Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Investigation – 200600001

Final

Collision with terrain - Willowbank, Qld
2 January 2006
VH-UYB
Cessna Aircraft Company U206

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Cessna Aircraft Company U206

Released in accordance with Section 25 of the TSI Act 2003

Published by: Australian Transport Safety Bureau
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ISBN and formal report title: see 'Document retrieval information' on page vi.

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DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
200600001	30 October 2007	77	978-1-921165-41-2

Publication title

Collision with terrain - Willowbank, Qld – 2 January 2006 - VH-UYB, Cessna Aircraft Company U206

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference No.

Oct2007/DOTARS50385

Abstract

At about 1040 Eastern Standard Time on 2 January 2006, a Cessna Aircraft Company U206 aircraft, registered VH-UYB, took off from the parachuting centre at Willowbank, Qld on a tandem parachuting flight. On board the aircraft were the pilot and six parachutists.

The surviving Tandem Master parachutist, who was also a private pilot, reported that, at about 100 ft, the aircraft performed as if the power had been ‘pulled back’. The aircraft was observed to bank right, before it impacted a tree and became submerged in a dam.

The aircraft was destroyed and five persons on board received fatal injuries or were drowned. The two survivors received serious injuries.

Technical examination and test of the aircraft’s engine and its associated components did not reveal any anomalies with the potential to have individually contributed to the partial engine power loss. However, the investigation could not discount the potential that:

- a number of less significant anomalies that were identified during the engine and components examination may have coincided to reduce the available engine power, or
- there may have been an anomaly of the engine or its components present during the accident flight that was not apparent during the subsequent disassembly, examination and testing of the engine and its components.

As a result of this investigation, the Australian Parachute Federation (APF) has addressed a number of safety concerns. The Civil Aviation Safety Authority (CASA) initiated safety action to clarify Airworthiness Directive AD/ENG/4 and the intent of Airworthiness Bulletin AWB 02-003 Issue 2. In addition, CASA is reviewing elements of the various training syllabi and supporting documentation affecting the management of engine and partial engine power loss after takeoff.

As a result of this investigation, the Australian Transport Safety Bureau has issued seven safety recommendations related to airworthiness bulletins, regulations, parachutists’ safety and survivability, aircraft maintenance documentation and pilot training in emergency procedures.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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.

ABBREVIATIONS

AAIB	UK Air Accidents Investigations Branch
AD	Airworthiness Directive
AGL	above ground level
ALA	Aeroplane Landing Area
APF	Australian Parachute Federation
AOC	Air Operator’s Certificate
ASO	Area Safety Officer
ASTM	American Society for Testing and Materials
ATC	air traffic control
ATSB	Australian Transport Safety Bureau
Avgas	Aviation Gasoline
AWB	Airworthiness Bulletin
BoM	Bureau of Meteorology
BPA	British Parachute Association
CAA	Civil Aviation Authority
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CAR	Civil Aviation Regulations
CASR	Civil Aviation Safety Regulation
CASA	Australian Civil Aviation Safety Authority
CCP	Club Chief Pilot
CEO	Chief Executive Officer
CG	centre of gravity
CPL(A)	Commercial Pilot (Aeroplane) Licence
DCA	Department of Civil Aviation
DEF STAN	Defence Standard
EFATO	engine failure after takeoff
FAA	US Federal Aviation Administration
FCU	fuel control unit
ft	feet
ft/min	feet per minute

GFPT	General Flying Progress Test
hp	horsepower
kg	kilograms
kts	knots
L	litres
MTOW	maximum take-off weight
m	metres
mm	millimetres
mph	miles per hour
NATA	National Association of Testing Authority
NPRM	Notice of Proposed Rulemaking
NTSB	US National Transportation Safety Board
POH	Pilot’s Operating Handbook
PPL(A)	Private Pilot (Aeroplane) Licence
RAAF	Royal Australian Air Force
RCA	Request for Corrective Action
RPM	revolutions per minute
RPT	regular public transport
STC	Supplemental Type Certificate
TSO	time since overhaul
TTIS	total time in service
VFR	Visual Flight Rules
UK	United Kingdom
US	United States of America

1 FACTUAL INFORMATION

1.1 History of the flight

At about 1040 Eastern Standard Time [1] on 2 January 2006, a Cessna Aircraft Company U206 (Cessna 206) aircraft, registered VH-UYB, was being operated from the Aeroplane Landing Area (ALA) at Willowbank, Qld on the second of a series of parachuting flights[2]. On board the aircraft were the pilot, three Tandem Master parachutists (Tandem Masters) and three Tandem Student parachutists.

The aircraft's engine was not shut down following the first flight, and was running at low RPM on the ground for a period of about 10 minutes. A number of witnesses in the area of the ALA buildings at that time reported that the aircraft's engine RPM appeared to be erratic[3] when at low power settings, and one witness observed smoke coming from the engine area.

Witnesses reported that the pilot backtracked[4] down the runway before turning the aircraft around and immediately taking off to the north. Several witnesses reported black smoke and/or vapour coming from the aircraft soon after takeoff.

One of the Tandem Masters on board, who was also the owner/operator of the parachute school and a private pilot, and survived the accident, stated that the takeoff appeared 'normal' until the aircraft overflew the end of the runway at about 100 ft above ground level (AGL). Following that, he reported that the aircraft performed as if the power had been 'pulled back'[5]. The owner/operator recalled asking the pilot whether the auxiliary fuel pump was selected ON, to which the pilot reportedly replied 'yes'. The surviving Tandem Student on board, who had not previously flown in a light aircraft, described the takeoff as being as expected, and was unconcerned until hearing the owner/operator tell the pilot to 'keep it up'[6].

Witnesses on the ground further reported that the aircraft climbed to no more than about 100 ft AGL, and then banked right somewhere between 5 and 10 degrees, before descending from view.

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

2 Typically, that involved flying the parachutists to an attitude of, or in excess of 10,000 ft above mean sea level (AMSL) in the immediate vicinity of the ALA, before the parachutists exited the aircraft.

3 Varying in RPM values.

4 After entering the runway in use, to proceed from that position along the reciprocal runway.

5 Normally associated with the action by a pilot to retard an aircraft's throttle, with the effect of reducing the power produced by an aircraft's engine. The Tandem Master later told the investigation that the power reduction was similar to when 'someone had completely closed the throttle'.

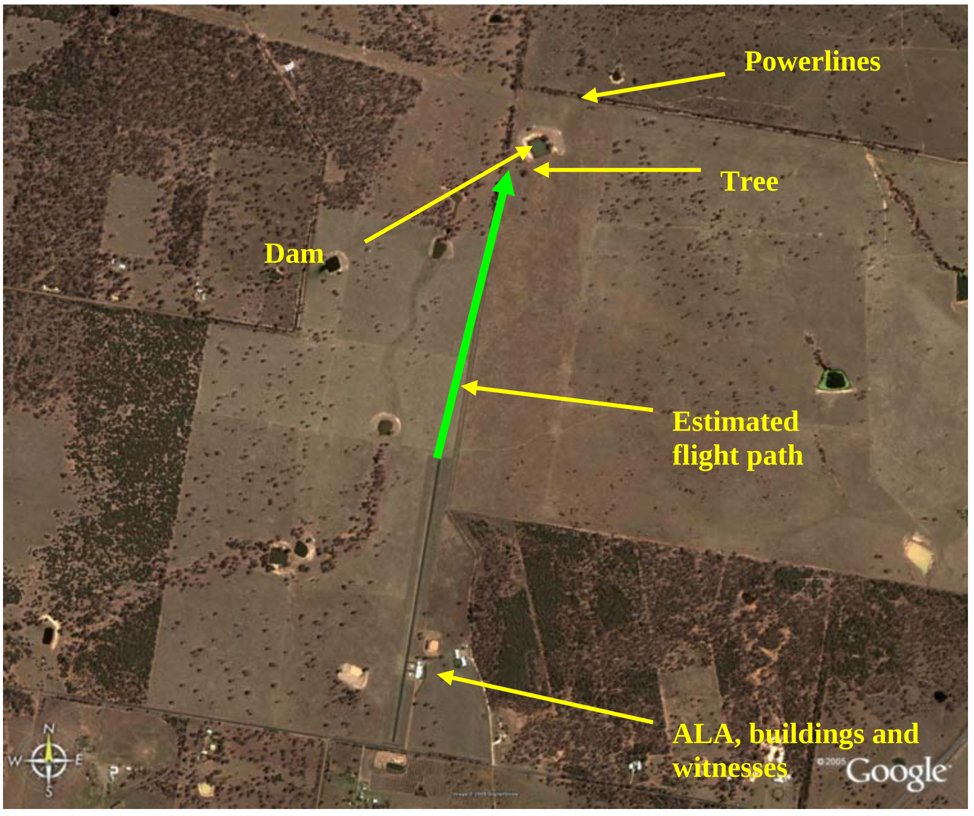
6 The two survivors differed in their recollection of the statements by the owner/operator in response to the reduction in engine power.

The owner/operator reported that he told the pilot 'don't stall the thing' and 'look out for the tree', and that the pilot was looking back towards him when the aircraft impacted a tree. The owner/operator also advised of hearing the aircraft's stall warning horn activate[7] shortly before the impact with the tree. He described the aircraft then doing what he considered to be a right roll before entering a dam.

The Tandem Student recalled the aircraft striking 'something of a wooden nature', but had no further recollection until in the dam.

Another of the owner/operator's pilots conducted an aerial search in the other company aircraft, in an attempt to locate the missing aircraft. Shortly after, the crew of a search and rescue helicopter located the missing aircraft submerged in a small dam that was located about 1,250 m from the end of the runway and slightly right of runway centreline (Figure 1). Rescuers found one of the Tandem Students walking near the dam and the owner/operator clinging to a section of the submerged aircraft. Five of the seven persons on board received fatal injuries or were drowned. Both survivors were severely injured.

Figure 1: Willowbank ALA[8]



Radar information

Radar information for the accident flight was obtained from the Royal Australian Air Force (RAAF) Base Amberley radar archives for examination by the

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7 According to the aircraft Owner's Manual, the stall warning activates at 5 to 10 mph (4.3 to 8.7 kts) prior to the aerodynamic stall.

8 Aerial photo sourced from Google Earth.

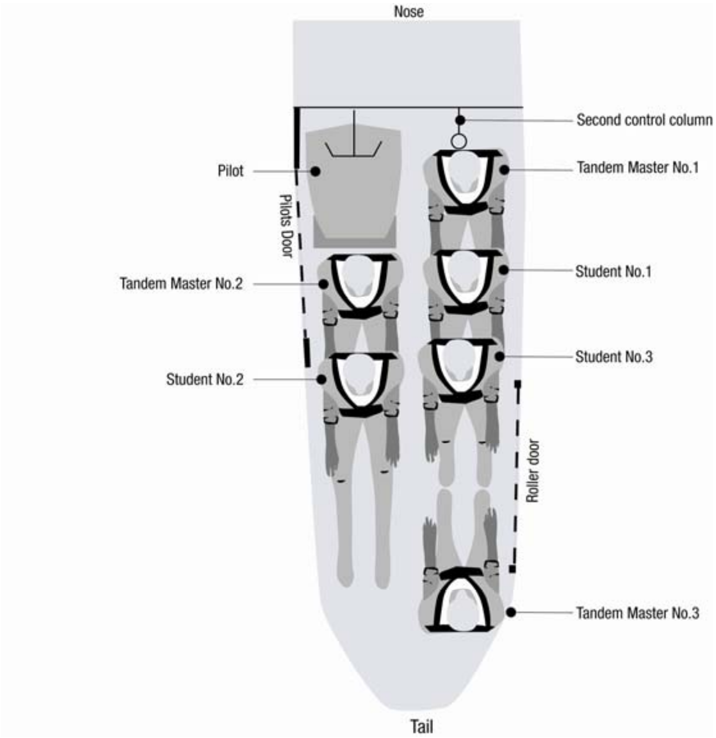
investigation. The first recorded radar contact for the aircraft during the accident flight showed that, at 1045:22, the aircraft was about 1.5 to 1.6 km north-north-east of the Willowbank ALA, with a ground speed of about 80 kts. At 1045:27, 1045:32 and 1045:36, positive radar returns for the aircraft indicated a ground speed[9] of about 70 to 80 kts. At 1045:41, radar contact with the aircraft was lost, indicating that the aircraft had descended below radar coverage.

A summary of the available radar information for the previous flight was obtained from Airservices Australia (Airservices), and is contained in Appendix A.

