilot included a late-notice request by the pilot to submit a flight plan for an ‘...urgent departure Essendon Shepparton return.’ The submission of IFR flight plan details by radio was permitted only if no other means was available, and would not normally be accepted by a controller at an operating position.

The pilot’s subsequent communications with the Melbourne Centre controller were routine and there were no emergency transmissions made by the pilot.

An assessment of the recorded information found that there were no anomalies in any aspect of the communications between the crew and air traffic control (ATC) or other aircraft.

## **1.7 Aerodrome information**

No evidence was found to suggest that the aerodrome facilities, or the characteristics of any of the runways used by the pilot, contributed to the occurrence.

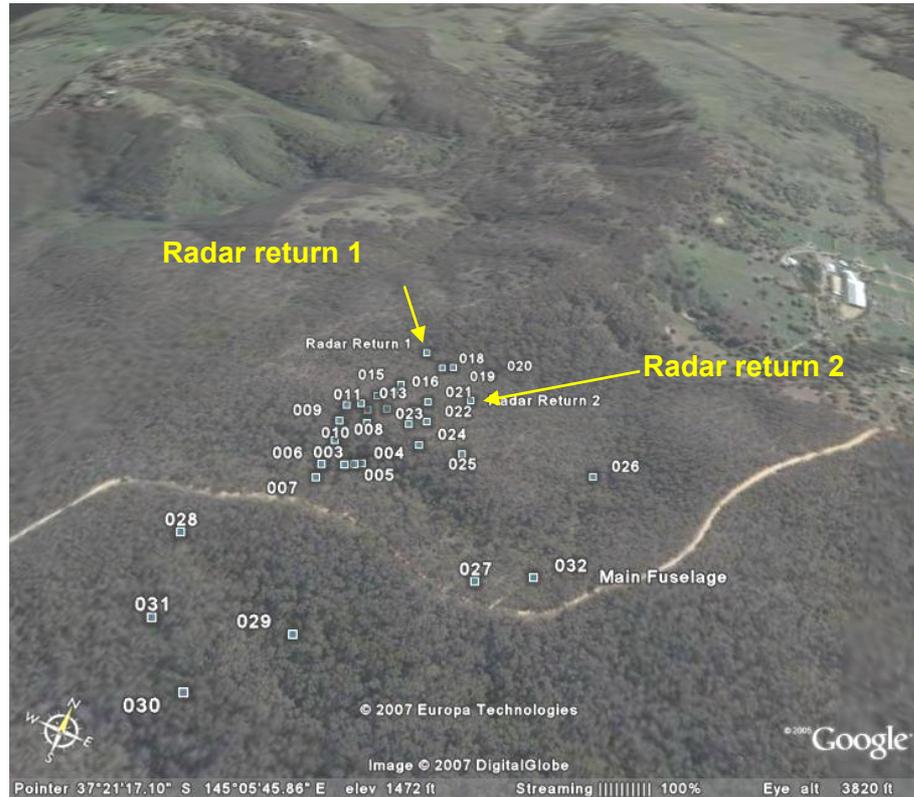
## **1.8 Flight recorders**

The aircraft was not fitted with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was there any legislated requirement for the installation of those recorders in the aircraft.

## **1.9 Wreckage and impact information**

The wreckage was distributed in timbered, hilly terrain at an elevation of approximately 1,400 ft. The area surrounding the site was covered with eucalypt trees that were 15 to 20 m high. The main section of wreckage was located at position 37° 21 39’S, 145° 05 92’E (Figure 5) on the northern face of a ridge, the slope of which was between 17 and 20 degrees. It had descended almost vertically through the tree canopy and impacted the sloping ground in a flat, inverted attitude (Figure 2). The main section of wreckage consisted of the fuselage and the inboard section of the main wing, which included the engine nacelles, engines and propellers. There was no evidence of a fire.

**Figure 5: Accident site, showing the distribution of the wreckage and the position of the last two radar returns.**



**Note: See Table 1 of Appendix A for wreckage item identification**

Both engines remained attached to the inner section of their respective wing, and each propeller remained attached to the corresponding engine. The evidence showed that the main landing gear was retracted, and became extended during the impact sequence. Wheel imprints in the upper surface of the wheel fairing and broken up-lock hooks attested to the landing gear being forcibly released (or rebounded) after the initial impact with the ground. The nosewheel and the flaps were fully retracted.

The outboard section of both wings from approximately the aileron/flap junction, the rear fuselage, the tail cone/empennage, and the aft cargo door had separated from the aircraft and were located up to 700 m north and west of the main wreckage. The empennage and the associated control surfaces had separated, and broken into nine major components. All control surfaces and trim tabs were recovered. Continuity of the control cables within the main section of wreckage, and in the separated wing and tail sections, was established. Damage to the severed cable ends was consistent with overload forces during the breakup. The elevator trim position was consistent with a normal cruise flight setting.

The investigation was unable to determine with any certainty, the pre-impact position of the power levers and aircraft ancillary controls. The replacement starter motor and LAME's tools were found strewn on the ground near the main wreckage, consistent with them having been ejected from the aircraft's rear locker.

The wreckage distribution was consistent with an in-flight breakup of the aircraft, and the recorded radar data showed that a sudden event had occurred during cruise flight at 7,000 ft. That negated the need for a trajectory analysis as a means to

establish the altitude and position of the breakup. The subsequent radar returns could not be explained by any normal flight manoeuvre.

A number of items and components were recovered for technical examination and to enable the re-construction of parts of the aircraft. That included the engines and propellers, the autopilot, and a number of airframe components.

### **1.9.1 Wreckage examination**

#### ***Engines and propellers***

Both engines, including those components necessary for normal engine operation, and both propellers were recovered from the accident site for more detailed examination to confirm their serviceability and operation prior to impact.

The engines and propellers were dismantled and examined at specialist facilities, under the supervision of Australian Transport Safety Bureau (ATSB) personnel. The engine examination did not reveal any pre-existing defect or anomaly that would have prevented either engine from developing its rated power.

The on-site inspection of the left and right propellers showed similar evidence of rotational damage to one of each of the propellers' 3-blades. The subsequent examination of the propellers determined that both were rotating and operating in the governed range at the time of the initial impact with the terrain. No pre-existing defects were detected that would have prevented normal operation of either propeller prior to impact. Damage to the propellers was consistent with a sudden stoppage from high RPM.

#### ***Autopilot***

The damaged EDO AIRE Mitchell Century III autopilot amplifier unit was removed from the wreckage for examination at a specialist facility. The specialist facility reported that a bench test of the unit found that it was capable of operating within the normal parameters for the type of amplifier, and that there were no major defects that would have caused any abnormal operation of the auto pilot.

The damaged panel-mounted autopilot 'mode selector' was also removed from the wreckage for more detailed examination. That examination showed that the autopilot was selected to the 'NAV' mode at impact, which was consistent with the use of Global Positioning System (GPS) navigation by the pilot. The autopilot controller, which was mounted on the power quadrant, was destroyed and it was not possible to determine if the altitude hold was engaged at the time of the breakup.

#### ***Fuel***

During the on-site examination of the wreckage, a small quantity of fuel was found in a badly-damaged right wing inner fuel cell. There was evidence of staining and fuel soakage to a large area of soil directly beneath the wreckage. No fuel was able to be retrieved for testing; however, the small quantity observed in the fuel cell appeared to be the correct colour, smell and consistency for Avgas.

Examination of the airframe and both engine fuel filters, including the very fine 'finger' fuel filters located in the engine fuel control units of both engines, showed

only clean fuel, with no evidence of water or other contaminants. The small quantity of fuel present in the fuel distributor valves and fuel control units was also found to be free of contaminants.

No evidence was found to indicate that the condition or quantity of fuel on board the aircraft at the time contributed in any way to the development of the accident.

### 1.9.2 **Wreckage reconstruction and fracture surface examination<sup>16</sup>**

Due to the known history of in-flight wing failures and main spar cracking associated with many Aero Commander aircraft models<sup>17</sup>, and a previous landing accident in this aircraft, which caused extensive damage to the aircraft's left outer wing, the investigation looked closely at the possibility that one of those factors, or a combination, may have resulted in wing spar failure.

A total of 32 discrete airframe sections and components were recovered from the accident site and transported to a suitable covered facility for detailed examination. A partial reconstruction of the damaged airframe components was undertaken to determine the breakup sequence, and laboratory examination of the fracture surfaces was made to identify the nature of the failure.

The reconstruction determined that the breakup initiated from the separation of both left and right outer wings sections at symmetrical locations. Both main spar wing breaks coincided with the outboard flap/aileron transition and exhibited overstress in a downward direction. Similar downward bending characteristics were also exhibited by the wing rear spar elements. The under-surfaces of both separated outer wing sections exhibited impact marks corresponding with those to the leading edges of the respective horizontal stabilisers. Similarly, the underside of the separated left engine nacelle rear fairing displayed damage that attested to an impact with a section of the left outer wing leading edge.

The empennage separated from the main fuselage along a downward, diagonal plane, extending from the forward transition region between fuselage and vertical stabiliser. Fuselage skin and longerons<sup>18</sup> were torn and fractured in a manner consistent with their exposure to the stresses associated with the breakup of the aircraft. Separation of the vertical stabiliser structure from the horizontal stabiliser and tail-cone occurred at a location coincident with the forward horizontal stabiliser spar.

All elevator, rudder and aileron control surfaces separated from their primary structure during the breakup sequence. In all instances, the surfaces were liberated through the fracture or structural failure of hinge points. Most surfaces had also folded and torn through the central span regions. All examinable control mechanisms and components displayed mechanical damage associated with the forceful separation from the primary structure. They did not exhibit any of the

---

16 See Appendix A of this report for a full description of the technical analysis of the wreckage and fracture surfaces.

17 Swift, S.J. (May 1995). 'The Aero Commander Chronicle', paper originally presented at the 13<sup>th</sup> symposium of the International Committee on Aeronautical Fatigue, Melbourne, Australia. <http://www.casa.gov.au/airworth/papers/AeroCommander.pdf>

18 Principal longitudinal structural members in the fuselage.

characteristics associated with aeroelastic oscillation (or flutter), such as the liberation of mass balances, trim tab separation, control surface over-travel in both directions, or reverse bending or twisting of the immediate structure.

An examination of the relevant fracture surfaces found that there was no evidence of a pre-existing fault or structural weakness in either wing spar. None of the failed wing main structural load-bearing elements showed any evidence of cracking or corrosion. All fracture features were typical of ductile, tensile or shear failure under elevated stresses.

Within the main aircraft fuselage, a number of sharp, outwardly oriented indentations and punctures were consistent with repeated impacts from the aircraft's main battery, which broke free from its mounts, but remained electrically connected. A characteristically stretched and elongated filament within a wing tip navigation light globe was a further indication of the magnitude of the forces sustained during the wing separation (while the light was still powered).

## **1.10 Medical and pathological information**

Autopsy examination found that the injuries to both occupants were consistent with an extreme (near vertical) ground impact, and that the accident was not survivable. There was no evidence that physiological factors affected the performance of the pilot or that the pilot was incapacitated.

## **1.11 Fire**

There was no evidence of either an in-flight fire or of a fire after impact.

## **1.12 Survival aspects**

An air and ground search was initiated soon after the aircraft was lost from radar. Two hours later, searchers located the wreckage and determined that there were no survivors.

No emergency locator transmitter (ELT) signal was received by aircraft in the area or by search and rescue satellite. A serviceable ELT was installed in the aircraft that complied with the requirements of Civil Aviation Regulation (CAR) 252A. Examination of the damaged ELT unit showed that it was subjected to impact forces that exceeded its design capability, and the resulting damage would have prevented it from functioning normally.

The on-site examination of the wreckage confirmed that the pilot was seated in the left (pilot) seat and that the passenger was seated in the right front (copilot) seat. The safety harnesses for both seats were of the lap and sash (single) type. Examination of the seat belts showed that both the pilot and copilot straps were fastened at impact, and that both safety harness buckles and clasp sections were forced apart by gross overload forces.

Both seats separated from their respective attachment points on the floor track, in an upward direction due to overload forces. That was consistent with the cabin section of the aircraft impacting the ground inverted. The seat belts remained attached to their respective seat anchor points.

The severity of the impact was such that the accident was not survivable.

## **1.13 Tests and research**

### **1.13.1 Other related Aero-commander occurrences**

In 1995, Mr S.J. Swift, Principal Fatigue Engineer with the then Civil Aviation Authority in Australia, delivered a paper titled *The Aero Commander Chronicle* to a meeting of the International Committee on Aeronautical Fatigue in Melbourne, Australia. The paper listed the number of wing structural failures in the various Aero Commander aircraft in the nearly 50 years of operation of the type until 1994. The majority of the 24 catalogued structural failures exhibited stress fatigue cracking or corrosion, originating from aspects of the design and manufacture of the aircraft. In addition, a number of failures resulted from the aircraft being overstressed during intentional manoeuvring by their pilots. More recently, there have been a number of Aero Commander in-flight structural failures where fatigue, corrosion or intentional manoeuvring, were not identified as contributing factors.

#### ***BASI Occurrence 199402804 and subsequent Commission of Inquiry***

On 2 October 1994, an Aero Commander 690B, VH-SVQ, disappeared while en route from Williamstown, NSW to Lord Howe Island. The investigation into the loss of the aircraft (BASI Investigation Report 199402804) was unable to determine the factors directly related to the loss of the aircraft, although airframe and propeller icing was considered to have been a likely factor.