1.2 Injuries

Based on the analysis of the available video footage of the flight and witness interviews, the occupants of the aircraft were seated approximately as displayed in Figure 2.[10]

Figure 2: Seating configuration of the aircraft



The two survivors (labelled Tandem Master No. 3 and Student No. 1 in Figure 2) sustained injuries including: aviation gasoline (Avgas) chemical burns, fractures, lacerations and bruising. Table 1 summarises the injuries to the aircraft's occupants.

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9 The radar display indicated the approximate groundspeed, but the recorded altitude information was not able to provide the actual altitude of the aircraft. There was the potential for the aircraft's low altitude and its distance from the radar head to have adversely affected the accuracy of the radar information.

10 The owner/operator reported that Tandem Master No. 3 normally sits with his right knee between Student No. 3's legs and his left knee and head between Students No. 2 and No.3.

Table 1: Fatalities and injuries[11]

Injuries	Flight Crew	Tandem Masters	Tandem Students	Totals
Fatal	1	2	2	5
Serious	-	1	1	2
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to the aircraft

The aircraft was destroyed by the impact with the tree and dam (Figure 3).

On the day following the accident, the aircraft wreckage was recovered from the dam by the Australian Transport Safety Bureau (ATSB) for subsequent examination.

Figure 3: Recovered wreckage[12]

1.4 Other damage

There was no other damage to structures or objects beyond that to the tree that was struck by the aircraft, and Avgas contamination of the dam.

11 Further information on the injuries sustained by the aircraft occupants is presented in Section 1.13.

12 Additional information on the aircraft wreckage is contained in Section 1.12.

1.5 Personnel information

1.5.1 Pilot information

The pilot was appropriately qualified to conduct the Private category flight. Table 2 lists the pilot's experience and licence types at the time of the accident.

Table 2: Pilot's licences and experience

Type of licences	Private Pilot (Aeroplane) Licence (PPL(A)) - issued on 7 October 2003, Commercial Pilot (Aeroplane) Licence (CPL(A)) - issued on 10 August 2005
Medical certificate	Class 2 (valid, no restrictions)
Flying experience (total hours)	401.5
Hours on type	41.0
Hours flown in the last 24 hours	0.4
Hours flown in the last 7 days	14.2
Hours flown in the last 90 days	75.8

On 9 May 2005, the pilot completed a familiarisation flight consisting of 1.2 hours under the visual flight rules (VFR) in a Cessna C182RG aircraft. On 27 June 2005, the pilot completed a check flight of 0.2 hours duration with the owner/operator in the operator's Cessna 182. There was no record in the pilot's logbook of any check flight having been carried out in the Cessna 206.

When the pilot first applied to fly for the operator, he had accumulated a total of 192.5 hours total flight time and 79.5 hours as pilot in command. He had no previous experience flying parachuting operations and no commercial experience.

The pilot began flying parachuting operations for the owner/operator in the Cessna 182 on 1 July 2005 and the Cessna 206 on 30 July 2005.[13] At the time he began flying parachuting operations in the Cessna 206, he had not yet accrued the required 10 hours flying time on type as required by the Australian Parachute Federation (APF) *Operational Regulations*.

The owner/operator reported that he considered the pilot sufficiently trained and capable of flying the Cessna 206 and of addressing any in-flight emergencies based on his flights with the pilot and the pilot's qualifications and training. The owner/operator reported that he supervised and coached the pilot during several parachuting flights in both the Cessna 182 and 206.

The pilot's last day of flying before the accident flight was on 30 December 2005. That day, the pilot flew 0.7 hours of parachuting operations in the Cessna 206 and 4.2 hours parachuting operations in the Cessna 182.

13 The pilot was not financially compensated for his flying duties by the owner/operator.

1.5.2 Pilot 72-hour history

The investigation experienced difficulty establishing the pilot's 72-hour history as a result of his movements during that time. The available information provided some indication of the pilot's activities; however, inconsistencies in that information rendered it unreliable.

Despite the limitations with the information provided, a review of the available evidence indicated that there were probably no enduring physiological or psychological factors that would have influenced the pilot's performance.

1.6 Aircraft information

1.6.1 Aircraft history

The aircraft, serial number U206-0314, was manufactured in the US in 1965 and was subsequently operated in New Zealand as a float plane. The aircraft data plate documented the model of the aircraft as a model U206. On 26 November 1997, a New Zealand Civil Aviation Authority Airworthiness Certificate was issued documenting the aircraft as a model U206. On 23 August 2002, the Australian Civil Aviation Safety Authority (CASA) issued a Standard Certificate of Airworthiness for the aircraft in the NORMAL category, Private operations as a model U206.

A review of the aircraft historical documentation revealed that, on several documents on file, the aircraft had been erroneously referred to as a model U206B.

At the time of the accident, the aircraft had accumulated 11,426.7 hours total time in service (TTIS).

1.6.2 Aircraft modifications

The aircraft had undergone extensive modification to the airframe and the original model engine had been replaced. According to the aircraft documentation, none of these modifications either changed the model designation or increased the allowable Maximum Take-off Weight (MTOW) [14] of the aircraft.

Airframe modifications

In December 2002, a Wipaire Incorporated wing tip extension kit was installed in accordance with US Federal Aviation Administration (FAA)-approved Supplemental Type Certificate (STC) number SA914NE. Installation of the kit involved extending each wing by 45.7 cm, which increased the total wing area by 7 percent. According to the manufacturer of the kit, the installation of the wing tip kit would:

- improve standard day[15] rate of climb after takeoff

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14 A certificated value exceeded only during certification flight testing.

15 At the International Standard Atmosphere pressure of 1013 mb, and temperature of 15°C at mean sea level.

- improve service ceiling
- reduce take-off distance
- decrease stall speed.[16]

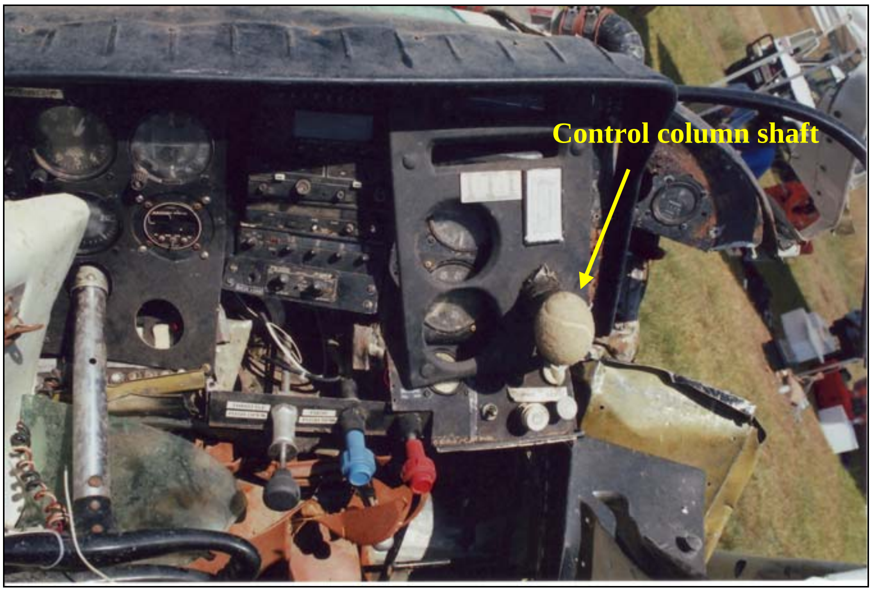
The manufacturer of the wing tip extension kit reported that the aircraft's stall speed would decrease by approximately 2 kts airspeed for all flap positions. The aircraft operational documentation did not contain any information on the aircraft's performance with the wing tip extensions installed.

In July 2003, a Pulselite speed brake kit was installed in the aircraft in accordance with US FAA-approved STC number SA00473SE. That modification included the installation of 'plates' on the upper surface of both wings. The in-flight activation of the speed brake decreased the available wing lift, and allowed the use of higher power during rapid descents. Examination of the aircraft following the accident showed that the speed plates were not extended at the time of impact.

The aircraft's fuselage in the right-rear of the cabin had been modified to install a roller-type door to facilitate parachuting operations. The door was in the open position during the take-off roll to facilitate video-filming of the takeoff, but was reported by the owner/operator to have been closed during the initial climb out. The aircraft's operational documentation did not contain any information on the door installation.

Additionally, the aircraft flight control system had been modified to disconnect the copilot's control column behind the aircraft instrument panel, and a tennis ball had been fitted to the end of the control wheel shaft (Figure 4). The owner/operator reported that that modification was completed in accordance with the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* Section 3.0 AIRCRAFT MODIFICATIONS. No other aircraft documentation, such as a Engineering Order, could be located in support of that modification.

Figure 4: Control panel indicating disabled copilot's control column shaft



16 A decrease in aerodynamic stall speed signifies that the wings produce more lift allowing the aircraft to fly at a lower airspeed without stalling.

Engine and propeller modification

On 2 April 2004, at 10,958.3 hours TTIS, a turbo charged 350 hp Lycoming model TIO-540 J2BD engine and a Hartzel model HC-C3YR-1RF propeller were installed in the aircraft in accordance with FAA-approved STC number SA2123NM.[17] The Lycoming engine, serial number L-4336-61A, replaced the previously-installed 300 hp Teledyne Continental Motors model IO-520F engine. The engine had accrued 468.4 hours time since overhaul (TSO). At the time of the accident, only four aircraft world-wide had been modified with that STC, which also included modifications to the aircraft's structure, wiring and fuel system.

Turbo charging an aircraft piston engine increases the engine's performance at higher altitudes beyond the capabilities of a normally-aspirated engine. A turbocharger is powered by an aircraft's engine exhaust gases and pumps air into the engine cylinders' intake ports. An automatic system is included to control the operation of the turbocharger, using devices that sense differences in air pressure at various points in the engine's induction system.

According to the engine manufacturer, depending on the failure mode and altitude, the loss of the aircraft's turbocharger system could result in a power loss of up to 100 hp.

On 19 July 1996, the originally installed Teledyne Continental Motors model IO-520A was replaced by a Teledyne Continental Motors model IO-520F engine and a McCauley model D2A34C58 propeller fitted. The aircraft logbook entry noted:

> Engine IO-520F fitted as per modification SSA42 and Cessna type certificate for C206 A4CE VIII Model U206B.

The reference in the logbook entry to the type certificate section VIII was believed to be a reference to the engine and propeller limits contained in that section of the FAA Type Certificate Data Sheet (TCDS).

1.6.3 Aircraft maintenance history

The aircraft was being maintained under the CASA Civil Aviation Regulations (CAR) 1988 42B Schedule 5 maintenance schedule. Civil Aviation Advisory Publication (CAAP) 42B-1(0) included the following guidance regarding the requirements of CAR 42B:

> The time-in-service between Periodic Inspections is to be 100 hours aeroplane time-in-service or 12 months, whichever is the earlier, and for aeroplanes below 5700 kg engaged in private operations this inspection may be performed annually irrespective of hours flown.

The 100-hourly inspections of the aircraft engine were being completed in accordance with the requirements of CASA Airworthiness Directive AD/ENG/4 Amdt 9. The inspections of the aircraft airframe items were being completed on an annual basis in accordance with CASA Schedule 5 irrespective of hours flown. For additional discussion of the Schedule 5 maintenance requirements see Section 1.18.5.

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17 The Lycoming TIO-540 J2BD engine is also installed in the Piper Aircraft Corporation PA31-350 aircraft, which is a twin-engine aircraft.

The last documented periodic (annual) inspection of the aircraft occurred on 22 September 2005 at an aircraft TTIS of 11,363.8 hours, and engine hours of 405.5 TSO. The aircraft's TTIS between annual inspections is listed in Table 3.

Table 3: Total time in service between annual inspections

Date of inspection	Aircraft TTIS in hours	TTIS since last annual inspection
22 September 2005[18]	11,363.8	318.6
03 September 2004	11,045.2	223.2[19]
29 August 2003	10,822.0	300.0
12 June 2002	10,522.0	Not on Australian registry.

1.6.4 Engine maintenance

The last documented maintenance of the engine was carried out on 13 November 2005, when the engine oil was changed.

On 22 September 2005, at 405.5 TSO engine hours, a 100-hourly inspection was completed. A notation on the engine's 100-hourly inspection worksheet and the piston engine condition report indicated that the number-1 engine cylinder compression was unsatisfactory. Subsequent inspection by maintenance personnel found a fault with the engine camshaft and followers. The engine was subsequently removed from the aircraft, disassembled, repaired and reinstalled.