A subsequent Commission of Inquiry into the relations between the [then] Civil Aviation Authority and Seaview Air [the operator of VH-SVQ] raised questions relating to the structural integrity of the Aero Commander design. The inquiry sought expert opinion on the subject from one of Australia's most qualified aeronautical engineers, Professor Lincoln Wood. In a statement provided to the inquiry, Professor Wood gave a thorough analysis of the design and structural integrity of the Aero Commander airframe. The subject aircraft was the turbine-engine variant, but the general principles discussed in the statement are applicable to all aircraft.

An extract from Professor Wood's statement relating to gust response in aircraft design and gust loads as applied to the Aero Commander airframe follows:

### ***Gust response***

Evaluation of the response of an aircraft structure to atmospheric gusts requires the determination of structural loads due to the gust. These are obviously influenced directly by the nature and strength of the atmospheric turbulence, but also by the elastic and inertial properties of the aircraft. Gust loads on an aircraft structure must be considered in the design process. Important limiting operational speeds such as the turbulence penetration speed and the manoeuvring speed are specified by this analysis.

Two major methods of specifying discrete gust loadings have been employed over the years. The first of these, introduced in the 1930's, was the "sharp edge gust" model which specified an instantaneous onset of gust with a gust velocity of 30 ft/sec for cruising flight conditions. The sudden onset of a gust results in a very severe loading case and does not take into account aircraft motion which can reduce the gust response of the aircraft. To account for the fact that aircraft with low wing loadings (such as gliders) would experience a less severe response than other aircraft, certain modification factors were introduced in 1941 so that the gust response would not be over-predicted.

During the 1950's a smooth gust profile was introduced in the shape of the "one-minus-cosine" mathematical curve. This shape more accurately represents the onset of a real atmospheric gust. Also, atmospheric data indicated that peak gust velocities as high as 50 ft/sec should be specified as the design case cruise conditions.

When comparing the two gust models for predicting aircraft gust loads, it is apparent that the sharp edge gust shape is extreme but the peak gust velocity is low (30 ft/sec), while for the smooth gust profile both the gust shape and the peak gust velocity (50 ft/sec) are both more representative of actual gusts. It is not possible to say which model produces the highest gust loads on an airframe without making extensive calculations which must take into account the motion and flexibility of the aircraft.

Current US regulations for transport category aircraft (FAR 25) specify a continuous gust model, as opposed to the discrete gust model discussed above. Current British regulations still employ the discrete gust model. This shows that there is not universal worldwide agreement on gust models for aircraft design, although the final design outcomes are very similar.

### ***Gust loads***

...Any aircraft that flies into extreme turbulence at speeds above the manoeuvring speed risks experiencing structural damage, if not failure. The Aero Commander is not unique in this regard.

...Although there are many claims made about gust loads on the Aero Commander aircraft in evidence before the Commission, and there is much discussion on the topic, there is no net evidence presented that I have seen which would lead me to believe that this aircraft type is deficient in this regard.

### ***ATSB Occurrence 200400610***

On 19 February 2004, Aero Commander 500-S, VH-LST, broke up in flight during a day, VFR flight from Hobart, Tas. to Devonport. The pilot, who was the sole occupant, was relatively inexperienced with 371 hours total aeronautical experience and 40 hours on type, and had only recently obtained an IFR rating. The investigation found that the aircraft structure failed in overload, consistent with a downward separation of both wings under symmetrical negative loading. None of the fracture surfaces exhibited any pre-existing damage and there was no fatigue cracking, corrosion or material defect evident in the airframe.

Trajectory analysis determined that the breakup occurred at high speed and at an altitude of approximately 3,150 ft, almost 5,500 ft below the pilot's planned cruising level. The apparent loss of altitude could be explained by the pilot engaging the Bendix FCS-810 autopilot with nose-down pitch inadvertently commanded. The attempted corrective actions of the pilot to manually override the resulting motion with the autopilot engaged, resulted in the opposing elevator trim force possibly overcoming the pilot's physical ability to prevent an increasing nose-down attitude. The rapidly increasing airspeed and negative g-forces exceeded the aircraft's structural and airspeed limitations.

The investigation was unable to discount other explanations for the departure from cruise flight, including a runaway pitch-trim condition, pilot incapacitation, the possible presence of mountain waves or severe turbulence, or a combination of any of those circumstances.

The autopilot installed in YJB was a different type to that installed in VH-LST.

### ***US Occurrence***

In October 2006, a US-registered, turbo-propeller Aero Commander 690A, broke-up during cruise flight at FL230 (23,000 ft) in an area of forecast moderate turbulence. In its investigation report (Docket No. DFW07FA004), the NTSB determined that the in-flight breakup was probably due to the pilot's failure to reduce airspeed while operating in an area of moderate turbulence.

The NTSB investigation found that the aircraft structure failed in overload, consistent with a downward separation of both wings under negative loading. None of the fracture surfaces exhibited any pre-existing damage, such as fatigue cracking, corrosion, or material defects.

The AC690A, although a different aircraft to the AC500-S, evolved from the basic Aero Commander design and shared a similar structure. The AC690A airframe was strengthened for the additional power and performance and for the increased weight of the turbine variant. The turbo-propeller engines of the 690A produced significantly faster cruising speeds than for the piston-engine Aero Commander variants, and were capable of flying at cruise speeds well in excess of its maximum 'design maneuvering speed' ( $V_A$ ) of 148 KIAS. The aircraft's speed at the time of the breakup was calculated by the NTSB to be approximately 44 kts greater than its  $V_A$ .

The NTSB investigation found that, in February 1995, Twin Commander Aircraft Corporation (the Type Certificate holder), issued Service Bulletin No. 220 – *Mandatory Reduction in Speed During Turbulence*, which stated:

...there have been two accidents involving Model 690 series aircraft resulting in loss of the aircraft, due to encountering turbulence while descending at high speed. Excessive airspeed in turbulence can cause structural damage or loss of the aircraft.

The report quoted a section of the AC690A Pilot's Operating Handbook (POH) that advised pilots to slow to  $V_A$  speed in severe turbulence, or turbulence penetration speed in moderate turbulence and contained the following statement:

WARNING: Failure to slow to  $V_A$  can result in structural damage or loss of airplane due to the magnitude of the gust loads or loss of control.

There have been no Service Bulletins issued by the Type Certificate holder for the Aero Commander 500 series aircraft requiring pilots to reduce speed in turbulence.

## 1.14 Organisational and management information

### *Managing director*

The passenger was the managing director of a company that owned and maintained a fleet of Aero Commander aircraft (almost half of those registered in Australia). The operating organisation was contracted to provide an airfreight service across a network that extended from a number of major centres throughout Australia. Also a LAME, the passenger had extensive experience on the Aero Commander aircraft type, and was widely regarded throughout the Australian aviation industry as an authority on those aircraft. The maintenance organisation repaired and re-built Aero Commander aircraft, and was reputed to be the largest and most experienced Aero Commander facility in the country.

The passenger was not a qualified pilot, but frequently flew in company aircraft and was reported to have provided feedback to the chief pilot on pilot handling techniques, especially those aspects that related to the care and operation of the aircraft's systems and engines.

### *Flight operations*

The nature of the operator's flying often resulted in flight through forecast and actual turbulent conditions. Generally, pilots were aware of the dangers of flying through areas of known severe turbulence, such as that found in or around thunderstorms. The potential for loss of control or structural failure resulting from the extreme turbulence associated with vertical air currents in cumulonimbus cloud (generally associated with thunderstorms), ensured that pilots normally avoided flying anywhere near them.

However, the existence of potential clear air turbulence and its severity could not be as accurately assessed before entering the affected area. Unlike thunderstorms, where the area of severe turbulence is readily identified by a visible column of cloud or lightning, or by a weather radar depicting areas of heavy rain or hail, the severe turbulence associated with rotors and breaking waves is often invisible and

undetected by weather radar. It can occur in clear air, and in isolated pockets over a broad geographical area in the lee of mountain ranges, at different levels and with varying degrees of intensity.

Some of the operator's pilots reported that, in the weeks prior to the accident, there were numerous SIGMET warnings about severe turbulence in strong wind conditions. Seasonally, that was no different from previous years when a strong north-westerly airflow across the Great Dividing Range frequently generated conditions similar to those on the night of the accident. None of those pilots recalled ever delaying or cancelling a flight due to forecast severe, mechanical turbulence. Additionally, two former pilots of the aircraft type, who had flown through the same area for many years, more than 30 years ago, could not recall ever cancelling or delaying flights because of forecast severe turbulent conditions.

Those pilots interviewed during the investigation reported that, when they encountered turbulent flying conditions in the Aero Commander 500-S aircraft, their technique was to disconnect the autopilot or the altitude hold function of the autopilot and reduce power to slow the aircraft. They would then manually control the aircraft in pitch<sup>19</sup> using only gentle elevator inputs while allowing the aircraft to 'ride'<sup>20</sup> the turbulent air. That resulted in the aircraft climbing and descending with the rising and falling air currents. The former pilots reported that, before the introduction of Mode C transponder equipment<sup>21</sup> (radar identification with aircraft altitude), there was less focus on maintaining altitude in severe turbulence conditions, and altitude excursions in excess of the 100 ft IFR tolerance were considered acceptable.

The 'Specific Operating Instructions' section of the company Operations Manual incorporated guidance to pilots regarding flight in turbulence. It instructed pilots encountering moderate to severe turbulence to fly the aircraft at the turbulence penetration speed for the specific aircraft or, if none was specified, to use the manoeuvring speed ( $V_A$ ). It also instructed pilots to disengage the autopilot's 'altitude hold' (if engaged). The technique to be used, whether flying manually, or with the autopilot, was to maintain the aircraft's attitude within safe limits while accepting altitude changes and speed variations. Both the aircraft flight manual and the operator's standard operating procedures manual (SOPM) for the Aero Commander 500-S listed the 'published maneuvering speed' ( $V_P$ ) as 141 kts.

Some of the operator's pilots reported that when they encountered turbulence they would reduce power and allow the airspeed to decrease. They reported that the usual procedure was to disconnect the autopilot or at least deselect the altitude hold function when encountering turbulence. One pilot stated that the landing gear could be extended below 156 kts and the speed then stabilised at 130 kts. None of the pilots made reference to the 'published maneuvering speed' ( $V_P$ ) as having application to flight through turbulence.

---

19 The term used to describe the motion of an aeroplane about its lateral (wingtip-to-wingtip) axis.

20 The pilot's operation of the flight controls to guide the aircraft, rather than attempting to correct every divergent movement with control inputs.

21 In Australian controlled airspace, the carriage of Mode C-capable transponder equipment, which enabled the display of an aircraft's altitude on a controller's radar screen, became mandatory in the late 1980s.

The operator's SOPM directed pilots to reduce power on descent at the rate of one inch of manifold air pressure per thousand feet of descent (equivalent to one inch per minute at the preferred descent rate of 500 ft/min).

## **1.15 Additional information**

### **1.15.1 Radar data**

The Australian Advanced Air Traffic System (TAAATS) processes and records radar signals from multiple surveillance sensors and correlates the information to produce synthesised aircraft tracks that are presented to air traffic controllers on an air situation display. The system records the information from each sensor as local track data and the synthesised track as system track data.

The recorded radar data was examined and showed that the aircraft climbed to a Mode C<sup>22</sup> altitude of 7,000 ft at groundspeeds of between 80 and 120 kts (Figure 6). The aircraft then maintained an altitude of 7,100 ft for nearly 5 minutes, with its groundspeed gradually increasing from 122 kts to 144 kts<sup>23</sup>. From 0957:42, the recorded altitude varied by between 100 and 200 ft<sup>24</sup> from the planned cruising altitude, and there was a gradual decrease in groundspeed from 144 to 140 kts. The aircraft's track was consistent with GPS navigation of the direct track to Shepparton.

A video replay of the recorded radar data showed that, after 1958:38, the aircraft turned right sharply onto a south-easterly track. At that time, the system indicated 'INVALID' Mode C altitude information, which was the default mode when a target's vertical speed exceeded 9,000 ft/min. The subsequent returns were primary radar signals that did not contain altitude information.

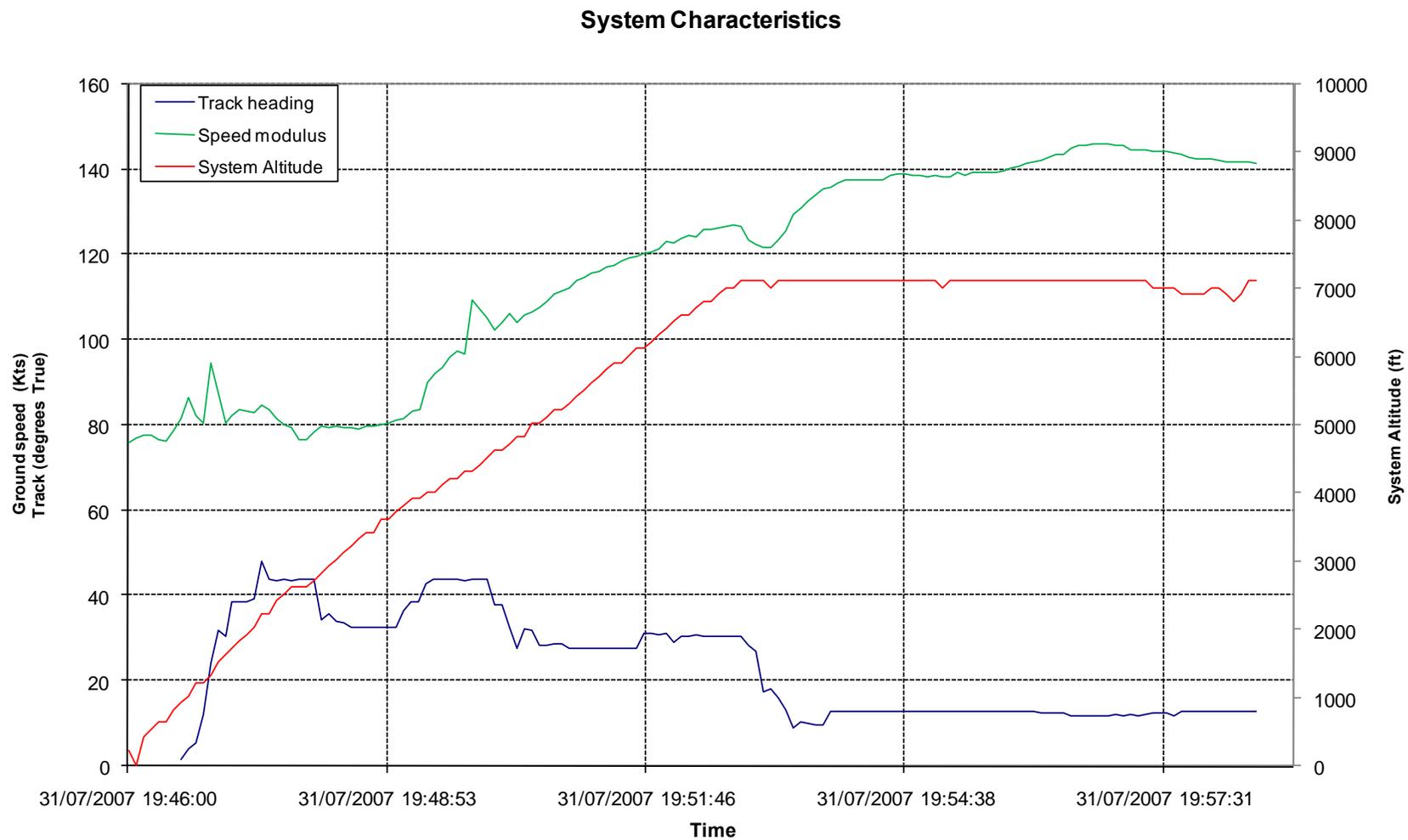
---

22 A transponder signal with barometric information from an encoding altimeter encrypted that enables altitude presentation on air traffic control radar screens.

23 Radar groundspeed is valid to within 1 to 2 kts.

24 Mode C altitude was shown in steps, rounded to the nearest 100 ft. Mode C altitude changes could not be assumed to be actual changes, or be used for determining the gusts or turbulence encountered by an aircraft.

Figure 6: Recorded radar data



### 1.15.2 Airspeed calculations

At 7,000 ft, a QNH<sup>25</sup> of 1006 hPa, and a temperature of 3° C<sup>26</sup>, the ‘published maneuvering speed’ (V<sub>P</sub>) of 141 KIAS was equivalent to a true airspeed of 158 kts. For comparison, the aircraft’s true airspeed during the last segment of cruise flight was calculated using the radar-derived track and ground-speed information, and the recorded 7,000 ft wind at Melbourne at 2100<sup>27</sup> (Table 1).

The actual true airspeed could not be determined with the same degree of accuracy as the groundspeed obtained from the recorded radar data. Variation in wind strength and direction between the 7,000 ft recorded wind at Melbourne airport an hour after the occurrence, and the actual wind affecting the aircraft before the in-flight break-up, could have resulted in correspondingly faster or slower airspeeds. However, the AMDAR wind data (Table 2) showed a consistent wind speed and direction throughout the period.

Additionally, transient airspeed fluctuations that occur during flight through turbulence are not apparent in the ground-speed data. The calculated true airspeeds, and hence the respective airspeed indications, are not the actual values and are, at best, indicative only.

**Table 3: Calculated true airspeeds**

Local time Hh/mm/ss	Radar Track (°T)	Radar Ground speed (kts)	Recorded Wind vector (Dir.°T / vel. kts)	Calculated True Airspeed (kts)
19:53:29	10.3	131.03603	310/46	158.9319
19:53:34	10.0	132.65938	310/46	160.6762
19:53:39	9.7	133.87601	310/46	162.0273
19:53:44	9.7	135.29675	310/46	163.4051
19:53:49	12.7	135.71886	310/46	162.0567
19:53:54	12.7	137.00002	310/46	163.2967
19:53:59	12.7	137.70642	310/46	163.9807
19:54:04	12.7	137.56514	310/46	163.8439
19:54:09	12.7	137.59465	310/46	163.8725
19:54:14	12.7	137.67899	310/46	163.9542
19:54:19	12.7	137.56816	310/46	163.8469
19:54:24	12.7	137.71552	310/46	163.9896
19:54:29	12.7	138.68234	310/46	164.9260
19:54:34	12.7	138.84557	310/46	165.0842

<sup>25</sup> A pressure setting that, when set on an altimeter on the ground, results in the display by the altimeter of the height of the position of the aircraft (such as at an airfield) above mean sea level.

<sup>26</sup> Derived from AMDAR data (Table 2).

<sup>27</sup> The actual wind vector at 7,000 ft at the time, and in the area of the in-flight break-up, was not recorded.

<b>Local time Hh/mm/ss</b>	<b>Radar Track (°T)</b>	<b>Radar Ground speed (kts)</b>	<b>Recorded Wind vector (Dir.°T / vel. kts)</b>	<b>Calculated True Airspeed (kts)</b>
19:54:39	12.7	139.04517	310/46	165.2776
19:54:44	12.7	138.68556	310/46	164.9292
19:54:49	12.7	138.57596	310/46	164.8230
19:54:54	12.7	138.34508	310/46	164.5993
19:54:59	12.7	138.48874	310/46	164.7385
19:55:04	12.7	138.28961	310/46	164.5456
19:55:09	12.7	138.36142	310/46	164.6152
19:55:14	12.7	139.27567	310/46	165.5009
19:55:19	12.7	138.58243	310/46	164.8292
19:55:24	12.7	139.36321	310/46	165.5857
19:55:29	12.7	139.29158	310/46	165.5163
19:55:34	12.7	139.29288	310/46	165.5176
19:55:39	12.7	139.34949	310/46	165.5725
19:55:44	12.7	139.56079	310/46	165.7772
19:55:49	12.7	140.36813	310/46	166.5598
19:55:54	12.7	140.70276	310/46	166.8842
19:55:59	12.7	141.56410	310/46	167.7194
19:56:04	12.7	141.70772	310/46	167.8587
19:56:09	12.3	142.06015	310/46	168.4410
19:56:14	12.4	142.85136	310/46	169.1487
19:56:19	12.3	143.71187	310/46	170.0441
19:56:24	12.3	143.68098	310/46	170.0141
19:56:29	11.7	145.00000	310/46	171.6547
19:56:34	11.7	145.64212	310/46	172.2788
19:56:39	11.7	145.65744	310/46	172.2936
19:56:44	11.7	146.00000	310/46	172.6266
19:56:49	11.7	146.00000	310/46	172.6266
19:56:54	11.7	146.00002	310/46	172.6266
19:56:59	12.0	145.63739	310/46	172.0945
19:57:04	11.7	145.63896	310/46	172.2757
19:57:09	12.0	144.70927	310/46	171.1928
19:57:14	11.7	144.65141	310/46	171.3160
19:57:19	12.0	144.63686	310/46	171.1224
19:57:24	12.4	144.29256	310/46	170.5478
19:57:28	12.3	144.36566	310/46	170.6790
19:57:33	12.3	144.35013	310/46	170.6639
19:57:38	11.7	144.00000	310/46	170.6831
19:57:43	12.7	143.48207	310/46	169.5802
19:57:48	12.7	143.00000	310/46	169.1124
19:57:53	12.7	142.64531	310/46	168.7682
19:57:58	12.7	142.64572	310/46	168.7686
19:58:03				

<b>Local time Hh/mm/ss</b>	<b>Radar Track (°T)</b>	<b>Radar Ground speed (kts)</b>	<b>Recorded Wind vector (Dir.°T / vel. kts)</b>	<b>Calculated True Airspeed (kts)</b>
19:58:08	12.7	142.64580	310/46	168.7687
19:58:13	12.7	142.25499	310/46	168.3895
19:58:18	12.7	141.64374	310/46	167.7966
19:58:23	12.7	141.71491	310/46	167.8657
19:58:28	12.7	141.64166	310/46	167.7946
19:58:33	12.7	141.62689	310/46	167.7803
19:58:38	12.7	141.31230	310/46	167.4752
	12.7	138.91975	310/46	165.1561



---

## 2

## ANALYSIS

---

### 2.1 Introduction

The pilot commenced this flight generally aware of the forecast severe turbulence on or south of the Great Dividing Range, in the area where the in-flight breakup occurred. The forecast conditions would not have been significantly different from other flights undertaken by the pilot, including the flight made immediately preceding the accident flight. In fact, the weather system was similar to many others encountered over the past four decades in which numerous flights were made in Aero Commander aircraft through this area. The decision to undertake the flight would not have been made with any awareness of undue risk and, under the circumstances, was quite reasonable.

This analysis considers the issues that may explain why, on this particular occasion, an apparently airworthy aircraft, flown by an experienced and appropriately qualified pilot, broke up in cruise flight.

### 2.2 Aircraft structure and in-flight breakup

The breakup of the aircraft was consistent with it being subjected to rapid and extreme aerodynamic forces during normal cruise flight at 7,000 ft. Examination of the damage to the aircraft's structure revealed no evidence of any pre-existing defect, such as metal fatigue or corrosion. The wing structure failed in negative overstress. The symmetrical nature of that failure was indicative of a break up in straight flight, consistent with the radar data, rather than during a turn or a spiral descent. That type of failure of the aircraft's structure can be explained by either the rapid onset of an extremely powerful downward gust, or by forward elevator control application by the pilot; possibly in response to a sudden nose-up pitching movement, or a combination of both.

### 2.3 Clear air turbulence

The Bureau of Meteorology (BoM) modelling of the airflow over the area of the accident site was unable to quantify the strength of any gusts, or to determine the existence of any localized severe turbulence within the airflow. However, on occasions areas of forecast severe mountain waves can include rotors and breaking waves, the intensity of which can exceed the gust values for which an aircraft was designed to withstand. In this case, the relevant special weather report (SIGMET) suggested a reasonable likelihood of the aircraft encountering severe turbulence.

The radar-derived gradual increase and decrease in aircraft speed in the few minutes of cruise flight could have been indicative of moderate wave action with the autopilot's altitude hold function engaged. However, the nature of clear air turbulence was such that a pilot could encounter severe turbulence with insufficient time to slow the aircraft before the onset of any gusts, which could be sudden and severe enough to overstress an aircraft's structure.

## **2.4 Flight through forecast areas of severe turbulence**

It could not be positively established if the pilot received the amended SIGMET that warned of severe turbulence or SIGMET ML03, which warned of occasional severe mountain waves. Having flown through part of the forecast areas of severe turbulence on the previous flight, and probably not having experienced any significant turbulence, it was possible that the pilot did not expect to encounter any different conditions on the flight to Shepparton. That could possibly explain why, in the few minutes of cruise before the in-flight break-up occurred, the aircraft was probably flying at speeds greater than its manoeuvring speed.

The recorded radar data showed that the aircraft's speed slowed by only a few knots in the minute or two after the altitude deviations commenced. That should have been enough time for a pilot who was anticipating severe turbulence to have reduced airspeed below the aircraft's manoeuvring speed. It was possible that the pilot was in the process of slowing the aircraft by using the operator's preferred technique of gradually reducing power. Alternatively, the urgency of the flight, as reported to the Essendon tower controller, might have influenced the pilot to delay slowing the aircraft only when and if, in the pilot's estimation, the turbulence became severe. In any event, the aircraft was still travelling in excess of the manoeuvring speed when it encountered a sudden and severe gust.

It was not possible to determine whether the pilot was manually controlling the aircraft or whether the autopilot was engaged at the time of the breakup. Either a pilot manually attempting to maintain altitude, or an autopilot with the altitude hold engaged, could inadvertently apply elevator control inputs that, when superimposed upon the aerodynamic forces encountered in severe turbulence, overstress the aircraft.

## **2.5 Application of manoeuvring speed**

Flight through an area of severe turbulence at speeds at or above the aircraft's manoeuvring speed increased the risk of aircraft structural failure. Transient airspeed fluctuations can occur in turbulence, resulting in an aircraft travelling at, or in excess of its manoeuvring speed. Using a slower speed, with a margin appropriate to the conditions, could avoid inadvertently exceeding the manoeuvring speed.

In this instance, the relatively low weight of the aircraft increased its susceptibility to the effects of severe turbulence. The pilot's technique for flying in turbulence could not be determined. However, there was no evidence that the pilot lacked the knowledge and training to operate the aircraft safely in severe turbulence.

Other Aero Commander pilots advised that, when they encountered turbulence that was severe enough to require counter action, their procedure was to reduce power and speed and to disconnect the autopilot or its altitude-hold function. None quoted a manoeuvring speed as the maximum speed for flight through turbulence, even though the operator's documentation stated that it was to be used for flight through moderate and severe turbulence, and the aeroplane flight manual listed the 'published maneuvering speed'.

It was possible that some pilots thought that the manoeuvring speed applied only to the speed at which intentional full-control inputs could be made during manoeuvring, such as pulling up from a dive or when turning an aircraft.

## **2.6 Conclusion**

Managing the risk of in-flight breakup commences with the design, certification and manufacture of an aircraft. When introduced into service, that risk is managed by maintaining each aircraft in accordance with its manufacturer's directions, and with any directions from the relevant airworthiness authorities. In this occurrence, there was no evidence that any of those aspects were managed inappropriately.

Generally, the risk of in-flight structural failure was managed by the operation of aircraft within prescribed limits, and the avoidance of extreme environmental conditions.

For reasons that the investigation was unable to determine, the aircraft was not slowed to a speed that minimised the risk of in-flight breakup in an area of forecast severe turbulence.