On 1 May 2004, at an unrecorded aircraft and engine TTIS, a logbook entry was made following a reported problem with a loss of engine manifold pressure. The entry noted that the 'tube' from the engine fuel control unit to the induction sump was weld-repaired and reinstalled. Following the accident, that repair was examined by the investigation and found to be serviceable.

On 19 February 2004, the engine was overhauled in accordance with the engine manufacturer's manual and the following engine components were removed, overhauled and reinstalled:

- all turbocharger system components
- the dual magneto
- the alternator
- the engine driven-fuel pump
- the fuel control unit
- all fuel nozzles.

18 The aircraft's engine was removed and repaired during this annual inspection.

19 The engine was replaced at 10,958.3 hours TTIS.

1.6.5 Aircraft fuel pumps

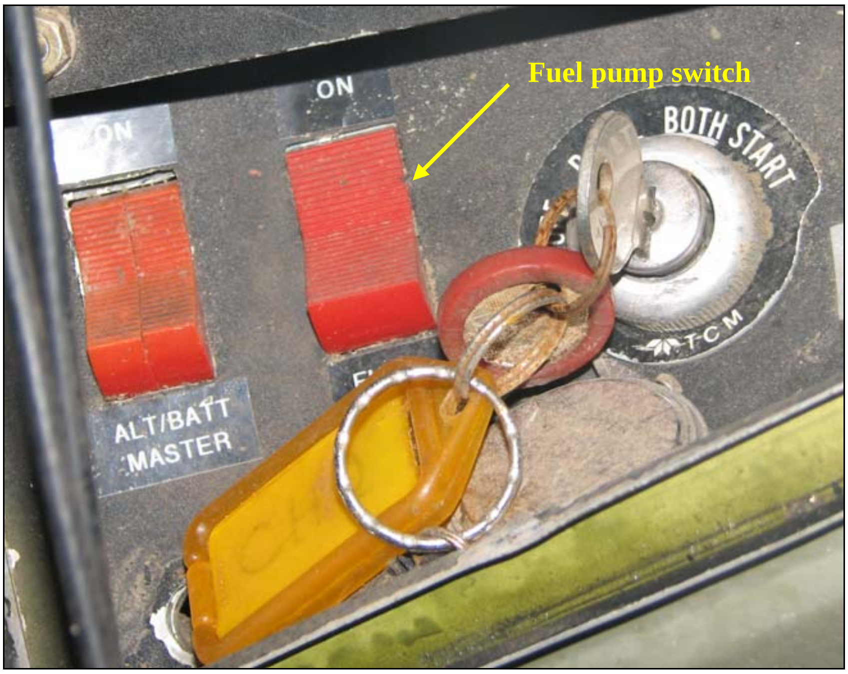
The engine-driven fuel pump was designed to supply the engine with a steady, uninterrupted flow of fuel. In addition, the aircraft was equipped with a 12-volt, direct current, electrically-operated auxiliary fuel pump that could be used to:

- prevent the vaporisation of fuel in the engine's fuel lines
- provide a positive fuel pressure to the engine-driven fuel pump
- provide for continued fuel supply to the engine in the event of a failure of the engine-driven fuel pump.

As part of the STC to replace the aircraft's original engine installation with the turbo charged engine, the originally-specified auxiliary electrically-operated fuel pump was replaced with a higher-capacity fuel pump, the same as that used in the PA 31-350 aircraft installation. In addition, the original fuel pump switch and wiring was replaced by a two-position, ON/OFF 'rocker' switch and associated wiring. The primary purpose of that pump was to prime the engine for start.

Following the accident, the auxiliary fuel pump switch was found in the ON position (Figure 5). The investigation confirmed the continuity of all wiring to the fuel pump and bench-tested the pump. That testing confirmed the serviceability of the pump.

Figure 5: Auxiliary fuel pump switch



The STC documentation for the engine modification did not include any procedures relating to the operation of the auxiliary fuel pump, or a reference to the PA 31-350 aircraft documentation, other than to state that the pump should be selected ON for engine start.[20] The US FAA-approved STC supplement stated:

> For procedures not listed here, consult the applicable Cessna Pilots Operating Handbook.

The aircraft Owner's Manual[21] did not recommend the use of the auxiliary fuel pump for takeoff. The manual referred to the auxiliary fuel pump switch as a yellow and red split-rocker-type switch, rather than a two-position ON/OFF rocker switch as installed in accordance with the STC. In the split-rocker-type switch installation, the yellow position was used for starting the engine (priming) and minor fuel purging, and the red switch position for emergencies in the event of an engine-driven fuel pump failure.

In the absence of any documented information on the use of the auxiliary fuel pump, the owner/operator of the parachute school advised his pilots to utilise the auxiliary fuel pump for takeoff up to an altitude of 1,000 ft AGL. He reported to the investigation that he had received that information from the maintenance facility that installed the turbo charged engine. He also reported that the aircraft was prone to fuel line vaporisation when operating on the ground with the engine running. To prevent fuel line vaporisation, the owner/operator advised his pilots to also utilise the auxiliary fuel pump during ground operations. The effect on the engine of using the auxiliary fuel pump as advised by the owner/operator to his pilots could not be established because of a lack of documentation on the subject in the STC supplement.

An owner/operator of a similarly-modified aircraft in New Zealand was contacted regarding that company's use of the auxiliary fuel pump during takeoff. That owner/operator did not use the auxiliary fuel pump for takeoff, unless the outside air temperature was higher than a standard day.

As a comparison, the aircraft manufacturer has more recently produced a model T206H aircraft with a 310 hp turbo charged Textron Lycoming model TIO-540-AJ1A engine. The aircraft manufacturer's information manual for that aircraft included a procedure to place the auxiliary fuel pump switch to the OFF position for takeoff.

1.6.6 Aircraft operation

Magnetos check

The aircraft Owner's Manual BEFORE TAKE-OFF check list included the following check:

> (6) Magnetos—Check (RPM drop should not exceed 150 RPM on either magneto or 50 RPM differential between magnetos).

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20 The PA 31-350 aircraft operating documentation stated that the auxiliary fuel pump should be selected ON for takeoff.

21 Early model years of the Cessna 206 contained an aircraft Owner's Manual instead of a Cessna Pilot's Operating Handbook.

In addition, the engine manufacturer also published information related to checking the engine magneto drop-off to determine the operating condition of the engine. Those procedures included:

> Preflight inspection of the aircraft invariably includes a magneto drop-off check to determine the operating condition of the ignition system. This test is accomplished by switching from both to either the right or left magneto and noting any appreciable variance or loss in RPM. Excessive loss, or variance in loss of RPM warns the pilot of some defective part in the ignition system, usually a spark plug or a magneto.[22]

The investigation was unable to establish whether a magnetos drop-off check was completed by the pilot on either of the previous or the accident flights.

Emergency procedures

The aircraft's operational documentation did not include specific emergency procedures on engine power loss.

1.6.7 Aircraft performance

In regard to aircraft performance, the FAA-approved STC supplement for the engine modification stated:

> General FAA approved performance data for this airplane equipped with the Lycoming TIO-540 engine and Hartzel HC-C3YR-1RF propeller are equal to or better than previously demonstrated for the unmodified Cessna 206 series airplane. Other data, such as fuel flow rates and time to climb supplied by Cessna does not apply to this aircraft as modified. To determine these performance data, the pilot should reference performance data for this powerplant installation.

Maximum take-off weight

The FAA-approved TCDS[23] documented the MTOW for the aircraft model U206 as 3,300 lbs (1,496.85 kg) and the centre of gravity (CG) range at that weight as from the forward limit of 40.5 inches (1,028.7 mm) to the aft limit of 47.4 inches (1,203.96 mm). The TCDS required the installation of a placard on the instrument console noting the gross weight[24] of the aircraft as 3,300 lbs (1,496.85 kg). When the aircraft wreckage was examined, no placard was located with that reflected that requirement.

The aircraft Owner's Manual stated that the gross weight for the aircraft was 3,300 lbs (1,496.85 kg) and included a CG moment envelope with a maximum weight value of 3,300 lbs (1,496.85 kg).

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22 *Service Instruction No. 1132A*, 2 Feb. 1968, Lycoming Division Williamsport PA USA.

23 US FAA Type Certificate Data Sheet No. A4CE Revision 43, dated 3 September 2004.

24 Gross weight. Traditional measure usually defined as an aircraft's maximum permitted flying weight. Now generally termed an aircraft's MTOW.

The aircraft was last weighed on 2 April 2004, following the installation of the turbo charged engine.[25] The empty weight of the aircraft at that time was 2,026.2 lbs (919.1 kg), with an empty weight CG of 33.5 inches (851 mm) aft of the datum. The weighing information documentation provided to the owner/operator following that weighing erroneously noted the model of the aircraft as a model U206B, and the MTOW of the aircraft as 3,600 lbs (1,632.9 kg). The owner/operator advised that he understood from that documentation that the MTOW of the aircraft was 3,600 lbs (1,632.9 kg), or about 299.8 lbs (136 kg) more that the amount specified in the TCDS for the model aircraft. However, there were a number of other aircraft documents that had been signed by the owner/operator that noted that the aircraft was either a ‘U206’ or ‘C206’. The MTOW for those aircraft was, in each case, 3,300 lbs (1,496.85 kg).

The owner/operator reported that the Tandem Students were required to indicate their body weight on their applications for membership of the APF that were required to be filled in prior to their tandem jumps. That information was reportedly then used to calculate the aircraft’s actual take-off weight. No weight and balance calculation form for the flight was found in the aircraft wreckage or with the pilot’s belongings. When interviewed, the owner/operator indicated that the pilot did not normally have a sheet for calculating the aircraft’s actual take-off weight.

The aircraft’s actual take-off weight was estimated by the investigation to be about 3,549.4 lbs (1,610 kg), or about 113 kg in excess of the aircraft’s MTOW. The aircraft’s CG was estimated as slightly within the aft limit. In later models of the aircraft, the MTOW was increased to 1,632.9 kg, and the CG range was moved slightly aft.[26]

The requirements of CAR 235(4) included that:

> The pilot in command of an aircraft must not allow the aircraft to take off if its gross weight exceeds its maximum take-off weight or, if a lesser weight determined in accordance with a direction under subregulation (2) is applicable to the take-off, that lesser weight.

An article by the New Zealand Civil Aviation Authority[27] advised that exceeding the manufacturer’s MTOW makes it difficult to ensure that an aircraft’s performance characteristics can be met as flight–tested, and confirmed as safe. The article stated that:

> Manufacturers conduct extensive flight tests to establish loading limits for their aircraft because they are critical for safe flight. It is important that you adhere to these limits when loading your aircraft.
>
> As far as performance is concerned, an overloaded aircraft will excel in only one area-rate of descent. This is not helpful when all you want to do is takeoff or climb.

25 The weighing sheet incorrectly noted the date of the reweigh as 2 April 2003.

26 The increase in MTOW was accompanied with changes to the tail control surfaces of the newer model aircraft. UYB did not have those changes incorporated.

27 *Weight and Balance*, New Zealand Civil Aviation Authority, June 2006, Lower Hutt, New Zealand.

> A heavy aircraft will have a:
>
> - higher takeoff speed
>
> - longer takeoff ground run
>
> - reduced rate of climb
>
> - reduced angle of climb
>
> - lower ceiling
>
> - shorter range
>
> - reduced cruise speed
>
> - increased stall speed
>
> - higher landing speed
>
> - longer landing roll.
>
> The effect[s] above show how the total performance of the aircraft is affected. These factors become critical in the critical flight phases of takeoff and landing.

The operation of an aircraft at weights in excess of its MTOW can also reduce its structural strength margins. The ATSB contacted the aircraft manufacturer for advice regarding the effect of exceeding the aircraft's MTOW. The manufacturer indicated that exceeding the aircraft's MTOW was not recommended. Additionally the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* cautioned against exceeding MTOW.

Tailwind limitations

The aircraft manufacturer advised that the early year model aircraft Owner's Manuals and POH did not include information regarding tailwind limits for takeoff.

The wind at the time of the accident would have meant that the pilot took off with a slight quartering tailwind of about 5 kts (see Section 1.7).

Flap usage

The flap range of the aircraft was from 0 (no flap) to 40 (full flap) degrees. The owner/operator indicated that flap was not normally selected for takeoff. Examination of the aircraft wreckage confirmed that flap configuration at the time of impact. The aircraft Owner's Manual stated that the flap configuration for takeoff was 0 to 20 degrees and permitted the pilot to determine the best flap setting for the situation. The New Zealand owner/operator of the similarly-modified aircraft indicated that they usually used 10 degrees of flap for takeoff.

The use of flaps reduces the ground run and total distance required to clear an obstacle.

Take-off distance

The aircraft's estimated take-off distance could not be calculated as the aircraft Owner's Manual take-off data did not address a takeoff with no flap or at take-off weights in excess of 3,300 lbs (1,496.85 kg). Furthermore, the configuration of the aircraft with the various engine and airframe modifications would have invalidated the aircraft manufacturer's original performance information.

According to witness reports, the aircraft used approximately 500 to 750 m of the available runway length during the take-off roll, which was consistent with their recollection of the previous takeoff that day.

Aircraft glide distance

No glide speed or distance information for the aircraft was available to the investigation because of its unique configuration and lack of performance data. However, a trajectory analysis was carried out in order to estimate the aircraft's potential glide distance from the end of the runway at 100 ft AGL after the power reduction. The assumptions affecting that estimation included there being no available engine power, no flaps used by the pilot, and that the performance information contained in the Cessna model U206G POH, a similar aircraft model to UYB, was appropriate in this case.

Those calculations indicated that, given the assumptions made, the aircraft's maximum glide distance from 100 ft AGL would have been approximately 280 m.

Aerodynamic stall speed

The aerodynamic stall speed of an aircraft is the speed at which a separation of the boundary layer occurs on the upper surface of the aircraft's wings. The result is that the wing no longer produces lift. At the MTOW of 3,300 lbs (1,496.85 kg), the stall speed of the aircraft with no flap, and in straight and level flight, was estimated to be 58 kts.

1.6.8 Aircraft Fuel

The aircraft's fuel system included a left and a right wing tank. The total capacity of each tank was 122 L. The fuel selector was found in the RIGHT tank position, signifying that the aircraft's engine was probably operating on fuel from that tank at the time of the accident. The owner/operator reported that the normal operating procedure in UYB was to use the left tank as a reserve fuel supply, and to operate using the right tank as the primary fuel source. The fuel lines to the right tank were damaged by impact forces, which allowed any fuel in that tank to escape. Any fuel in the aircraft's left tank would have been contaminated by dam water and was not tested. The aircraft's fuel filters and screens were clear of debris and contamination.

The owner/operator of the parachuting school advised that, on the night before the accident flight, he refuelled the aircraft using drum fuel stock. During that refuel, he reportedly filled the aircraft's right wing tank by adding approximately 100 L of aviation gasoline (Avgas) 100/130 (high lead) grade, but did not add any fuel to the aircraft's left wing tank, as it already held about 30 to 40 L. The owner/operator reported that the drum used was sealed prior to the refuelling and that, the following morning, he placed approximately 100 L of fuel from the same drum (Figure 6) in the company's Cessna 182.[28]

Figure 6: Fuel drum and pump used to fuel the company aircraft the previous night[29]

The owner/operator reported normally using a fuel filter-equipped fuel truck to refuel the company's aircraft. However, the fuel truck was empty the night before the accident, and replacement fuel had been unavailable during the holiday period. The fuel pump used to fuel the aircraft from the fuel drum did not include a monitor type cartridge filter or filter/water separator cartridge.

The investigation estimated that, at the time of takeoff, the aircraft had about 112 L of fuel on board.[30] See section 1.16.1 and Appendix B for further information on the quality of the fuel used and its characteristics.

1.7 Meteorological information

Witnesses reported that, at the time of the flight, there was little or no wind, unlimited visibility and a temperature of about 35° C. Photographs taken just prior to the flight, and examined by the investigation, included a view of the windsock in the background of the photographs. The windsock indicated an estimated maximum wind of about 5 kts from the south-west.

The nearest recorded observations of the meteorological conditions in the vicinity of Willowbank were taken at the Bureau of Meteorology (BoM) Automatic Weather Station that was located at RAAF Base Amberley, about 13 km north-east

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28 As a minimum, the engines of both aircraft used Avgas 100/130 low lead often referred to as Avgas 100LL. During flights completed the day of the accident, the Cessna 182 did not display any engine abnormalities as a result of the use of fuel from the shared drum stock. Additionally, no abnormalities were reported by users of the same batch of Avgas stock.

29 Photo altered to de-identify drum supplier.

30 Based on average burn rates for the aircraft, fuel capacity and witness reports.

of the ALA. Those observations at around the time of the flight are listed in Table 4.

Table 4: Observed meteorological conditions

Time	Observations				
	Wind direction[31]	**Wind speed**	**Temperature (°C)**	**Dewpoint (°C)**	**Relative humidity**
0900	From 270 degrees	5 kts gusting to 9 kts	30	10	52%
1000	From 260 degrees	7 kts gusting to 13 kts	33	19	44%
1100	From 230 degrees	8 kts gusting to 13 kts	35	18	37%

1.8 Aids to navigation

There were no aids to navigation at the Willowbank ALA.

1.9 Communications

A review of the relevant Airservices and RAAF Base Amberley audio files was carried out following the accident. That review established that the normal radio broadcasts were made by the pilot during the previous flight, and that there appeared to be no anomalies affecting the operation of the aircraft for the duration of that flight. During the accident flight, the pilot transmitted a routine taxi broadcast, but no emergency broadcast was recorded.

1.10 Aerodrome information

Willowbank ALA was located about 13 km to the south-west of RAAF Base Amberley. The runway was oriented 180/360 degrees magnetic, was 1,000 m in length and its surface was sealed with hard-surface bitumen. The nearest obstacles on the extended upwind centreline of runway 36 were a number of trees about 30 m tall that were located about 1,000 m from the runway end.

The facilities at the ALA included two hangars and an administration building to the east of the runway (Figure 1). Two aircraft parking areas were located between the hangars and the runway. A windsock was located directly across from the hangars, on the western side of the runway.

31 The wind observations were referenced to magnetic north and were averaged every 10 minutes.

1.11 Flight recorders

The aircraft was not fitted with either a flight data or cockpit voice recorder, nor was there a regulatory requirement for their installation in this class of aircraft and operation.

1.12 Wreckage and impact information

The impact forces sustained by aircraft structures in occurrences of this type can result in erroneous control position indications. In general, the position of the flight and other controls after impact, including for the engine and propeller, cannot be relied upon as evidence of the aircraft's pre-impact configuration.

1.12.1 Wreckage examination

The aircraft had impacted a 23 m (75 ft) high tree that was about 1,200 m from the end of the runway before then impacting water and submerging in a small, 2 m deep dam that was located about 47 m from the tree. The aircraft entered the dam in a nose-down, left wing-low attitude. The forward section of the cabin was extensively damaged by impact forces, but the cabin section remained relatively intact. The tail section was heavily damaged.

The right wingtip was separated by the initial impact with the tree and was located near the impact tree. The right and left wings had impact damage to their leading edges. The right wing strut had failed in overload at the mid-strut point. Both fuel tanks were intact, but the fuel lines connected to the right wing tank had separated, resulting in the fuel draining from that tank. The nose landing gear was deflected aft, and the left main landing gear wheel and strut had separated.

The flaps were in the retracted position and the speed brakes (plates) were retracted. The elevator trim was in the approximately zero degrees position. The continuity of all flight and engine controls was confirmed. The magneto switch was in the BOTH position.

Damage to the propeller showed indications of low operating RPM at the time of impact.

1.12.2 Disassembly and examination of recovered components

A number of aircraft components, including the propeller and engine, were removed from the accident site for further examination under the supervision of the ATSB.

Engine

The engine was disassembled and examined at an approved engine overhaul facility. That disassembly and examination showed no evidence of any pre-existing damage to any of the power train rotating assemblies or gear drives, but the following items of interest were identified:

- the magneto-to-engine timing was advanced by 6 degrees[32]
- carbon deposits[33] on the spark plugs and piston domes, which was consistent with a rich-running fuel-air mixture.

The spark plugs had been immersed in the dam water and were also oil fouled[34]. When tested in the as-found condition, nine of the engine's 12 spark plugs did not spark or operate normally. Following cleaning, all 12 of the spark plugs sparked successfully.

The degree to which a spark plug disperses heat is termed its 'heat range'. The higher the number following the letters in a spark plug model designation, the hotter the heat range. For example, '50' would be a hotter heat range compared with '26', which would be a colder heat range. The spark plugs installed in the engine were Champion model RHB32E plugs. Information sourced from the spark plug manufacturer indicated that the Lycoming model TIO-540-J2BD engine required the RHB37E spark plugs for standard usage.[35] Therefore, the RHB32E spark plugs found installed in the engine would have had a colder heat range than that specified. An article on spark plug deposits stated: [36]

> Closed throttle and low rpm idle increases spark plug deposits. Deposits that form on the insulator core nose are of two basic types: carbon and lead. These deposits are conductive, and if formed in sufficient quantity, provide a leakage path from the center electrode conductor back over the core nose to ground. This causes the plug to stop firing. There is a steep change in the temperature of the spark plug core nose immediately above idle. At low idle speeds, the heat range of the spark plug has little effect on the temperature of the spark plug since at some point both "hot" and "cold" heat range plugs will operate at cylinder head temperature. At low spark plug temperatures, deposits are in volume proportion to operating time. Deposits that form at idle are mostly carbon. They form on the spark plug insulation core when the plug operating temperature is below 800ºF. The most desirable range to avoid spark plug fouling is 900ºF-1,300ºF at the spark plug electrode tip. The spark plug never reaches these temperatures when idling with closed throttle.

Turbocharger and fuel components

The disassembly and examination of the turbocharger and induction system did not identify any anomalies that would have affected engine performance. Similarly, the disassembly, examination and testing of the turbocharger controllers did not identify any anomalies that would have affected engine performance.

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32 The engine manufacturer advised that the advanced magneto timing probably would not have significantly affected engine performance.

33 Soft, black, sooty, dry-looking carbon.

34 Covered in an oily coating.

35 *Aviation Catalog AV-14*, September 2002, Champion Aerospace Inc., USA.

36 *Sky Ranch Engineering Manual*, Second Edition, Sacramento Sky Ranch Inc., Sacramento CA, USA.

Further testing of the turbocharger controllers was accomplished by their installation on a comparable test engine. The results of that testing found no anomalies in the performance of the recovered turbocharger controllers when run.

The airframe fuel filter was heavily-damaged in the impact and was unable to be tested. The airframe fuel filter bypass had not activated, indicating that there was no blockage of the fuel filter.

The disassembly, examination and testing that was possible of the fuel system components did not reveal any anomalies that would have affected engine performance. The fuel control unit (FCU) fuel filter screen exhibited no contamination.

Black soot was noted in the intake to the FCU, which was considered abnormal by the technical specialist who assisted the investigation with the disassembly and examination of the unit. However, the engine overhaul facility that had most recently overhauled the engine reported to have witnessed the black sooting on the intake during that overhaul.

Propeller

The disassembly and examination of the propeller indicated that, at the time of impact with the dam water, the propeller blades were in the 'fine' pitch[37] position. The impact damage to the propeller pitch stops showed that it was probable that the propeller was operating at a relatively low RPM (low engine power and not windmilling) at the time of impact.

Bench-testing of the propeller constant speed unit was accomplished at an approved overhaul and repair facility. The results of that testing indicated no anomalies of the unit.

1.13 Medical and pathological information

Post-mortem examinations and toxicology testing was completed on all of the fatally-injured aircraft occupants by the relevant State authorities.

The pilot's medical records and post-mortem report indicated no pre-existing disease with the potential to have affected his performance. Toxicology testing of the pilot indicated no factors that would have affected his performance.

According to the post-mortem reports, four of the five fatally-injured occupants survived the deceleration forces and impact. Although a number of those occupants sustained head injuries, the cause of death in each case was listed as drowning. The fifth fatally-injured occupant succumbed to impact-related injuries.

1.14 Fire

There was no indication of an in-flight or post-impact fire.

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37 Governed propeller-blade angle most suitable for takeoff and low-speed flight, between ground fine and a range of coarser cruising settings.