---

## **3 FINDINGS**

---

From the evidence available, the following findings are made with respect to the in-flight breakup of the Rockwell International Aero Commander 500-S aircraft, registered VH-YJB, on the evening of 31 July 2007 and should not be read as apportioning blame or liability to any particular organisation or individual.

### **3.1 Contributing safety factors**

- The aircraft was flown in an area of likely severe turbulence at speeds probably greater than its manoeuvring speed, thereby increasing the risk of structural overstress.
- The aircraft structure failed in flight as a result of overstress in negative loading, probably produced by an abrupt and severe gust associated with a rotor or breaking wave turbulence, an elevator control input by the pilot, or a combination of both.

### **3.2 Other safety factors**

- The aircraft manufacturer's documentation did not provide information or guidance to pilots for flight in turbulent conditions, increasing the risk of an inadequate pilot response to an encounter with severe turbulence. [*Safety issue*]
- There was a degree of urgency for the flight that might have influenced the pilot's decision-making and actions during flight through an area of severe turbulence.

### **3.3 Other key findings**

- The aircraft was maintained in accordance with the manufacturer's procedures and with the relevant regulatory requirements, and there was no evidence of any pre-existing defect, such as undetected metal fatigue or corrosion, or component failure.
- The pilot was appropriately qualified and rated to perform the flight and there was no evidence of any physiological condition that may have affected the pilot's performance.
- The Bureau of Meteorology (BoM) issued appropriate warnings relating to severe turbulence and mountain wave activity in the area of the accident.



---

## 4 SAFETY ACTIONS

---

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.

### 4.1 Australian Transport Safety Bureau

#### 4.1.1 Guidance for flight in turbulent conditions

##### ***Safety issue***

The aircraft manufacturer's documentation did not provide information or guidance to pilots for flight in turbulent conditions, increasing the risk of an inadequate pilot response to an encounter with severe turbulence.

##### ***Action taken by the ATSB***

Safety action undertaken by the ATSB in response to this safety issue includes the:

- revision of the January 2005 ATSB Safety Education Material titled *Mountain Wave Turbulence*. That revision had effect on 31 July 2009 and is included as Appendix B to this report. Alternately, the publication is available for download at [http://www.atsb.gov.au/publications/2005/mountain\\_wave\\_turbulence.aspx](http://www.atsb.gov.au/publications/2005/mountain_wave_turbulence.aspx)
- distribution of a copy of this investigation report to all Australian operators of Aero-Commander aircraft
- issue of a Safety Advisory Notice to all operators
- release of a media article to ensure the widest possible dissemination and understanding of the safety factors and issues in this occurrence and their management. That media release is included in this report as Appendix D.

##### ***Safety advisory notice AO-2007-029-SAN-097***

The Australian Transport Safety Bureau draws the attention of all operators to the contributory and other factors identified by this investigation. Operators are encouraged to review their procedures to ensure an appropriate awareness amongst operating personnel of the implications for aircraft performance of the combination of aircraft weights and speed, and of the ambient conditions.



---

# **APPENDIX A: TECHNICAL ANALYSIS REPORT**

---

**ATSB TECHNICAL ANALYSIS**  
Investigation No. A0-2007-009

## **Structural Failure Analysis**

**Rockwell International Aero Commander 500-S,  
VH-YJB**

**In-flight breakup - Clonbinane, Vic.  
31 July 2007**



## SUMMARY

On 31 July 2007, a Rockwell International Aero Commander 500-S *Shrike Commander* aircraft broke-up while in flight and impacted terrain near Clonbinane, Vic. The pilot and passenger on-board were fatally injured.

The aircraft wreckage was located over an area of approximately 15 hectares and elements were subsequently collected and assembled for examination. Both outboard wing sections had separated from the main fuselage, as had the empennage and tailplanes.

All failures within the principal load-bearing sections of the aircraft's wings, tailplanes and control surfaces, had occurred under conditions of gross overstress. No pre-existing damage, degradation or cracking (such as fatigue or stress-corrosion cracking) that could have reduced the structural integrity of the aircraft, was evident at, or associated with the locations of failure and separation. The directionality of the permanent, plastic deformation associated with the wing spar structural failures, was indicative of both wings failing symmetrically under downward bending conditions.

Comparative impact witness marks and deformation along the leading edges of the horizontal stabilisers and the surfaces of both outboard wings, was evidence of the corresponding impact between those sections during the breakup sequence. It was probable that the forces imparted during the impacts resulted in the separation of the tailplanes and empennage from the aircraft structure.

None of the aircraft's principal or secondary control surfaces showed any evidence of oscillatory movement or flutter. All failures of hinge points or control system attachments were attributable to the overstress conditions associated with the breakup of the airframe.



## FACTUAL INFORMATION

### Introduction

On 31 July 2007, a Rockwell International Aero Commander 500-S aircraft with a pilot and one passenger on-board collided with treed, sloping terrain near Clonbinane, Vic. during a planned, instrument flight rules flight from Essendon to Shepparton. The pilot and passenger were fatally injured.

Preliminary on-site investigation located parts of the aircraft's wings, empennage and ancillary structures distributed over an area of around 15 hectares of hilly, sloping terrain within the Wandong regional park (Victorian state forest). The main fuselage and inboard wing sections were located towards the eastern limits of the wreckage field, at a location of S 37° 21.39', E 145° 05.92' (WGS84 datum).

The wide distribution of wreckage and its partial fragmentation was consistent with the aircraft structure failing and breaking up while in flight. Both outboard wings and the empennage (tailplanes) had separated from the primary airframe, with all showing evidence of secondary damage from impact with the ground or other structural elements.

### Investigation brief

The major components of the aircraft structure were subject to a forensic engineering examination by ATSB specialists, to determine:

- the principal modes and mechanisms of structural failure
- whether any anomalous feature/s or pre-existing defects or damage may have contributed to the structural failures sustained
- the general sequence of structural failure and breakup of the airframe.

### Wreckage recovery

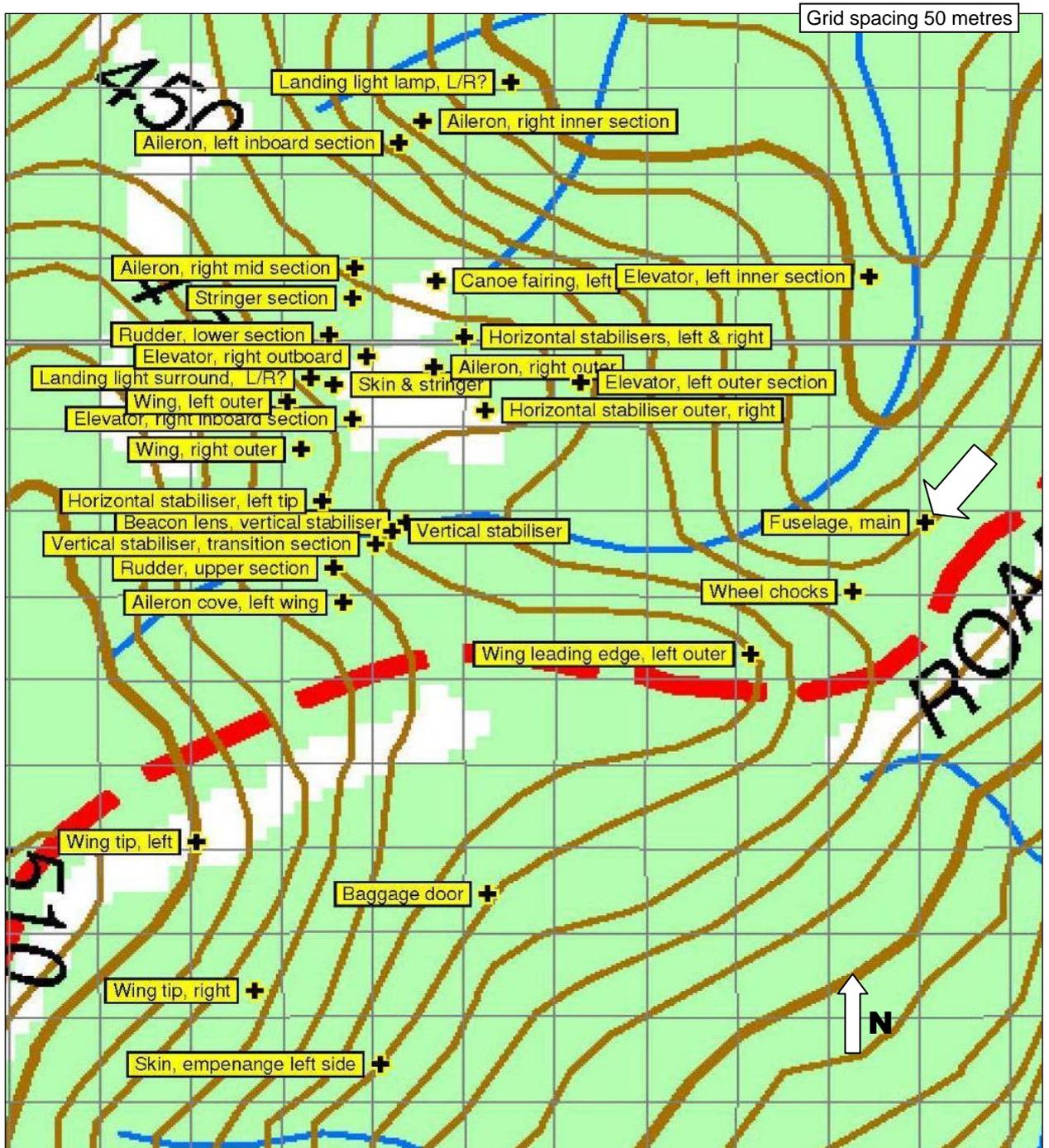
All of the aircraft wreckage was recovered from the accident site after each item was identified and its position recorded (Figure 1). All structural components that had separated from the main fuselage of the aircraft (see Table 1) were relocated to a hangar at Tyabb Aerodrome, Vic. where they were arranged in a layout fashion that represented the original aircraft structure. To facilitate the study of the wing failures, the inboard fracture surfaces and adjacent material (approximately 30 cm) were removed from the inboard section of both wings and transported to Tyabb with the other items.

The principal points of failure and separation of each item were studied in the context of their separation from the airframe and the mechanism of fracture. The wreckage was also inspected by a representative of the Civil Aviation Safety Authority (CASA) at the time it was being examined in Tyabb.

**Table 1: Wreckage items**

<b>Position / Item No.</b>	<b>Identification</b>
001	Reference position 1 (not wreckage)
002	Reference position 2 (not wreckage)
003	Vertical stabiliser beacon lens
004	Vertical stabiliser and empennage sub-structure
005	Vertical stabiliser, section of fuselage transition
006	Rudder, upper section
007	Wing, left, section of aileron cove
008	Horizontal stabiliser, left, tip
009	Wing, right outer
010	Elevator, right, inboard section
011	Wing, left outer
012	Skin & stringer, unknown location
013	Landing light surround, unknown if left or right
014	Rudder, lower section
015	Aileron, right, mid-section
016	Stringer section, unknown location
017	Elevator, right, outer section
018	Aileron, left, inner section
019	Aileron, right, inner section
020	Landing light lamp, unknown if left or right
021	Nacelle, engine, left canoe fairing
022	Horizontal stabilisers, left and right inner, with rear empennage & tail cone
023	Aileron, right, outer section & trailing edge strip
024	Horizontal stabiliser, right, outboard tip
025	Elevator, left, outer section
026	Elevator, left, inner section
027	Wing, left, partial outer section leading edge
028	Wing, left, winglet tip
029	Door, baggage
030	Skin, empennage section, left side forward of vertical stabiliser
031	Wing, right, winglet tip
032	Wheel chocks
033	Aileron, left, outer section

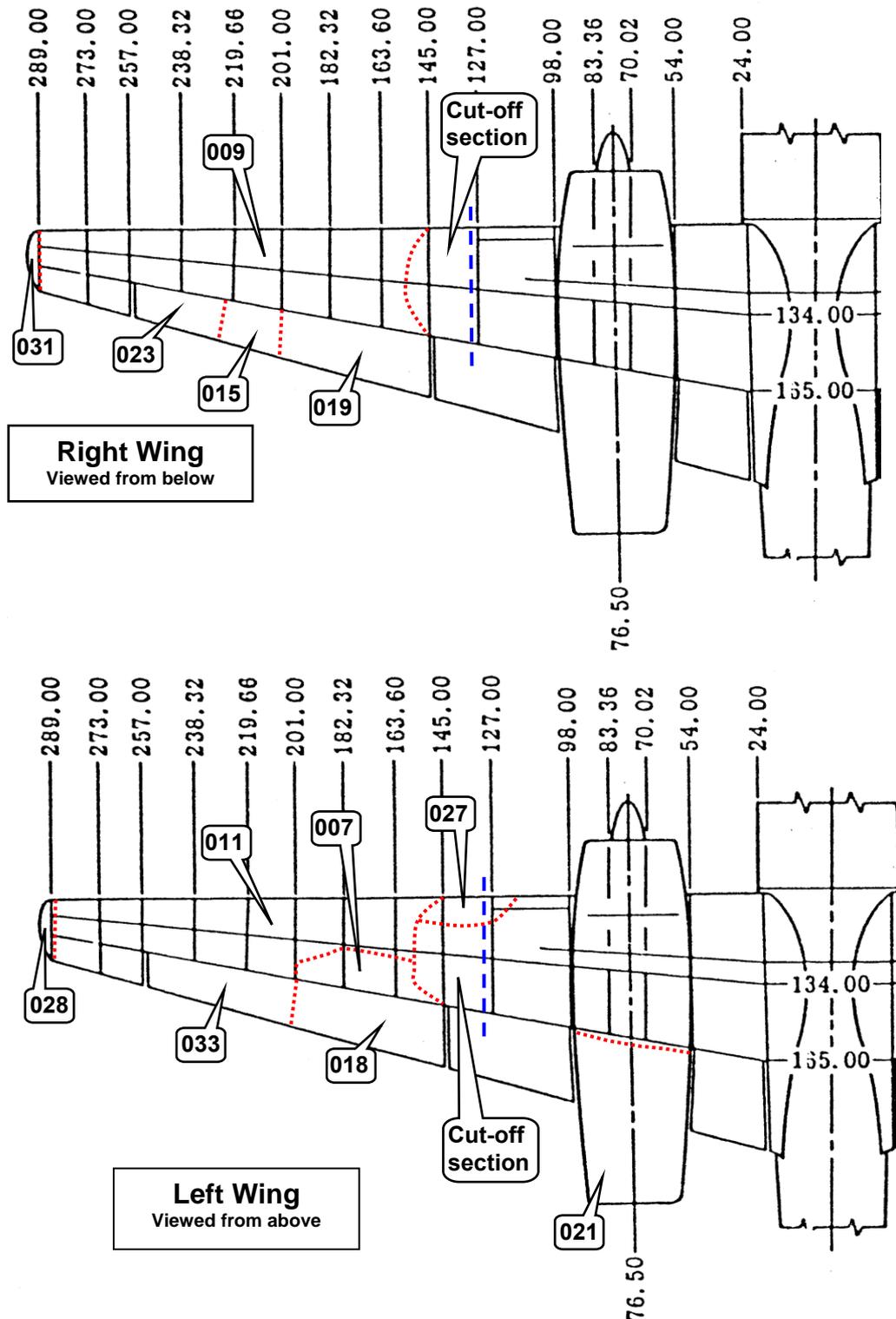
Figure 1: Wreckage distribution (main fuselage arrowed)