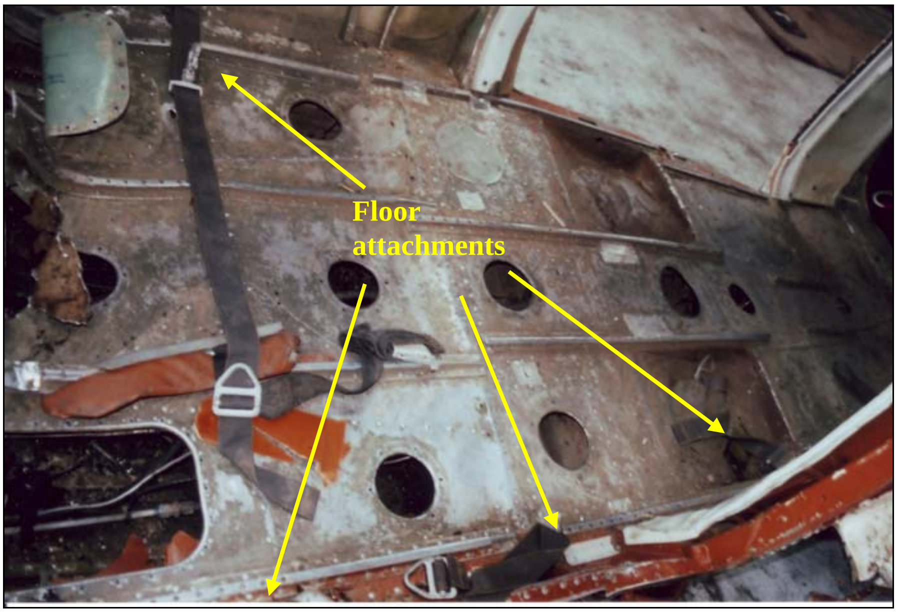
1.15 Survival aspects

The damage to the cockpit area was severe, but the cabin area remained relatively intact. Of the aircraft's seven occupants, only two successfully exited the aircraft. The owner/operator (Tandem Master No.3, see Figure 2) advised the investigation that he exited the aircraft after it submerged in the dam water. Tandem Student No. 1 had no recollection of exiting the aircraft.

The pilot's seatbelt attachment fittings were intact following the accident but the seat itself had detached from the floor seat rail track. The right front and left rear seat attachment brackets had failed in overload.

The aircraft cabin had four cabin floor restraint attachments for the six cabin occupants. The pilot's seatbelt attachment also served as one of the cabin floor restraint points for a Tandem pair (Figure 7).

Figure 7: Cabin floor restraint attachments



The APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual*[38] outlined the preferred aircraft operational procedures during parachuting operations. Pilots were required to sign that manual, acknowledging their understanding of its content. The manual advised the use of restraints as follows:

> It is required that there be a seat restraint available for each passenger and crew member and also that these restraints be used in accordance with their briefing.

Evidence indicated that none of the Tandem Student parachutists or Tandem Masters were restrained to the floor of the aircraft. Witness reports and video evidence indicated that there was no pre-flight briefing on the use of the available cabin restraints, or of the procedures for emergency exit from the aircraft in the event of a forced landing, fire or other emergency. None of the student parachutists were wearing a helmet.

38 *Jump Pilot's Handbook & Aircraft Operation Procedures Manual*, Australian Parachute Federation, June 2005, Canberra ACT Australia.

In preparation for a tandem jump, a Tandem Student was attached by harnesses to their respective Tandem Master, who wore the parachutes for the jump. Normal procedure was for the Tandem Student to be harnessed to the Tandem Master at an altitude close to the planned jump altitude. Although the APF *Operational Regulations* did not specify exactly when tandem parachutists should be harnessed together,[39] it did offer the following guidance: [40]

> If the aircraft is fitted with an in-flight door, the students must be attached to the Tandem-Master before the door is opened in flight.

When recovered from the aircraft wreckage, Tandem Master No. 2 and Tandem Student No. 2 were found to be harnessed together. The position of the Tandem Student harnesses was such that they would have had to have reached above and behind their shoulders to detach their harnesses.

1.16 Tests and research

1.16.1 Origin and movement of the fuel used for the flight

The origin and movement of the drum fuel that was used for the flight is listed in Table 5.

Table 5: Origin and movement of the drum fuel stock

Date	Event
10 March 2005	Manufacture and initial Avgas 100/130 test in accordance with DEF STAN 91-90/1.
23 March 2005	Product test and approval in accordance with DEF STAN 91-90/1. Test report and release note issued.
26 June 2005	Distribution to respective terminals.
27 June 2005	Drums filled from bulk stock.
8 August 2005	Department of Defence orders 24 total 200 L drums of Avgas 100/130 for delivery to Willowbank ALA.
29 August 2005	Department of Defence order of 24 drums delivered to Willowbank ALA.

The majority of the drums of fuel were used by the owner/operator of the parachute school during flights in support of RAAF parachuting operations during August and September 2005.

39 Varying aircraft types, configurations, etc influenced the timing of that activity.

40 *Operational Regulations*, Australian Parachuting Federation Inc., 15 December 2004, Canberra ACT, Australia.

1.16.2 Fuel testing

Typically, testing laboratories prefer to validate their test results by retesting a number of samples of the same fuel. That can require a sample of 10 L or more. Testing of fuel using limited quantities may mean that the testing sample is not representative of the fuel stock from which the sample was drawn. The small amount of fuel left in the drum that was used to refuel the aircraft restricted the size of the fuel sample able to be drawn for subsequent testing to 1 L. In addition, as noted at section 1.6.8, the fuel remaining in the aircraft's tanks was either contaminated by dam water, or unable to be recovered.

On 25 January 2006, the ATSB arranged for the 1 L sample of recovered drum fuel to be tested at a National Association of Testing Authority (NATA)-approved laboratory.[41] That test was carried out in accordance with the laboratory's Quality Management System, which complied with the requirements of Australia/New Zealand Standard ISO 9001:2000. The tests also conformed to the requirements of UK Defence Standard (DEF STAN) 91-90/1,[42] American Society for Testing and Materials (ASTM) Standards 2700 and D 910-04a, as well as other industry standards.

A comparison was made between the NATA-approved test report and the results of the post-production fuel manufacturing refinery's test results (refer to Table 5, Section 1.16.1). That comparison showed:

- high amounts of visible solid matter in the drum fuel sample
- a significant change in the density of the tested fuel
- an unacceptably high fuel sample boiling point at the distillation range 10% evaporated test point
- high levels of existent gum in the sample
- a knock-rating (octane rating) lean mixture in excess of 107.7.[43]

The report included the following observations:

> Comments: The sample does not meet the relevant specification. The sample fails visual appearance due to the presence of visible solid matter. It fails the distillation 10% evaporated limit and also fails the existent gum limit. From the distillation results, it is estimated that the fuel has lost approximately 6% volume due to weathering (evaporation). This suggests that the storage and integrity of the sealing of the drum were less than adequate. The presence of solid matter also suggests probable poor handling and storage.

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41 Information received from a fuel industry representative indicated that the 1 L fuel sample that was recovered for testing may not have been representative of the fuel used to fuel the aircraft the night before the flight as the large headspace in the nearly empty drum may have allowed the fuel's 'light ends' to evaporate in the time between that refuel and drawing the sample from the drum.

42 The UK Defence Standard requires the representative samples of each batch of the finished product to be tested but that was not possible.

43 That rating was considered acceptable by the NATA-approved laboratory.

> It is possible that the loss of some volatiles from the fuel may affect starting performance and possibly transient speed performance. This should be confirmed with the engine supplier. The presence of gum may affect the flow from fuel injectors over a long period. In our opinion, this Avgas 100/130 sample is not suitable for use.

When asked to comment on the reported differences in the density of the post-production and recovered fuel sample, the testing laboratory replied:

> As for the density, the maximum density variation allowed for Avgas (& Jet fuel) after movement is 0.0030 kg/l. Outside this limit is an alert for contamination. A difference of 0.0331 kg/l indicates a serious contamination issue, i.e. a high boiling residue being present or the dissipation of the volatile ends from the Avgas dur to poor storage and/or handling. This may explain the high existent gum result. It would definitely affect engine combustion.

The engine manufacturer's response included that:

> Since the fuel seems to have the 100 plus octane rating, engine performance should not be limited by the fuel.

In an effort to understand the apparent disparity in the testing laboratory's and the engine manufacturer's interpretations of the potential effect of the change in the density of the fuel sample from specification, the UK Air Accidents Investigations Branch (AAIB) was also provided a copy of the fuel test results. UK AAIB comment was sought on the possible effect of the identified change in fuel density on the engine's performance. The AAIB enlisted the expertise of a consultant expert to view the test results. In its response, the AAIB advised that:

> The change in density will mean that for a given volume of fuel, a larger mass will be metered into the engine, assuming no automatic or manual adjustments are made. This could mean that the fuel mixture would be richer. However, to put this in perspective, it should be noted that the fuel density is within the normal range expected of AVGAS (all be it at the top end). Therefore density alone is unlikely to be an issue.
>
> It should be noted that all engines will react slightly differently to fuel property changes and that I do not have any information on how this engine was qualified. Further information on this should perhaps be sought from the engine manufacturer.
>
> In conclusion, I would agree that the fuel is not fit for use due to appearance, distillation and existent gum. Solid matter, if transferred to the aircraft, may block fuel filters inhibiting fuel flow. From the information available, the most likely cause of the fuel being off specification is due to weathering, not contamination with a higher boiling material. The change in density may make a difference to the mass of fuel metered into the engine, but the density is within the normal range experienced with AVGAS.

Regarding evaporation of gasoline (Avgas) an article produced by a major fuel manufacturer advised:

> The gasoline light ends needed for easy starting have the same tendency to vaporise in storage as they do in an engine. If the storage container is not tightly sealed, some of the light ends gradually will be lost. Too great a loss decreases the gasoline's ability to start an engine.

> Evaporation of gasoline from a vented fuel tank or a can with a loose cap would be minimal if the temperature of the container were constant. But daily temperature changes cause the temperature of the container to cycle. The heating portion of the cycle raises the pressure of the gas (gasoline vapour and air) above the liquid gasoline which, in turn, drives some of the vapor-air mixture out of the container. The succeeding cooling cycle lowers the pressure of the gas, drawing fresh air into the container. Light ends evaporate from the liquid gasoline to saturate the new air. The daily repetition of this cycle gradually pumps light ends out of the container.
>
> The cycle also brings air and water vapor into the container, especially during periods of high humidity. The oxygen in the air contributes to gum formation. (See Oxidation section.) And the water vapor, if it condenses during the cooling cycle, contaminates the gasoline with liquid water.
>
> A larger volume of gas will be pumped in and out of the container when the air space above the liquid fuel is larger and when the daily temperature change is larger. Consequently, keeping the container almost full of gasoline and controlling the temperature fluctuations will minimize the loss of light ends, the exposure of the gasoline to air, and the contamination of the gasoline with water.[44]

According to one industry expert, the loss of 6 % by volume of stored fuel (its light ends) was expected anytime the fuel was stored in either a container or wing tank where head space or ullage was present, or when a storage container was vented to atmosphere. Those conditions would exist anytime fuel was not stored in its manufacturer's storage facility, or not stored inside a full container that was not vented to atmosphere. According to that expert, the evaporative changes between the post-production and recovered fuel sample would have been unlikely to have negatively affected engine performance.

For further information regarding the characteristics of the Avgas, the fuel sample test results, and the comparison of the NATA-approved laboratory and post-production test results, refer to Appendix B.

1.17 Organisational and management information

1.17.1 Administration of sports parachuting operations in Australia

The genesis of the 'self-administration' of sports aviation dates back to 1949, when the then Department of Civil Aviation (DCA) allowed the Gliding Federation of Australia to undertake a number of tasks on behalf of the DCA and of its own members. That arrangement came to be termed 'self-administration'.

Parachuting as a sport began in Australia in the late 1950s and the self-administration of the sport commenced in 1960 under the auspices of the DCA. Over the ensuing years, seven more organisations evolved to administer new sections of sports aviation[45] on behalf of the DCA and its successors, including most recently, on behalf of CASA.

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44 *Longer-Term Storage of Gasoline*, Chevron USA Inc., 2002-2006.

45 Ultralights, hand gliders, gyroplanes, etc.

The self-administering arrangement was gradually formalised over many years and is presently being formalised further with the development of Civil Aviation Safety Regulation (CASR) Part 149. Some of the key events in that formalisation process have included:

- An Australian Government decision in 1983 to make payment from the aviation budget to self-administering organisations for work performed on behalf of the regulator
- the establishment of a Memorandum of Understanding with an attachment payment in line with the above policy
- an early input was made to the formalisation process with the House of Representatives Standing Committee on Transport Safety inquiry in 1987. That inquiry found the concept of the self-administration of the then new ultralight movement by sports aviation organisations to be appropriate, and made various technical and financial recommendations
- a move to a more formalised Deed of Agreement (2002) with the need for organisations to require performance reporting and standards to be met in consideration of payment being made.