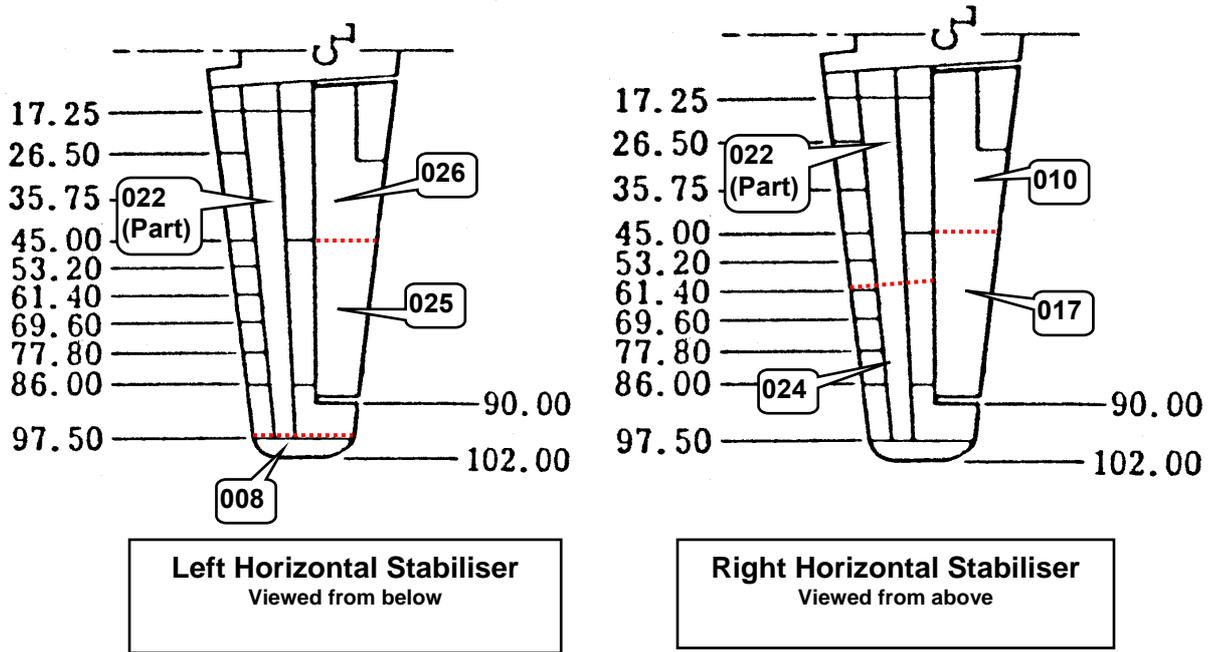
## Structural examination

Preliminary examination of the recovered wreckage focussed on identifying the points of primary structural airframe failure. With reference to the aircraft station diagram, the locations of structural separation were identified as shown in Figures 2-4.

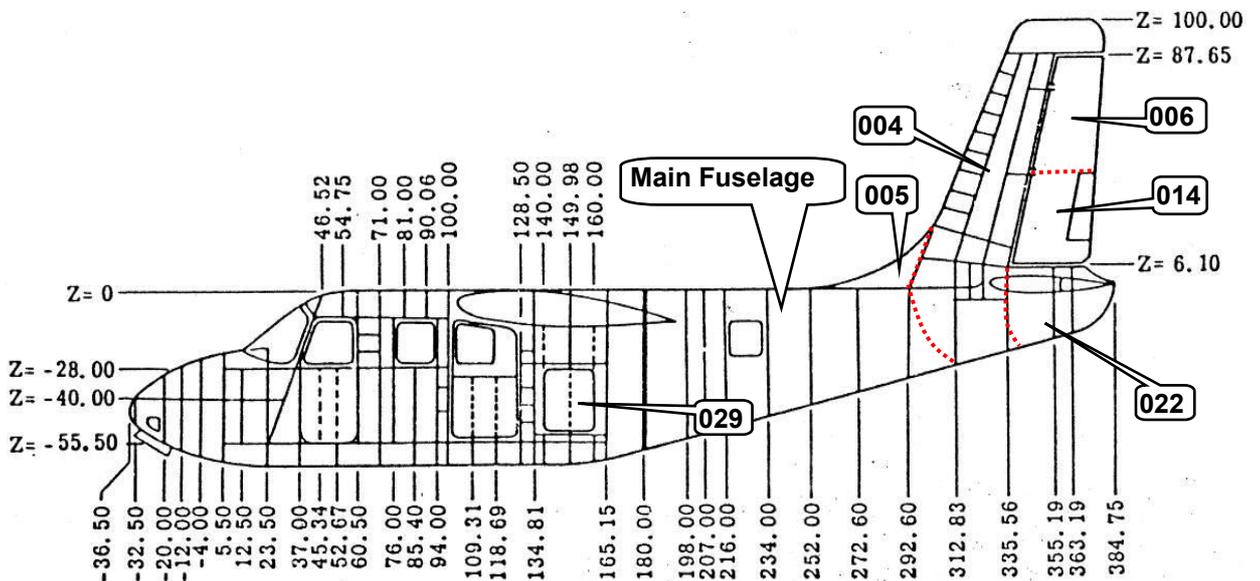
**Figure 2: Right wing section (upper) and left wing section (lower). Paths of separation indicated as red dotted lines**



**Figure 3: Horizontal stabiliser sections (left and right as oriented). Paths of separation indicated as red dotted lines**



**Figure 4: Fuselage, empennage and vertical stabiliser sections. Paths of separation indicated as red dotted lines**



## Fracture detail

### *Wings*

Both aircraft mainplanes had fractured in a chord-wise, semi-symmetric manner, at a position coincident with the outboard flap / aileron transition (wing station 145) (Figures 5 and 6). Comparable levels of mechanical deformation were present in the upper and lower main spars of both wings, with the permanent structural distortion being consistent with the failure and separation of both outer wing sections under downward bending loads. Similar downward bending characteristics were also exhibited by the wing rear spar elements.

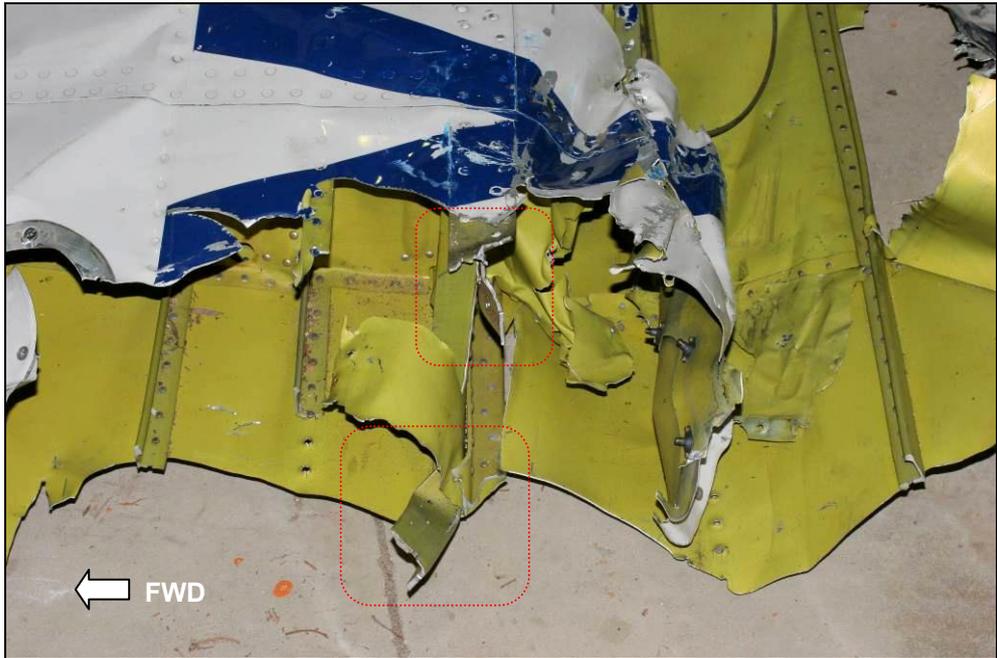
**Figures 5 and 6:** Wing failure presentation. Inboard fracture sections removed along broken lines shown



Figures 7 & 8: Separated wing structure and aileron control surfaces



**Figure 9: Left wing main spar cap fractures (viewed from wing underside)**



**Figure 10: Left wing rear spar cap fractures (viewed from wing underside)**



**Figure 11: Right wing spar cap fractures (viewed from wing underside)**



***Wings (cont'd)***

All of the wing spar fracture surfaces presented characteristics typical of ductile tensile and/or shear failure under combined tensile/bending loads. There was no evidence of pre-existing cracking, corrosion, material discontinuities or other anomalous features that could have affected the structural integrity of the spar elements or the wing structure generally.

Both wing main spar failures had occurred immediately outboard of the design connection between inboard wing and outer wing spans (wing station 145). In the right wing instance, failure of the upper main spar element had occurred through the reinforced section adjacent to the outboard spar termination.

**Figure 12: Left wing lower main spar cap fracture**



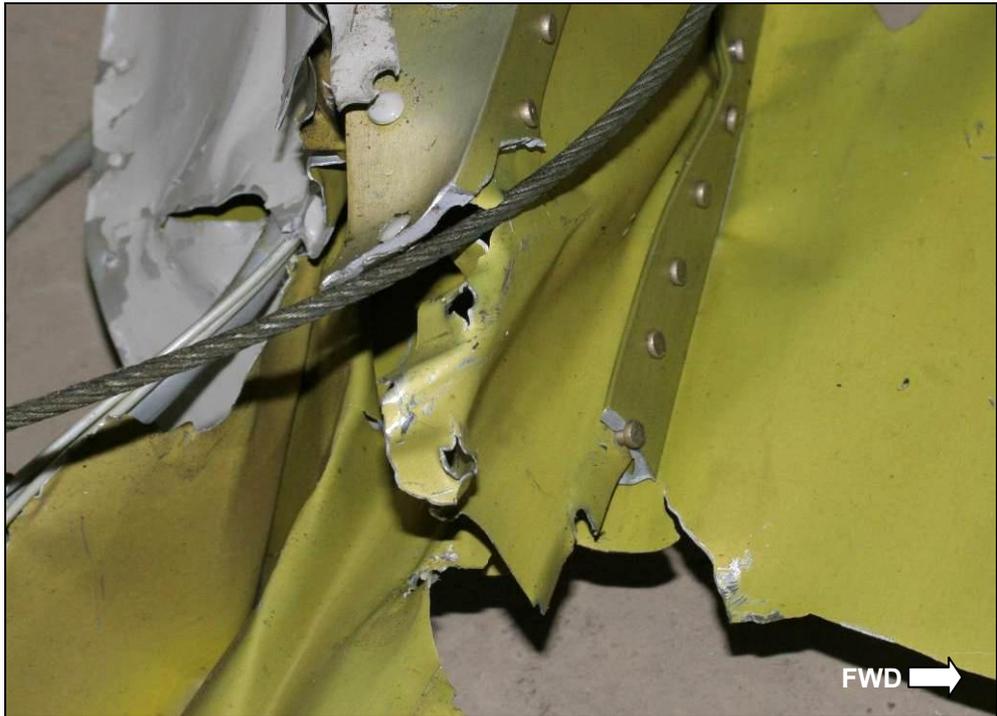
**Fig. 13: Left wing upper main spar cap distortion and fracture**



**Figure 14: Reinforced section at inner/outer left wing splice joint (upper main spar cap, section removed from inboard wing)**



**Figure 15: Upper and lower rear spar cap fractures – left wing**



**Figure 16: Right wing main spar upper cap fracture – through reinforced section adjacent to splice joint**



**Figure 17: Right wing main spar lower cap fracture**



**Figure 18: Right wing rear spar upper cap fracture**



**Figure 19: Right wing rear spar lower cap fracture**



### ***Empennage / tailplanes***

The aircraft empennage had separated from the main fuselage along a transverse diagonal plane, extending from around station 292 at the top of the fuselage, to station 312 at the fuselage base (refer to Figures 4 and 20). The separated empennage had itself broken into two principal sections – the forward-most section carrying the vertical stabiliser and sub-structure (Figure 21); the rear section comprising both horizontal stabilisers, carry-through structure, control surface rigging and tail-cone (Figure 22). Separation between the two empennage sections had occurred predominantly along the bulkhead at fuselage station 335 (Figures 23 and 24).