The self-administering organisations remained subject to CASA oversight, and a new section of CASR Part 149 is being devoted to formalising the regulatory arrangements affecting the self-administering organisations.

CASA audits all sports aviation self-administering organisations on an approximately biennial basis. CASA, at their discretion, may conduct audits on organisations' members at any time.

1.17.2 The Australian Parachute Federation

Structure of the Federation

Sports parachuting from civil aircraft in Australia was primarily administered by the membership-driven Australian Parachute Federation (APF) on behalf of CASA. That administration was via deed of agreement. With the approval of CASA, the APF set the operational standards, conducted competitions, issued parachutist licences and instructor qualifications, conducted exams and published a magazine and newsletter to keep its members informed of current events and safety standards. The APF also assisted CASA in the control of parachute rigger and parachute packer standards in Australia.

At the time of the accident, the APF included nine Area Councils, each of which appointed two members to the APF Board. In addition, seven Technical Directors attended the Board meetings. In May 2004, the Board gave a management committee the power to make decisions. The APF also had a Chief Executive Officer (CEO) to whom reported the Office Manager, Manager Training, the Technical Officer and the Administration Manager. One of the board members was also an APF Area Safety Officer (ASO). The APF had implemented an accident and incident reporting system.

Deed of Agreement

On 28 January 2005, CASA signed a Deed of Agreement with the APF affecting the period 1 July 2005 to 30 June 2006. The agreement set out the financial compensation provided to the APF by CASA in order for it to administer sports parachuting in Australia on behalf of CASA. A total of $102,850 dollars was provided by CASA for that to occur. The agreement allowed for CASA to perform safety audits of the APF during the term of the agreement.

Schedule A of the agreement listed the compliance functions to be performed by the APF as:

> 1. Seek to ensure that all members of the Federation conduct their parachuting operations in accordance with the applicable CASA specifications, the APF Operational Regulations and other applicable manuals and directives of the APF;
>
> 2. Monitor the operational standards and procedures of members and member clubs and rectify any deficiencies detected to ensure compliance with the standards specified in the APF Operational Regulations and other APF and CASA directives;
>
> 3. Examine the results of incident and accident investigations relevant to sports parachuting to ensure that existing standards have been complied with;
>
> 4. On behalf of the Authority, investigate alleged breaches of the Civil Aviation Regulations and APF Operational Regulations and other applicable APF and CASA directives by sports parachutists and member clubs;
>
> 5. Assist the Authority by monitoring airworthiness standards of parachutes to ensure compliance;
>
> 6. Assist the Authority by monitoring standards of parachutists, parachute instructors and parachute riggers to ensure compliance;

During interview, the APF indicated the understanding that:

- CASA must approve all changes to the APF manuals
- the APF had no concerns with PPL (A) pilots flying their members' aircraft
- their preference was for members' aircraft to be maintained on a 100-hourly maintenance interval
- the APF did not have the expertise or authority to audit their members' aircraft operations
- the funding provided to the APF by CASA would have met less than one quarter of the association's operating costs.

Accident and incident reports to the APF by the operator

During the period 26 January 2003 to 13 May 2005, the operator reported a total of 13 incidents to the APF involving parachutists sustaining landing injuries. The operator reported no aircraft accidents or incidents to the APF during that time.

APF workgroup activities

The APF held annual conferences for its members. During those conferences, relevant operational and safety-related issues were discussed and actioned by workgroups that were formed from within the membership. At an annual conference in Sydney in May 2003, the items that were discussed by a workgroup included a proposed jump pilot endorsement, and the use of single-point restraints in parachuting aircraft. The workgroup minutes for that conference noted:

> CASA presented to the workgroup on a proposed jump pilot endorsement. This proposed endorsement would require a flight check with a flight instructor. APF Instructor B's who hold a private pilots licence may become eligible to become flight instructors.
>
> This project has a proposed implementation date of April 2005.
>
> Resolved: That we explore ways to satisfy CASA that we are properly educating and training our pilots thereby keeping the training and endorsement process in house and available to non pilot APF instructors.

In addition, the workgroup minutes noted that the APF encouraged the continued use of single-point restraints.

APF Jump Pilot's Handbook & Aircraft Operation Procedures Manual

The June 2005 revision of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* stated that:

> Some parachutists, drop zone operators and aircraft owners who are not pilots assume that a pilot's basic flying training should enable the pilot to operate safely and efficiently but experience has shown that this is not always the case.

The manual also encouraged parachuting operators to tailor its *Appendix 1 – Parachuting Aircraft Procedures* to their own particular requirements and aircraft, and to tailor procedures in order to enhance the safety and efficiency of the overall parachuting operation.

With reference to engine failure and critical altitudes, the manual stated:

> When flying jumpers the procedures for a forced landing are no different than the normal forced landing techniques except that your passengers may choose to leave, altitude permitting.
>
> In the event of an engine problem or failure, first control the aircraft and immediately check that the movements of a jumper's backpack has not:
>
> -pulled the mixture,
>
> -unlocked the [fuel] primer,
>
> -turned off the mags [magnetos],
>
> -retarded the throttle,
>
> -or turned off the fuel.

Appendix 1 of the manual, in part, outlined pilot minimum experience, induction requirements, rostering, general responsibilities, aircraft loading, and aircraft emergency procedures. In particular, the Appendix stated that pilots needed to complete a knowledge check that was specific to the aircraft to be flown. Appendix 2A of the manual contained the items to be covered during an operational knowledge check, including questions on an aircraft's: general aircraft data, airspeed limitations, emergency and normal procedures, weight and balance, fuel system, engine and propeller, airframe, electrical/radios, flight instruments, and general operations. With reference to emergency procedures, the knowledge check required a pilot to detail the emergency procedures for various situations, including in the case of an engine failure after takeoff (EFATO). There was no similar requirement affecting the management of partial EFATO.

Appendix 1 also stated that an aircraft's loading shall not exceed the MTOW specified in the aircraft documents and that the aircraft emergency procedures were to be in accordance with the APF *Pilot's Operating Handbook*, the aircraft manufacturer's recommendations, and industry best practice as applicable.

In addition, the manual highlighted the risks associated with the practice of loading parachutists to an aircraft with the engine running as follows:

> The jump pilot faces a greater risk of having someone walk into the propeller than does a pilot working in any other environment. Jumpers at the student stage might not be aware of a spinning propeller and many parachutists, students in particular, frequently have friends who want to get pictures of them entering the aircraft. Crouching in the propeller arc is a favourite spot for such a picture, therefore never start the aircraft until all jumpers are aboard and the spectators are clear.

Witnesses reported, and the analysis of recovered video confirmed, that the parachutists were loaded onto the aircraft with the engine operating.

There was no evidence that the pilot had completed a knowledge check on the Cessna 206 aircraft in accordance with Appendix 2A of the manual, or that appropriately-documented emergency procedures were available for the modified Cessna 206 aircraft.

Despite the requirements of Schedule A of the Deed of Agreement with CASA, the APF advised the understanding that compliance with the contents of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* was not mandatory for members of the APF.

1.17.3 Auditing of the operator and organisations

A number of audits of parachuting operations in Australia were carried out by CASA and by the APF in 2005, as detailed below.

CASA audits of the APF

During 2005, CASA conducted:

- an audit of the APF audit system
- an audit of a sample of APF operators with parachute-through-cloud permissions
- an audit of the corporate head office of the APF
- a special audit, in which CASA personnel accompanied APF personnel during the conduct of federation audits.

CASA audits of the management of the APF-administered audit function

In a letter to the APF dated 19 April 2005, the CASA Senior Air Safety Auditor notified the APF of the intent to audit the self-administered audit function. The letter expressed concern about the 'soundness of APF's enforcement, investigation and disciplinary systems'.

The last CASA audit of the APF prior to the accident was carried out between 14 and 16 June 2005. The audit team concluded that the APF was meeting its overall obligation to CASA under the deed of agreement. However, it was noted that there was no clear system established to action compliance issues that might emerge from Drop Zone audits conducted by APF ASOs. In addition, the CASA audit identified that there was the potential for a Request for Corrective Action[46] (RCA) task, if issued, to be overlooked.

CASA audits of the operator

Because sports parachuting operations are self-administrated, and parachuting aircraft are typically operated under the Private category, the surveillance of the operation by CASA was limited to periodic aircraft 'ramp checks' in order to confirm their serviceability. A review of the CASA aircraft file indicated that no ramp checks of the aircraft had been completed since it had been placed on the Australian register.

APF audits of the operator

Periodic audits of APF members' parachuting operations were carried out by volunteer APF ASOs in each state. One APF ASO was nominated per state, and all APF ASOs were experienced parachutists. Few, however, had aircraft operational experience and none were formally-trained in the conduct of an audit. However, the APF Technical Officer had received training at a Quality/Safety Lead Auditor course and advised the ASOs in auditing techniques and best practices.

The APF ASOs completed their audits according to a checklist-type document referred to as the APF Safety Audit Package 2005/2006. That package included a note referring to aircraft that were used for parachuting operations as follows:

> **Aircraft:** the aircraft are an important part of any parachute operation and more often nowadays the APF is being asked to assist and advise with aircraft and pilot matters. An ASO needs to have some knowledge of aircraft and pilot operations and should be prepared to question an operator or experienced pilot to gain a working knowledge of requirements and procedures.

The Safety Audit Package contained a supplement titled the *2005/2006 Aircraft Operations Supplementary Safety Audit*. The supplementary material contained checklist items such as: maintenance release details, maintenance required/carried out, flight times recorded, pilots licence and medical details, restraints fitted and serviceable, and so on. The package included a statement that:

46 A Request for Corrective Action detailed deficiencies that involved non-compliance with legislation and that must be addressed.

> If deficiencies are found they need to be followed up by the ASO. It is not constructive, nor is it the intention of this "Aircraft Operations" Supplementary Safety Audit to record deficiencies in a member organisation's aircraft operation. It is suggested that any deficiencies be rectified at the discretion of the ASO and that the audit be not considered complete until these deficiencies are rectified to the satisfaction of the ASO.

The last periodic audit of the operator by the APF was in June 2005. The auditor's comments included that:

- incident reports were not being submitted
- one individual was identified with questionable licensing details
- the master log did not nominate a Drop Zone Safety Officer
- pilots were not recording daily flight details in the maintenance release
- more safety posters were needed.

The auditor also commented on the good order of the operation and parachuting equipment, but that the paperwork, filing and record-keeping was poor.

1.17.4 Classification of sports parachuting operations and proposed regulations

Parachuting operations have long been classified as Private operations[47] under the terms of the CARs. That is, they have not been regarded as falling into any of the other CAR 206 commercial purposes categories of regular public transport (RPT), Charter or Aerial Work. Those other operations attract a higher level of surveillance, require more robust maintenance inspections of the aircraft and have more stringent flight crew currency, recency and medical examination requirements than affect the conduct of Private operations. Commercial purposes operations also provide more consideration for passenger safety when compared with Private operations.

The classification of parachuting operations as Private operations was discussed in the early 1990s by the then Civil Aviation Authority (CAA) and the APF. However, it was understood that the classification of operations was to be the subject of review as part of the ongoing regulatory reform program.

Since the late 1990s, a number of Notices of Proposed Rule Making (NPRM) have been issued addressing different aspects of the classification of operations generally, and of parachuting operations in particular. To date, no final outcomes from these proposals have been promulgated. However, a common thread throughout the process has been that parachuting operations should remain in a classification less than Aerial Work, and therefore not require the operators of parachuting aircraft to hold an Air Operator's Certificate (AOC) for that purpose.

In 1999, the CASA Board, in reviewing a proposal to clarify the requirements of CAR 206, specifically agreed that 'the aircraft operation aspect of commercial parachuting should be excluded from the AOC requirement in CAR 206'. The Board also agreed that parachuting aircraft would be required to carry a warning sign to advise participants that the operation of the aircraft was not necessarily being conducted to the standards of a fare-paying passenger flight. At the time of publishing this report, the proposed changes to CAR 206 had yet to be finalised.

There were no warning signs in the aircraft to inform the tandem student parachutists that the operation of the aircraft was not necessarily being conducted to the standards of a fare-paying passenger flight, nor was there a regulatory requirement to do so. However, the owner/operator reported that the aircraft and the facilities included signage stating that:

> In all other cases and except where inconsistent with the above, any person parachuting, learning to parachute, training to parachute, flying in any aircraft being used for or in connection with parachuting, participating in any activity carried on by the Club or visiting the Club's premises to watch persons participating in any activity carried on by the Club ("the Activities") **does so entirely at his/her own risk.**

Tandem Students were also required to join the APF and sign an indemnity form which was annotated that they accepted the risk associated with flying in sports parachuting aircraft and with parachuting itself.