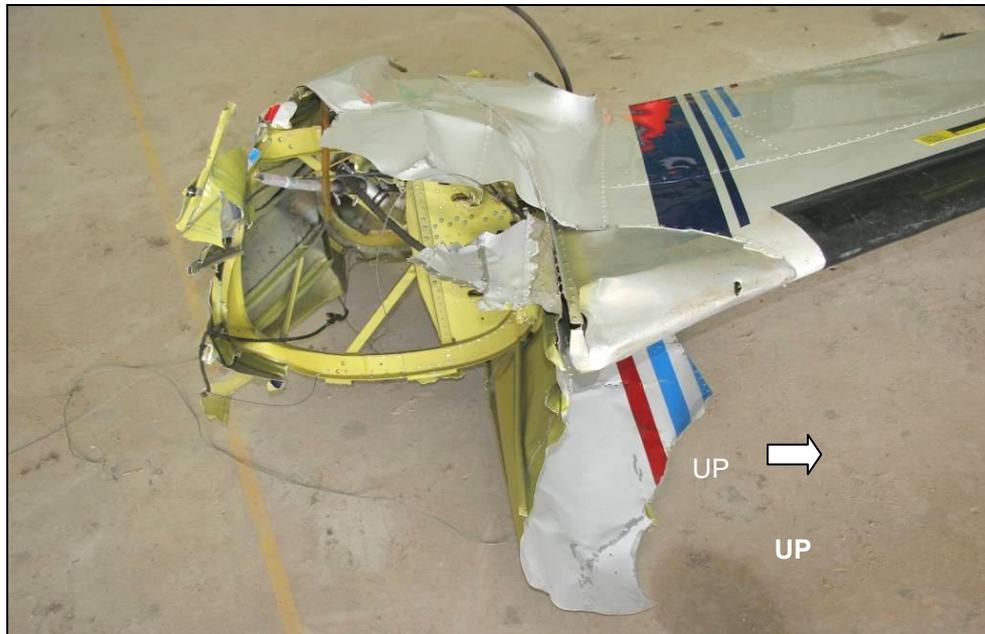
The mechanism of separation between the fuselage and empennage was typically one of ductile shear / tearing of the skin and underlying longerons. Sections of skin toward the top of the structure had torn along or through rivet lines in some locations, however, all such failures were entirely characteristic of overstress conditions, with none showing any evidence of weakening or susceptibility to failure from pre-existing degradation or defects.

Separation between the vertical and horizontal stabilisers occurred at the station 335 bulkhead, which was aligned with the horizontal stabiliser main spar. A section of the spar webbing had been torn out of the stabiliser spar carry-through. Distortion and deformation around the tearing was toward the rear, with all fractures again typical of ductile overstress conditions.

**Figure 20: Plane of fracture of the empennage from the fuselage (aircraft inverted)**



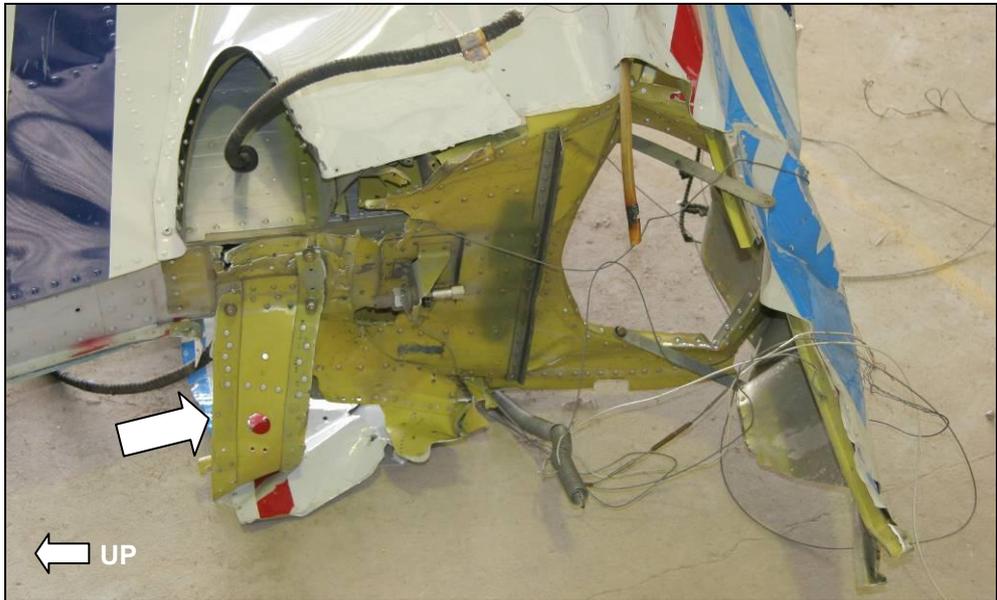
**Figure 21: Forward empennage with vertical stabiliser – corresponding view to Figure 20. Bulkhead visible is at fuselage station 312.83**



**Figure 22:** Rear empennage section including horizontal stabilisers and tail cone



**Figure 23:** Bulkhead at station 335.56 – plane of separation between forward and rear empennage sections. Horizontal stab tear out arrowed



**Figure 24: Rear empennage plane of separation – horizontal stabiliser spar pull-out shown at arrow**



### ***Empennage / tailplanes (cont'd)***

The elevator and rudder control componentry contained within the empennage section showed no evidence of miss-rigging or anomalous operation. All associated fractures and failures of the assembly were typical of the overload forces associated with the fuselage and empennage breakup.

### ***Control surfaces***

All elevator, rudder and aileron control surfaces had separated from the aircraft during the breakup sequence and were recovered amongst the wreckage field.

Without exception, all surfaces had fractured into two or three sections, with failure typically occurring transversely through the region adjacent to the centrally-located hinge point (Figures 25 – 28). All such fractures were typical of a tearing failure mode, with the buckling and creasing of the surface skin towards the trailing edges suggesting the contribution of backward-bending forces.

Separation of the control surfaces from their parent structure (mainplane or tailplane) had occurred at the hinge points in all instances – either by failure of the hinge mechanism itself, or by tearing of the hinge away from the primary structure (Figure 30). In all cases there was no evidence of prior damage or defects associated with the hinge-points, with all failures considered typical of exposure to gross overstress conditions.

Each of the control surface sections was specifically examined for evidence of cyclic over-travel, i.e. forceful, repeated movement and contact with the physical limits of normal surface movement. In several instances, over-travel in one direction was indicated, however there was no suggestion that this had occurred in a repeated or oscillatory fashion, nor was there evidence of over-travel in *both* directions within the same component.

Control linkage failure in the aileron surfaces had occurred principally in bending overload through the tubular pushrods. The interconnecting torque tube controlling

both elevators had fractured in ductile shear around the rivet line between the tube and elevator mounting boss (Figure 29). Separation of the rudder from its controlling mechanisms had occurred by fracture through the torque tube boss flange at the base of the rudder section (Figure 33). In all cases, there was no evidence of pre-existing damage or defects, nor was there any indication that the surfaces had disconnected from their respective control mechanisms prior to the airframe breakup. All of the associated fractures and failures within the control assemblies and cables located within the empennage structure were typical of overstress conditions.

### ***Trim-tabs***

Both elevators and the rudder carried individual trim-tabs set along the trailing edges. All tabs were comparatively undamaged and had remained in-situ on their respective surfaces during the breakup event. The left elevator tab (pitch trim) presented in a near-neutral position with respect to the primary surface, whereas the right elevator tab presented slightly tab-up (aircraft nose down trim effect). Some indentation and impact damage to the tab pushrod and surrounding structure of the right elevator may have accounted for the elevator tab position discrepancy. The rudder trim-tab (yaw trim) was also intact, positioned slightly to the left of centre (aircraft nose right trimming effect). The aircraft was not equipped with an aileron (roll) trim facility.

**Figures 25 & 26: Left elevator control surface**



**Figures 27 & 28: Right elevator control surface**



**Figure 29: Right elevator torque tube connection failure**



**Figure 30: Right elevator outer hinge point failure**



**Figure 31: Rudder control surface – right side**



**Figure 32: Rudder control surface – left side**



**Figure 33: Rudder base – torque tube connection failure**



**Figure 34: Rudder trim-tab position, as-recovered**



### **Structural impact evidence**

Several of the primary structural sections of the aircraft showed damage and markings consistent with contact against other parts of the airframe during the breakup sequence.

### ***Right wing – right horizontal stabiliser***

The underside of the separated right outer wing showed a localised, diagonally-oriented crush-line, running from just outboard of the landing-light, to a position just inboard of the end of the aileron cove. A notable amount of black scuffing and smear marks were associated with the damaged area; consistent with the wing impacting, or being struck by, the leading edge of another mainplane or tailplane section – all of which carried black rubberised protective strips. Indeed, the profile of the compressive damage sustained along the leading edge of the right horizontal stabiliser outer section (item 024) conformed to a significant degree with the profile of the wing underside damage (Figures 35 and 36).

### ***Left wing – left horizontal stabiliser***

The under-surface of the left wing, adjacent to the plane of fracture and separation, showed an elongated and diagonally-oriented puncture through the wing skin, extending for approximately 1m and intersecting the wing trailing-edge (aileron cove). The inwardly-folded skin along the puncture showed intermittent score marks through the paint; typical of sliding contact with a line of surface rivets. Adjacent to the outermost end of the puncture was a semi-elliptical surface impact mark within the blue paint comprising the aircraft registration marking. When compared against the outer cap of the left horizontal stabiliser (item 008), some conformance was noted between the surface mark and the partially-crushed cap corner. Smears of blue paint and crushing along the outer leading edge profile of the left horizontal stabiliser further suggested forceful contact with the wing underside surfaces.

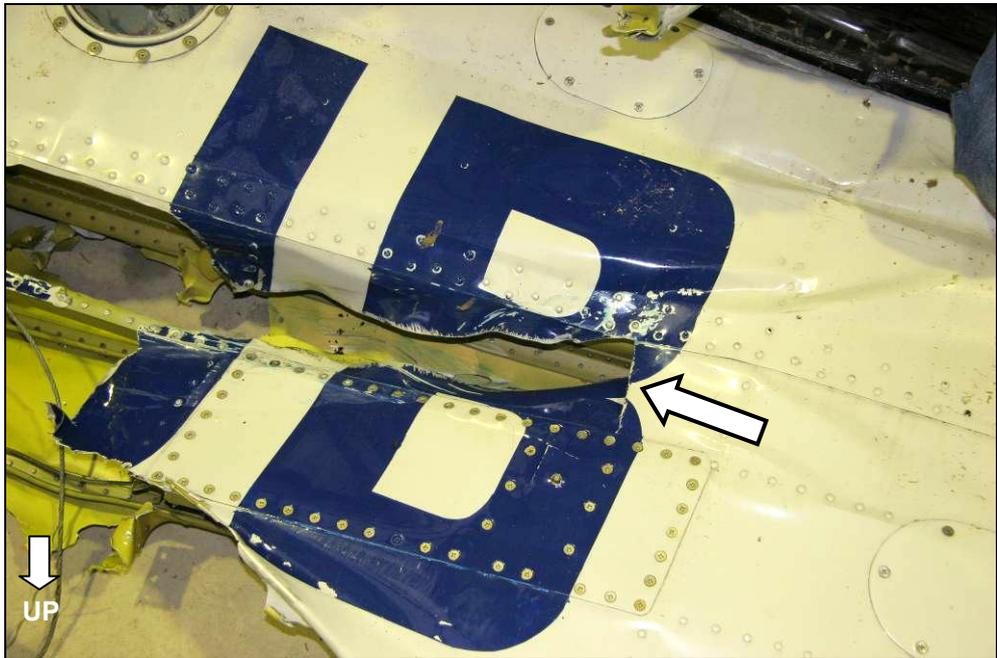
**Figure 35: Underside of right wing and right horizontal stabiliser outer section arranged to illustrate conformance of impact damage**



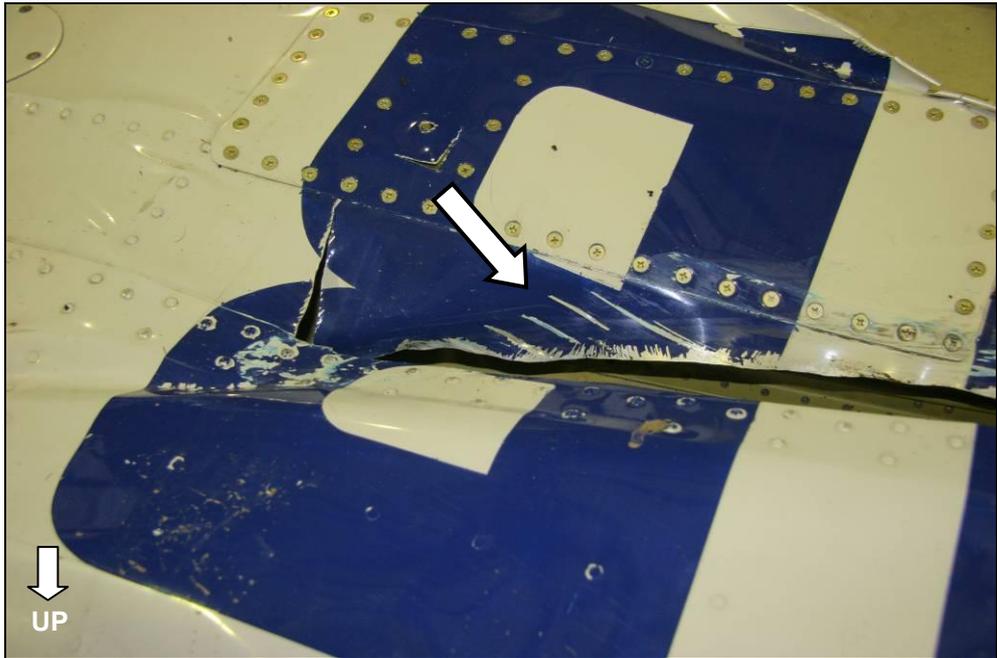
**Figure 36: Leading edge rubber smear marks on right wing underside, with outer tip of right horizontal stabiliser**



**Figure 37: Underside of left wing, with angled puncture indicated**



**Figure 38: Regular rivet head score marks in paintwork**



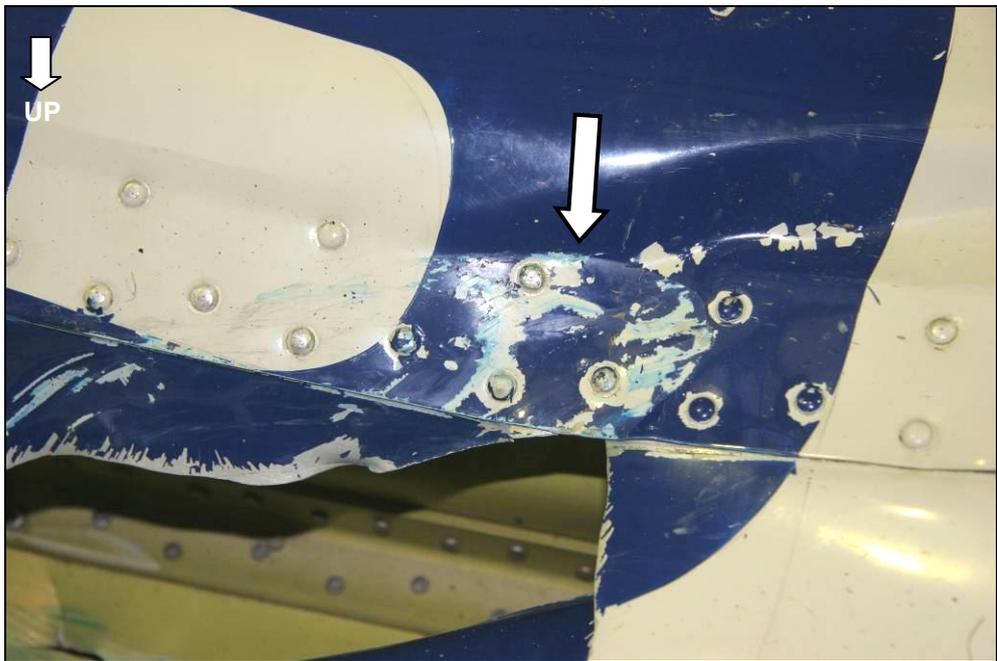
**Figure 39: Leading edge and tip of left horizontal stabiliser. Note blue paint smears**



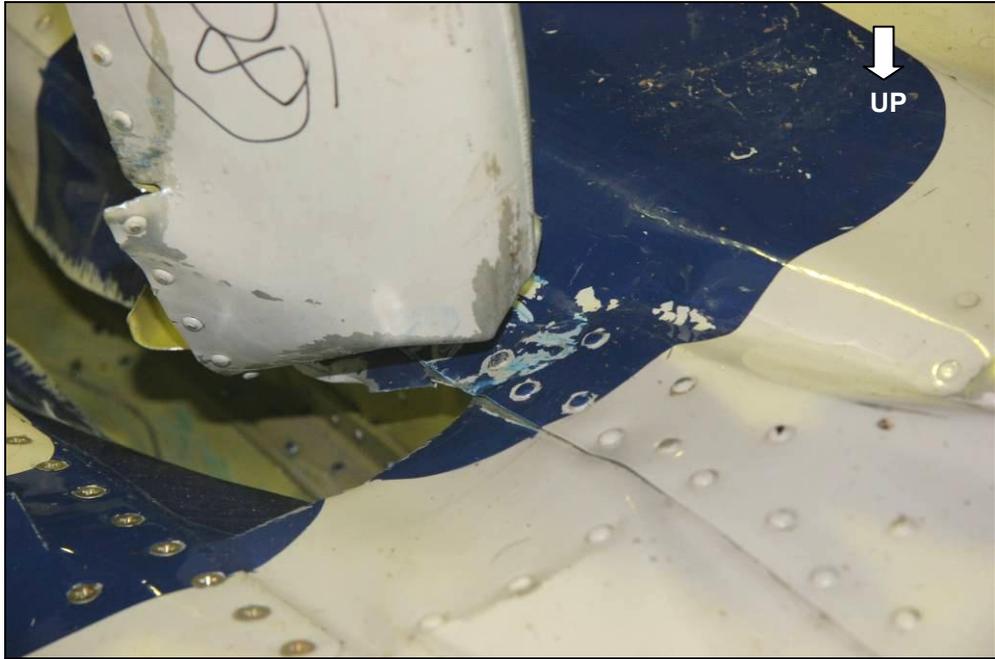
**Figure 40: Crushed left horizontal stabiliser tip with blue paint smears**



**Figure 41: Semi-elliptical impact mark at left wing skin puncture**



**Figure 42: Left horizontal stabiliser tip held to indicate possible source of semi-elliptical paint mark and angular skin puncture**

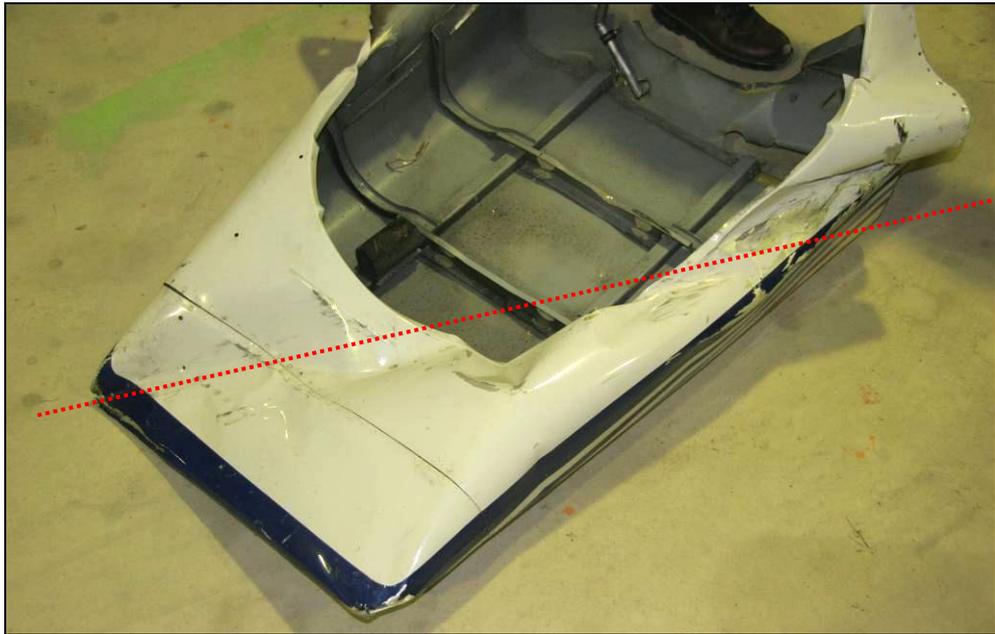


***Left wing – left engine nacelle canoe fairing***

The rear nacelle fairing (canoe fairing, item 021) from the left engine / landing gear assembly had sustained a forceful impact with structure along a line extending diagonally across the wheel-well region on the underside of the fairing. Dark smears, similar to those visible along the underside of the right wing, were associated with the impact line.

A comparison of the canoe fairing impact damage with the section of left wing leading edge material (item 027) showed similar profiles and surface markings (black marks on the fairing from the leading-edge rubber boot; white marks on the leading-edge boot from the fairing paint).

**Figure 43: Left nacelle canoe fairing underside – impact line illustrated**



**Figure 44: Black smear / markings along impact line**



**Figure 45: Left wing inner leading edge section (item 027) held to illustrate conformance with the nacelle impact damage**





## **ANALYSIS**

### **Structural failure and damage**

From the detailed examination and study of the aircraft wreckage undertaken by ATSB investigation staff, it was evident that all principal structural failures had occurred under gross overstress conditions i.e. stresses significantly in excess of the physical strength of the respective structures. The examination found no evidence of pre-existing cracking, damage or material degradation that could have appreciably reduced the strength of the failed sections, nor was there any indication that the original manufacture, maintenance or repair processes carried out on the aircraft were in any way contributory to the failures sustained.

### **Breakup sequence**

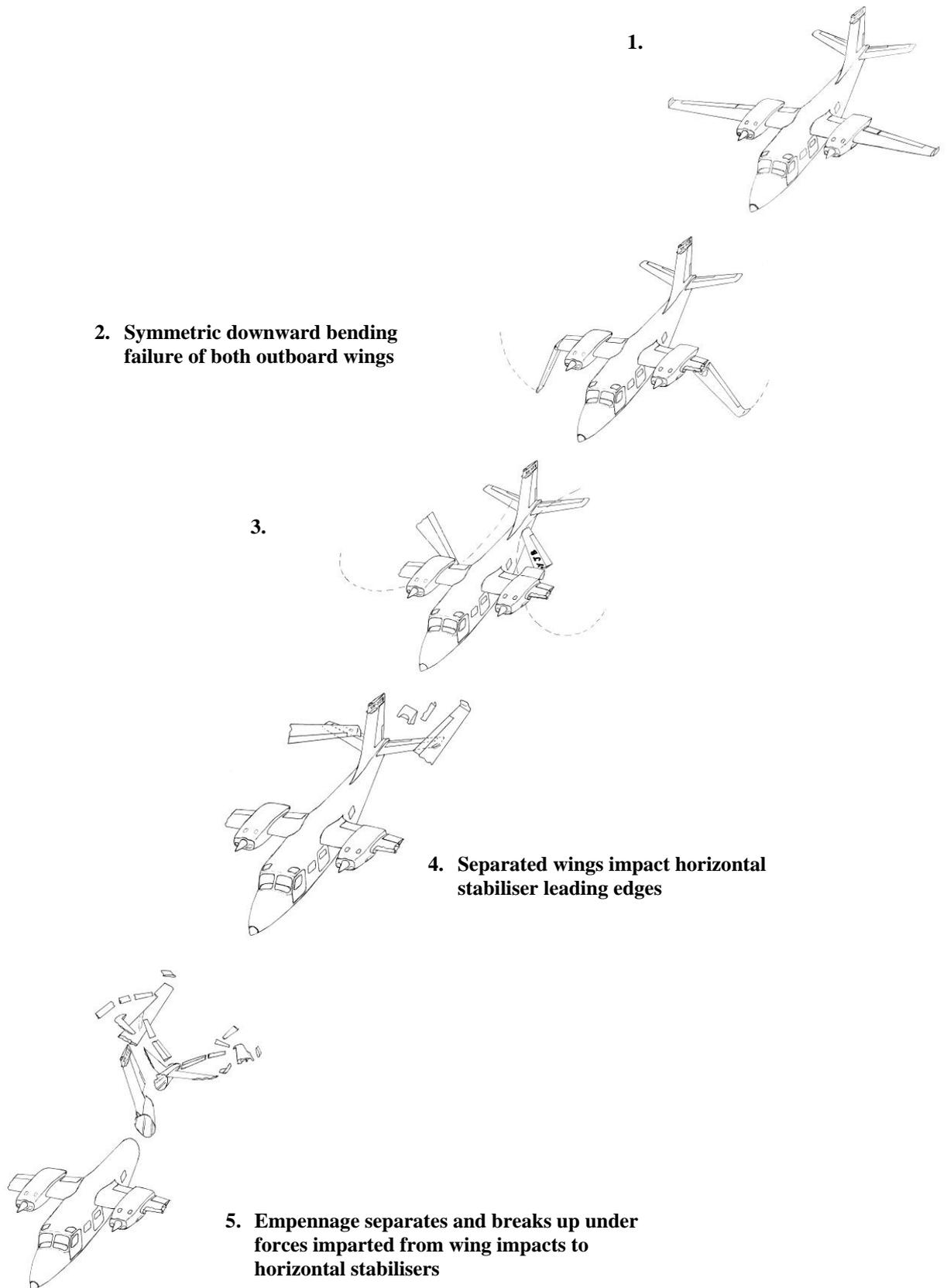
From the localised deformation associated with the spar failures, it was evident that the aircraft had sustained a large negative (downward) loading on the wing structure. That downward load resulted in the localised bending failure of the wing around the station 145 position (145" outboard of the aircraft centreline). The symmetry of both wing failures and the absence of axial twisting within the fuselage section suggested that the load encountered was sudden and well in excess of the ultimate strength of the wing structure.

Based upon the witness marks on both wing under-surfaces and the crushing and paint transfer along the leading edges of the horizontal stabilisers, it was concluded that after separating from the inboard structure, both wings had moved aft in an axial twisting and rotating fashion; simultaneously impacting the leading edges of both horizontal tailplanes. Forces imparted into the empennage structure from that impact subsequently produced the rearward separation of the complete empennage from the fuselage. The loss of the left engine nacelle fairing was likely brought about through an impact with a section of wing leading edge as it rotated under and to the rear.