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47 Although some aircraft used in these operations are maintained to the Charter or Aerial Work categories.

The next of kin of one of the deceased Tandem Students reported that the tandem student had selected the operator from a listing in the telephone directory. Despite the classification of parachuting operations in the Private category, that student was reported to have assumed that the aircraft and operation had a high level of safety, comparable to when flying in an airliner.

In April 2000, CASA published NPRM 0007MS *Recreational Aviation Administration Organisations, Civil Aviation Safety Regulations Part 149*. A potential problem that was identified in the NPRM was that, under current legislation, a number of recreational and sporting aviation activities (such as sports parachuting) were administered by organisations that were specifically named in the legislation. The majority of those organisations have, in effect, 'monopoly rights' over the aviation activities involved. The NPRM proposed three basic options to best administer recreational and sport aviation activities:

a. Adopt a revised version of the New Zealand Civil Aviation Authority's Part 149 which provides a formalised process for approving qualified administrative organisations; or

b. Delegate to organisations the broadest possible array of regulatory authorisations necessary to administer specified aviation activities; or

c. Extend the authorities of existing certificate holders and authorised persons (e.g. flying training organisations, ATO's, CAR 35 engineers, etc.) to issue the regulatory authorisations required for recreational and sport aviation activities.

The *Impact Analysis* section within the NPRM noted that:

> Requiring organisations to conduct surveillance on their members should increase the level of safety because CASA, with its limited resources, would not be able to carry out surveillance to the same levels of effectiveness. Also, experience has often shown that members of organisations are inclined to respond more readily to peer pressure than they are to an approach from a regulator. Notwithstanding, CASA will conduct audits of the approved organisations to ensure that surveillance is being carried out comprehensively.

The NPRM also outlined how the recreational aviation organisations could develop an internal evaluation program to ensure the continued safety of operations. As of 2 July 2007, the NPRM was in the 'Consultation Legal Drafting' stage of the development process, and was scheduled for completion in the third quarter of 2007.

On 10 November 2006, CASA issued a draft policy document titled *CASA Industry Sector Priorities and Classification of Civil Aviation Activities* addressing the prioritisation of CASA's activities, and its particular focus on the interests of the air-travelling public. The document set out CASA's policy on the classification of aviation activities conducted by civil aircraft in Australian airspace, and outlined three proposed levels of safety oversight for application to non-crew aircraft occupants. Those levels of safety oversight included for:

> a. *Passengers* who were not expected or assumed to have knowledge of the risks they were exposed to and have little or no control over the risks (other than choosing not to fly)
>
> b. *Task specialists* who have assigned in-flight duties related to a specialised use of an aircraft and are informed of and accept the associated risks; and
>
> c. *Participants* who voluntarily engage in an aviation activity, are informed of the risks, and have explicitly accepted the risks of their involvement in that activity.

Under that policy, individuals who engaged in sports parachuting activities would appear to fall into the '*Participants*' category of aircraft occupant. However, according to the witness and video evidence, the Tandem Student parachutists on board the aircraft were not informed of the risks of the flight itself to the extent that they would if treated as a *'Participant'* under the proposal.

In December 2006, CASA published NPRM 0605OS *Parachuting Operations from Aircraft*. That NPRM was developed to be a 'one-stop shop', containing all of the necessary operating, licensing and maintenance rules affecting the conduct of parachuting operations from aircraft. It proposed that all requirements for sports and recreational parachuting from aircraft should be contained in the newly-proposed Civil Aviation Safety Regulation (CASR) Part 105. Part 105 will reportedly reflect internationally-accepted best practice regarding the operation and regulation of sports and recreational parachuting. The NPRM noted that:

> The rules will give effect to Government policy that CASA devotes its major safety efforts to the safety of the travelling public and people on the ground, by devolving the responsibility for administering these recreational activities to industry organisations that have shown the ability to do so safely.

CASA proposed retaining the right for overall responsibility for the standards affecting parachuting operations and their safe application, and to prosecute breaches of the Civil Aviation Act 1988 or of a CASR. The NPRM noted that the proposed regulatory regime has shown itself over the years to achieve an adequate level of safety in parachuting operations, with only slightly more accidents than the more highly-regulated forms of aviation. Section 3.5.7 of the NPRM noted that:

> There are aspects of parachuting from aircraft that have not fitted easily into the traditional classification scheme. Because people who engage in parachuting from aircraft are voluntary participants in an aviation activity, where they have indicated an understanding and acceptance of the risks of participation, CASA proposes to regulate the activity on the basis that it involves informed 'participants' rather than as 'passengers' for whom the operator is responsible.

The NPRM also proposed to permit aircraft used in parachuting operations to exceed the maximum number of occupants in an aircraft as specified by the aircraft manufacturer, as long as aircraft limitations regarding weight and balance requirements were followed.

1.17.5 Pilot licensing

Pilots who conduct sports parachuting operations are required to hold, as a minimum, a PPL(A). Pilots who are involved in the carriage of fare-paying passengers must hold either a CPL(A) or an Air Transport Pilot (Aeroplane) Licence (ATPL(A)). Those licence holders are required to obtain a Class 1 medical certificate on at least an annual basis if they seek to remain involved in the carriage of fare-paying passengers. Holders of a PPL(A) are required to obtain a Class 2 medical certificate on at least a four-yearly basis.[48]

1.18 Additional information

1.18.1 Occurrence pilot aeronautical knowledge and experience

The familiarisation flights undertaken by the accident pilot when engaged by the owner/operator of the parachuting school did not include the practice of actions in response to engine power loss, or abnormal engine operation after takeoff[49]. In that case, the pilot could be expected to react to such emergencies in accordance with previously-assimilated competencies, standards and training.

During interview, the owner/operator of the parachuting school advised that, in his opinion, pilots who are holders of a CPL(A) should know what to do in the event of an emergency. The owner/operator also commented that, as a holder of a PPL(A), he was not appropriately-qualified to be conducting pilots’ emergency training.

The accident pilot completed his student, private and commercial pilot training in accordance with the CASA *Day (VFR) Syllabus – Aeroplanes*. In accordance with government policy, national competency standards for private and commercial aeroplane pilot licences were developed by the aviation industry in conjunction with CASA and the Australian National Training Authority.

The Aeroplane Pilot Competency Standards became mandatory on 1 September 1999, and required each training organisation to ensure that its curriculum provided for the training and assessment of all units of competency relevant to a particular qualification. The pilot received flying instruction in accordance with those units of competency.

1.18.2 Occurrence pilot training and knowledge of emergency procedures

The pilot completed flying training 5 months earlier at a CASA-certificated flying school. The syllabus at the flying school included training in emergency procedures. Typically, pilots are trained to deal with a range of emergencies such as

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48 The frequency of the medical examinations required for these certificates is increased with the pilot’s age.

49 Nor was this a requirement of the extant regulations.

an EFATO. However, there was no specific regulatory requirement to train or check pilots in the case of a partial EFATO, including during biennial flight reviews or proficiency checks.

The flying school syllabus included a general consideration of partial engine failures as follows:

> Decide if the aircraft can maintain height by ensuring zero flap and raising the nose to the attitude that will give an IAS [indicated airspeed] similar to the zero flap Best Angle of Climb speed (lower than Best Glide and Best ROC [rate of climb] speed).

The pilot's student pilot training records indicated that he received EFATO training and had been exposed to some general discussion regarding a partial EFATO. The extent of any actual practice of partial EFATO during the pilot's training could not be established.

The owner/operator informed the investigation that the pilot had been given a copy of the relevant manuals for the Cessna C182 and the U206, along with a handbook relating to the Lycoming engine model that was installed in UYB and told to read each handbook. In addition, the pilot had signed an acknowledgement that he had read and understood the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual*.

The owner/operator also reported that he had advised the pilot of the available emergency landing areas surrounding the ALA.

1.18.3 Pilot competency requirements affecting the management of engine failure and partial power loss

The CASA *Day (VFR) Syllabus – Aeroplanes* detailed the competency requirements for the issue of a PPL(A) and CPL(A). The 'manage abnormal situations' units in that syllabus included the element 'manage engine failure after take-off'. The assessment guide for that competency element included the following evidence requirements:

- an action plan is determined in preparation for an EFATO
- that action plan includes not turning back towards the airfield after an engine failure, unless above a safe altitude
- the aircraft's nose is immediately lowered to maintain best gliding speed
- a suitable landing area is selected
- turns are minimised.

In addition, the supporting Assessment Guide required the pilot candidate to perform EFATO or other abnormal situation checks and actions as evidence of the pilot's ability to meet the relevant licensing standards.[50] The syllabus did not specifically address the management of a partial EFATO.

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50 The checks and actions in that guide were advisory. Checks and actions in approved checklists, placards, Flight Manual/Pilot's Operating Handbooks, or Operations Manuals had precedence and were to be complied with in the first instance.

A pilot licence candidate was also required to satisfy promulgated Associated Training and Aeronautical Knowledge requirements for the award of either the PPL(A) or CPL(A) Theory Examinations. Associated Knowledge was defined as that knowledge that must be known by the pilot completely, and that related directly to the safety of the aeroplane, including:

- the ability to recall the emergency actions listed in the pilot's operating handbook, including the actions after an EFATO
- describing the symptoms when approaching, characteristics of, and recovery from the stall.

Each flying training syllabus requirement included performance standards that applied to the practical flying phases of the respective pilot licences. The General Flying Progress Test (GFPT) [51] was a test to demonstrate the candidate's ability to safely and confidently handle the aircraft to the standards specified in the *Day (VFR) Syllabus – Aeroplanes*, and lasted a minimum of 1 flight hour. The GFPT contained a discussion point on the flight test form on the actions in the event of a partial EFATO in the circuit. In the case of the CPL(A), the standards ensured that, prior to an attempt to fulfil the requirements of the flight test, pilots demonstrated a high level of proficiency when conducting certain exercises when under pressure. Included amongst those exercises were:

- EFATO and elsewhere in the circuit
- partial engine failure/malfunctions.

The *Flight Instructor's Manual*[52] was produced by CASA as a guide to elementary flying training. While the 'emergency and special procedures' section of the manual did not specifically address a partial EFATO, in the context of a forced landing it recommended that:

> If the failure is partial, resulting in reduced or intermittent running, the engine may be used at the pilot's discretion, remembering that it may pick up temporarily or fail again at a critical stage. In such a case it is probably best not to rely on the faulty engine and to assume a total failure.

The *Flight Instructor's Manual* did not endorse the development of the practice by the student of developing an action plan for application in the case of an EFATO.

1.18.4 Pilot requirements when flying different single-engine aircraft types

The pilot of a single-engine (piston) aeroplane below 5,700 kg MTOW requires a class endorsement and any applicable special design feature endorsements to act as a pilot in command. A pilot must also comply with the requirements of Civil Aviation Order (CAO) 40.1.0 section 4.4, which stated:

> The holder of a class endorsement must not fly as pilot in command or co-pilot of any aeroplane unless he or she:

51 Issue 3.1, effective 1 April 2004.

52 Issue 1, published by CASA in 2005 and current at the time of the accident.

> (a) is familiar with the systems, the normal and emergency flight manoeuvres and aircraft performance, the flight planning procedures, the weight and balance requirements and the practical application of take-off and landing charts of the aeroplane to be flown; and
>
> (b) has sufficient recent experience or training in the aeroplane type, or in a comparable type, to safely complete the proposed flight; and
>
> (c) if an aeroplane in that class has a special design feature, holds a special design feature endorsement referred to in paragraph 5.1 for that design feature.

In regard to the requirements of CAO 40.1.0, the term 'familiar' was not defined and there was no formal guidance as to how to comply with the CAO requirements.

1.18.5 Regulations, airworthiness directives and bulletins

Engine airworthiness directives

In December 2001, CASA issued Airworthiness Directive (AD) AD/ENG/4. At the time of the accident, AD/ENG/4 amendment 9 was in effect.[53] The AD outlined the continued airworthiness requirements affecting piston engines in Private, Aerial Work and Charter operations aircraft. One of the airworthiness requirements of Amendment 9 was for the completion during periodic inspections of a Piston Engine Condition Report Form 728. A review of the aircraft's documentation indicated that two Piston Engine Condition Report Form 728s had been recorded since the aircraft was placed on the Australian register.[54]

Airworthiness bulletin AWB 02-003 Issue 2

In 2004, CASA advised registered owners that: [55]

> Owners have three options for maintenance. You could follow the CASA schedule (schedule 5), the manufacturer's schedule, or seek approval from CASA for your own system of maintenance.