The damage sustained by all of the aircraft's control surfaces was consistent with failure and separation from their respective primary structure under overstress conditions associated with the breakup of the aircraft. There was no evidence of cyclic or oscillatory movement of the surfaces before separation that might have suggested the contribution of an aerodynamic flutter effects.

Figure 46 provides an illustration of the breakup sequence.

**Figure 46: Illustrated impression of the probable aircraft breakup sequence**



## **FINDINGS**

The following statements are a summary of the verified findings made during the progress of the aircraft wreckage structural examination and analysis:

- All principal failures within the aircraft wings, tailplanes and empennage had occurred as a result of exposure to gross overstress conditions.
- The damage sustained by the aircraft wreckage was consistent with the aircraft having sustained multiple in-flight structural failures.
- The damage sustained by the aircraft wreckage was consistent with the structural failure sequence being initiated by the symmetric, downward bending failure of both wing sections, outboard of the engine nacelles.
- Breakup and separation of the empennage was consistent with having been initiated by impact of the separated outboard wings with the leading edges of the horizontal stabilisers.
- There was no evidence of material or manufacturing abnormalities within the aircraft structure that could be implicated in the failures and breakup sustained.
- There was no evidence of service-related degradation mechanisms (such as corrosion, fatigue cracking or environmental cracking) having affected the aircraft structure in the areas of failure.



---

## APPENDIX B: ATSB SAFETY EDUCATION MATERIAL

---

### Mountain wave and associated turbulence

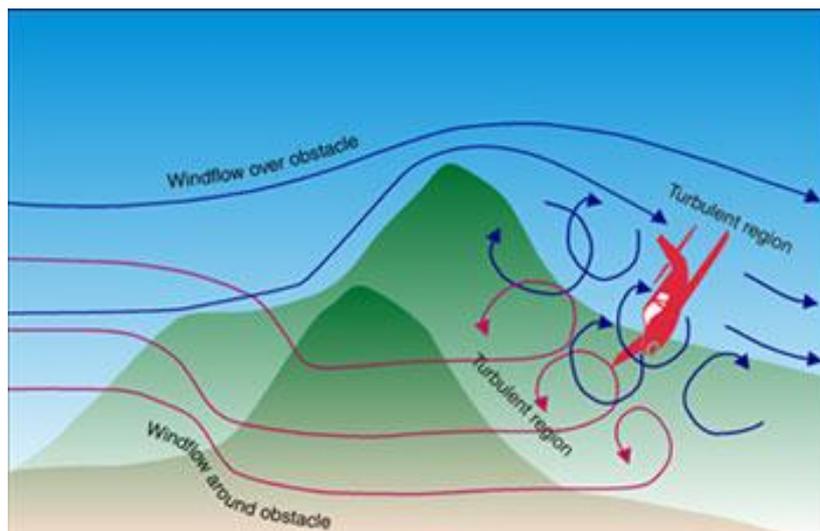
In Australia, mountain waves are commonly experienced over and to the lee of mountain ranges in the south-east of the continent. They often appear in the strong westerly wind flows on the east coast in late winter and early spring.

Mountain waves are a different phenomena to the mechanical turbulence found in the lee of mountain ranges, and can exist as a smooth undulating airflow or may contain clear air turbulence in the form of breaking waves and 'rotors'. Mountain waves are defined as 'severe' when the associated downdrafts exceed 600 ft/min and/or severe turbulence is observed or forecast.

'Breaking waves' and 'rotors' associated with mountain waves are among the more hazardous phenomenon that pilots can experience. Understanding the dynamics of the wind is important in improving aviation safety.

Glider pilots learn to use these mountain waves to their advantage; typically to gain altitude. However, some aircraft have come to grief in those conditions. Encounters have been described as similar to hitting a wall. In 1966, clear air turbulence associated with a mountain wave ripped apart a BOAC Boeing 707 while it flew near Mt. Fuji in Japan. In 1968, a Fairchild F-27B lost parts of its wings and empennage, and in 1992 a Douglas DC-8 lost an engine and wingtip in mountain wave encounters.

Mountain waves are the result of flowing air being forced to rise up the windward side of a mountain barrier, then as a result of certain atmospheric conditions, sinking down the leeward side. This perturbation develops into a series of standing waves downstream from the barrier, and may extend for hundreds of kilometres over clear areas of land and open water.



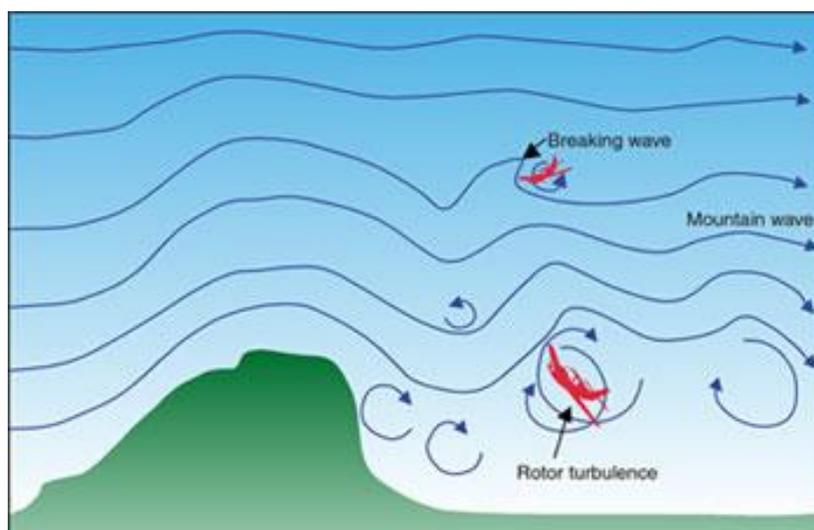
Mountain waves are likely to form when the following atmospheric conditions are present:

- the wind flow at around ridge height is nearly perpendicular to the ridge line and at least 25 kts
- the wind speed increases with height
- there is a stable layer at around ridge height.

If the wave amplitude is large enough, then the waves become unstable and break, similar to the breaking waves seen in the surf. Within these 'breaking waves', the atmospheric flow becomes turbulent.

The crests of the waves may be identified by the formation of lenticular clouds (lense-shaped), if the air is sufficiently moist. Mountain waves may extend into the stratosphere and become more pronounced as height increases. Some pilots have reported mountain waves at 60,000 feet. The vertical airflow component of a standing wave may exceed 8,000 ft/min.

Rotors or eddies can also be found embedded in mountain waves. Formation of rotors can also occur as a result of down slope winds. Their formation usually occurs where wind speeds change in a wave or where friction slows the wind near to the ground. Often these rotors will be experienced as gusts or windshear. Clouds may also form on the up-flow side of a rotor and dissipate on the down-flow side if the air is sufficiently moist.



Many dangers lie in the effects of mountain waves and associated turbulence on aircraft performance and control. In addition to generating turbulence that has demonstrated sufficient ferocity to significantly damage aircraft or lead to loss of aircraft control, the more prevailing danger to aircraft in the lower levels in Australia seems to be the effect on the climb rate of an aircraft. General aviation aircraft rarely have performance capability sufficient to enable the pilot to overcome the effects of a severe downdraft generated by a mountain wave or the turbulence or windshear generated by a rotor. In 1996, three people were fatally injured when a Cessna 206 encountered lee (mountain) waves. The investigation report concluded, "It is probable that the maximum climb performance of the aircraft was not capable of overcoming the strong downdrafts in the area at the time".

Crossing a mountain barrier into wind also reduces the groundspeed of an aircraft and has the effect of keeping the aircraft in the area of downdraft for longer, while an aircraft flying downwind on the upwind side of a mountain range is likely to initially encounter updrafts as it approaches rising ground. Rotors and turbulence may also affect low level flying operations near hills or trees. In 1999, a Kawasaki KH-4 hit the surface of a lake during spraying operations at 30 feet. The lack of sufficient height to overcome the effects of wind eddies and turbulence was a factor in the accident.

Research into 'braking waves' and 'rotors' or eddies continues but there is no doubt that pilots need to be aware of the phenomenon and take appropriate precautions. Although mountain wave activity is usually forecast reasonably well by the Bureau of Meteorology, many local factors may effect the formation of 'breaking waves' and 'rotors'. When planning a flight a pilot should take note of the winds and the terrain to assess the likelihood of waves and rotors. There may be telltale signs in flight, including the disturbances on water or wheat fields and the formation of clouds, provided there is sufficient moisture for cloud to form.

Prudent flight planning may include allowing for the possibility of significant variations in the aircrafts altitude if updrafts and downdraughts are encountered. A margin of at least the height of the hill or mountain from the surface should be allowed, and consideration given to the need to adopt a manoeuvring airspeed appropriate to the circumstances. Ultimately, it may be preferable for pilots to consider diverting or not flying, rather than risk flying near or over mountainous terrain in strong wind conditions conducive to mountain waves containing 'breaking waves' and 'rotors'.

#### Further Reading

Bureau of Meteorology. (2007). Manual of Aviation Meteorology. Second Edition, pp 59, 60, 68. Airservices Australia.

Bureau of Air Safety Investigation Journal. (1991, September). Downslope winds are dangerous. BASI Journal, 9, pp 38-39.

Jorgensen, K. (undated). Mountain flying: A guide to helicopter flying in mountainous and high altitude areas. Westcourt, QLD: Cranford Publications.

Lester, P. F. (1993). Turbulence: A new perspective for pilots. Englewood, CO: Jeppesen Sanderson.

McCann, Donald W. (2006). Diagnosing and forecasting aircraft turbulence with steepening mountain waves. National Weather Digest, pp 77-92.

New Zealand Civil Aviation Authority (2006), Good Aviation Practice, Mountain Flying booklet.

Welch, John, F. (Ed.). (1995). Van Sickles modern airmanship (7th Ed). New York, NY: McGraw-Hill.

Woods, R. H., & Sweginnis, R. W. (1995). Aircraft accident investigation. Casper, WY: Endeavor Books.

ATSB Publication Type: Safety Education Material

Publication Date: 01/01/05. Revised 31/07/09



---

## APPENDIX C: SOURCES AND SUBMISSIONS

---

### Sources of information

The sources of information for the investigation included:

- the aircraft operator
- pilots who flew Aero Commander 500-S aircraft for the operator and pilots who flew them for former operators
- Airservices Australia
- the Bureau of Meteorology (BoM)
- the Victorian Police Service
- the Office of the State Coroner of Victoria
- the US National Transportation Safety Board (NTSB).

### References

Staunton, J. H. (1996). *Report of the Commissioner – Commission of Inquiry into relations between the CAA and Seaview Air*, Australian Government Publishing Service Canberra, Vol. 2, Appendix VII, pp 403-429.

Swift, S. (1995). *Aero Commander Chronicle*. A paper presented to the International Committee on Aeronautical Fatigue's 18th Symposium, Melbourne.

Hurt, H. H. (1960). *Aerodynamics for Naval Aviators*, The Office of the Chief of Naval Operations, Aviation Training Division, USA.

McCann, Donald W. (2006). *Diagnosing and forecasting aircraft turbulence with steepening mountain waves*. National Weather Digest December 2006, National Weather Association, USA.

Crawford B, Flightlab, 2009 *Flight Emergency & Advanced Maneuvers Training* Plymouth Airport, USA.

### Submissions

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

A draft of this report was provided to:

- the aircraft operator
- the next-of-kin of the pilot
- the Civil Aviation Safety Authority (CASA)

- Airservices Australia
- the BoM
- the Office of the State Coroner of Victoria
- the NTSB
- the aircraft manufacturer.

Submissions were received from:

- the aircraft operator
- CASA
- Airservices Australia
- the BoM.

The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

---

## APPENDIX D: MEDIA RELEASE

---

### **Pilots reminded to be aware when operating in areas of known or forecast turbulence**

The investigation of an in-flight breakup that occurred near Clombinane, Victoria on 31 July 2007 has found that it most likely resulted from an encounter with localised and intense turbulence, from an elevator control input, or from a combination of both. The accident resulted in the death of the pilot and passenger on board the Rockwell International Aero Commander 500-S aircraft on a business flight from Essendon Airport to Shepparton.

As a result of its investigation, the Australian Transport Safety Bureau reissued the publication *Mountain Wave Turbulence* (available for download at [www.atsb.gov.au](http://www.atsb.gov.au)), distributed the investigation report to all Australian operators of the Aero Commander aircraft, and issued a safety advisory notice to aircraft operators and pilots. That notice encouraged aircraft operators to review their procedures to ensure an appropriate awareness amongst operating personnel of the implications for aircraft performance of the combination of aircraft weights and speed, and of the ambient conditions; in particular, when flying in, or near areas of forecast severe turbulence.

The investigation found that some pilots operating the aircraft type were generally unaware of the applicability of the aircraft's manoeuvring speed during flight through turbulence, despite the inclusion of relevant advisory information in the operator's documentation. There was also a concern that pilots generally may not have been exercising as much caution in forecast severe turbulence conditions as they would for thunderstorms, even though the intensity of the turbulence could be similar.

At the time of the in-flight breakup, special weather reports for severe turbulence and severe mountain waves were current for the area. Wind speeds on the ground were reported to be 50 kts and calculations using the recorded radar data and forecast wind showed that the aircraft had been in cruise flight at 7,000 ft above mean sea level at speeds probably greater than its published manoeuvring speed, prior to it disappearing from radar. The wreckage and its distribution pattern were consistent with an in-flight breakup during cruise flight.

There was no evidence of any pre-existing defect, corrosion or fatigue found in the aircraft structure. An examination of the wreckage and fracture surfaces showed that the aircraft structure failed under symmetrical negative overstress.

A full report is available from the ATSB website [www.atsb.gov.au](http://www.atsb.gov.au)

In-flight breakup – Clonbinane, Vic.  
31 July 2007, VH-YJB  
Rockwell International Aero Commander 500-S