On 22 June 2006, CASA issued Airworthiness Bulletin (AWB) 02-003 Issue 2 in order to clarify the requirement under CAR 42A, B and C for all forms of manufacturer's maintenance schedules to include airworthiness limitations. The AWB took the form of a frequently-asked questions document, and explained CASA's requirements regarding aircraft maintenance. Included in the AWB was a reference to Schedule 5, which stated:

> The CASA maintenance schedule, which is Schedule 5 of the CARs, is widely misunderstood. Many think it replaces and relaxes the manufacturer's maintenance schedule.

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53 Amendment 10 was issued on 26 October 2006.

54 Amendment 10 of AD/ENG/4 later clarified the completion intervals; see section 4.2.1 for further information.

55 *CASA Flight Safety Magazine*, March-April 2004, CASA, Canberra ACT, Australia.

> However, in CAAP 42B-1 (0), *CASA Maintenance Schedule*, in the Purpose, we recommend 'a study be made of the manufacturers schedule as it is considered that these are generally more appropriate for the maintenance of the aeroplane'.

and further stated that:

> So, the CASA maintenance schedule *does not replace* the manufacturer's maintenance schedule.
>
> If you don't follow the manufacturer's maintenance schedule, you should know why, and be able to explain your reasoning to an auditor or accident investigator.

The AWB concluded by stating:

> So, the CASA maintenance schedule *does not relax* the manufacturer's maintenance schedule. It asks you to check if you should do more.

There was no evidence that the owner/operator had requested CASA's approval for an alternate maintenance schedule or had compared the aircraft manufacturer's requirements to those of Schedule 5.

The requirements of the aircraft manufacturer's maintenance documentation included the inspection of the aircraft on a 100-hourly basis, and an 'as specified' interval for some items. The manufacturer's 100-hourly inspection included the inspection of critical items such as the:

- flight control cables and pulleys
- fuel lines and hoses
- electrical wiring
- control surfaces
- fuel strainers and selector.

1.18.6 Examination of similar parachuting accidents

During the investigation, a number of accidents were examined that, as was the case in this accident, involved some form of power loss during parachuting operations. That included accidents during the conduct of overseas and Australian parachuting operations. Refer to Section 1.18.7 for further information regarding partial engine power loss accidents in general.

UK-registered Cessna U206F

On 27 June 2004, a UK-registered Cessna Aircraft Company model U206F aircraft crashed during parachute operations following a reported engine problem resulting in a loss of power. Of the six occupants, the pilot and three parachutists sustained fatal injuries and two parachutists were seriously injured. The reason for the power loss was believed to be fuel starvation. None of the parachutists were restrained, with all being seated on the floor of the aircraft.

The British Parachute Association (BPA) administers the operation of sports parachuting in the UK. Included in their responsibilities was the audit by the BPA of parachuting organisations once every 3 years.

As in Australia, sports parachuting operations in the UK are classified as Private category operations and the aircraft may be flown by PPL(A) pilots. In order to conduct parachuting operations, the association requires pilots to obtain a BPA parachute pilot's authorisation in addition to their PPL(A).

In the UK, the operation of parachuting aircraft is the responsibility of the appointed Club Chief Pilot (CCP). The CCP's responsibilities include all aspects of the flying operation, including the aircraft, the pilot and the provision of fuel.

The subsequent investigation into the accident conducted by the AAIB determined that the organisational factors with the potential to have influenced the development of the accident included that:

- the pilot information manuals contained incorrect and out of date information
- the payment by parachutists for jumps, and profit taken from the event, led to a perception of a commercial operation without its being subjected to the same standards as affected a commercial operation
- sports parachuting organisations benefited commercially from the conduct of parachuting operations, without having to pay for the services of professional pilots
- no bracing or emergency information was provided to tandem student parachutists
- novice jumpers payed for their jumps, without being aware that the pilots and aircraft involved were not operating to a normal commercial requirement
- a number of maintenance issues were identified, such as: the absence of fuelling records; the conduct of poor quality fuel samples; the contamination of fuel systems; and poor quality, 'unapproved' maintenance.

The report also noted that:[56]

> It is accepted by all parties that parachuting operations place a considerable strain on aircraft with frequent takeoffs, landing and climbs at maximum power followed by descents at reduced power. In more usual commercial operations, where fare paying passengers are carried, certain standards are required by the CAA [UK Civil Aviation Authority] to be met by operators, and these standards are embedded in the Air Operators Certificate (AOC).

UK-registered aircraft that are used in commercial operations, including light single-engine aircraft, are usually certificated in the Transport (Passenger) category, and subject to a more intensive maintenance schedule than aircraft in the Private category.

The AAIB issued the following recommendations as a result of its investigation:

- the CAA review their oversight of parachute schools to ensure the highest standards of aircraft maintenance, including that the operational standards of pilots and aircraft are meeting the original intent (that was, the establishment and maintenance of the highest reasonable standards of operation of such schools, including the operations standards for the aircraft and pilots engaged in parachuting operations)

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56 *AAIB Bulletin, G-BGED EW/C2004/06/02,* November 2005, AAIB, Aldershot, Hampshire, England.

- the BPA revise sections of their operations manual to clarify the flying training syllabus and testing syllabus for BPA-authorised pilots
- the BPA review the contents of the pilot's information manuals to ensure accuracy of content
- the CAA consider the installation of energy-attenuating material in the flooring of aircraft used for parachuting
- there be specific advice in BPA manuals detailing emergency situations that might be encountered concerning conjoined tandem jumpers and when they should separate
- the BPA, in consultation with the CAA, consider the practicality of installing restraint systems for parachutists in all aircraft engaged in parachuting operations
- the BPA, in consultation with the European Aviation Safety Agency, conduct a review of cabin interiors on aircraft engaged in parachuting operations with regard to improving their crashworthiness.

May 2004 occurrence involving VH-UYB

Two former Tandem Students advised the investigation that they had flown in the aircraft in May 2004. On board the aircraft with the students were the pilot[57], another person they believed to be a co-pilot[58], two of the three Tandem Masters from the accident flight, and another solo parachutist.

The individuals informed the investigation that the engine was idling poorly while the aircraft was on the ground and that, prior to the aircraft reaching the jump altitude, the Tandem Masters became concerned because of a problem with the aircraft. The Tandem Masters quickly prepared to jump and the Tandem pairs departed the aircraft at about 6,000 to 7,000 ft AGL instead of the planned altitude.

Afterwards, the co-owner of the operation apologised for the problem. It appeared that the aircraft experienced difficulty achieving the planned jump altitude because of a possible engine power-related problem.

A review of the aircraft documentation was unable to locate an associated maintenance entry related to any anomaly of the aircraft or its engine at that time. The occurrence was not reported to the ATSB as a routinely reportable matter[59] as required by Section 19 of the *Transport Safety Investigation Act 2003*.[60]

June 2005 occurrence involving VH-UYB

A review of the ATSB database revealed that, at 1158 on 10 June 2005, VH-UYB sustained an in-flight engine failure. According to an Airservices report, the aircraft

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57 Not the occurrence pilot.

58 Possibly the owner/operator.

59 Transport Safety Investigation Regulations 2003, Regulation 2.4(2)(f)(i).

60 Although this was a breach of the reporting requirements, Statute of Limitations implications precluded any legal action being taken. The ATSB is currently reviewing its legislation in regard to the application of the Statute of Limitations to the reporting requirements.

had been dropping parachutists and was descending through FL118 when the engine failure occurred. The pilot broadcast a MAYDAY[61] to Airservices and requested a forced landing at RAAF Base Amberley.

At 1159, the pilot notified Air Traffic Control (ATC) that power had been restored to the aircraft's engine and the pilot requested, and was granted permission by ATC, to return to the Willowbank ALA, where an uneventful landing was completed.

According to ATSB records, the owner/operator of the aircraft did not submit a routine report[62] as required by Section 19 of the *Transport Safety Investigation Act 2003*.[60] When asked about the circumstances of the occurrence, the owner/operator advised the investigation that the pilot in command had mis-selected the fuel selector to the incorrect tank, momentarily starving the engine of fuel.

Previous sports parachuting aircraft occurrence BO/199602836

On 7 September 1996, a Cessna Aircraft Company model C172K aircraft that was conducting sports parachuting operations, was involved in a non-fatal accident following takeoff from Toogoolawah ALA, Qld. On board the aircraft were one pilot and four sports parachutists.

The pilot reported that, following a longer than normal ground roll and takeoff, on reaching about 200 ft AGL, the aircraft's engine failed. He initiated a return to the landing strip and touched down midway along the strip before becoming airborne again. At about 300 m beyond the end of the strip, the aircraft struck powerlines at about 8 m above the ground and collided with the terrain.

The calculated take-off weight of the aircraft exceeded the aircraft manufacturer's MTOW by 155 kg.

The pilot and two of the parachutists received serious injuries and the other two parachutist minor injuries.

The investigation into that occurrence found that the pilot had only a lap-sash seat belt, and that there were no cabin restraint harnesses available for use by the parachutists.

1.18.7 Previous occurrences involving partial engine power loss

As a result of this and a number of other occurrences involving partial engine power loss after takeoff, the ATSB has initiated a safety issues investigation into the circumstances of those occurrences. That investigation will examine the factors that can affect the control of an aircraft following a partial engine power loss after takeoff.

61 International call for immediate assistance.

62 Transport Safety Investigation Regulations 2003, Regulation 2.4(2)(h).

1.19 Other investigation techniques

1.19.1 Camcorder video recovery

Two Sony model DCR-PC109E digital video camera recorders found on board the aircraft following its recovery from the dam were secured by the ATSB. Under ATSB supervision, the information from the recorders was downloaded into a useable audio and visual format. The recovered data included footage of a number of pre-flight briefings, and flights that were carried out sometime prior to the day of the accident. The footage also included the flight prior to the accident flight, and elements of the accident flight itself. As a result of the recorder's submersion in the dam, and the resultant damage to some of the water-soluble tape,[63] the recovered data was limited regarding the accident flight.

An analysis of the recovered data indicated that the recorded flights were carried out by differing pilots, and in both of the company's aircraft. In addition:

- the auxiliary fuel pump sounded 'normal' during priming for engine start on the flight prior to the accident flight
- the position of the fuel pump switch was unable to be determined for any of the flights
- flap was retracted for all of the flights
- the stall warning horn[64] activated momentarily a number of times during all recorded takeoffs, including during rotation from the runway.

Analysis of the video footage of the period spent on the ground prior to the accident flight indicated that the engine RPM was dropping off to a very low value. That RPM could not be quantified. Idling at a low RPM, and the accompanying low turbocharger RPM, has the potential to allow engine oil to leak past the turbocharger compressor seal.[65] That oil could appear as blue smoke coming from the engine's exhaust.

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63 The recorded data on the tape that was wound tightly against the recorder tape reels was largely intact. The remainder of the tape was damaged by water contact.

64 According to the aircraft Owner's Manual, the stall warning horn activates at 5 to 10 mph (4.3 to 8.7 kts) prior to the stall.

65 *Aircraft Turbocharger and Control Reference with Troubleshooting Guide GA 3004*, 15 January 1996, Allied Signal Automotive, Torrance CA, USA.

2 ANALYSIS

2.1 Introduction

The aircraft did not climb as expected following takeoff and witnesses reported black smoke and/or vapour coming from the aircraft. Witness reports, and radar information indicated that the performance of the aircraft following takeoff was consistent with an engine power loss.

Technical examination of the aircraft's engine and testing of its components did not reveal any anomalies with the potential to have individually contributed to the partial power loss to the extent reported by the witnesses. However, the investigation could not discount the potential for a combination of the identified anomalies to have coincided to reduce the available engine power. Additionally, there may have been an anomaly of the engine or its components present during the accident flight that was not apparent during the subsequent disassembly, examination and testing of the engine and its components.

The effect on engine operation of the quality of the fuel used to fuel the aircraft could not be determined because of conflicting information from fuel industry experts.

The significant events and conditions that were identified by the investigation, and their potential to have contributed to the development of the accident, are discussed in the following sections.

2.2 Pre-takeoff considerations

Despite the possible confusion by the owner/operator in regard to the aircraft's maximum take-off weight (MTOW), the aircraft's documentation confirmed that its MTOW was 3,300 lbs (1,496.85 kg). The apparent lack of a weight and balance form for the flight, or of the normal use by the pilot of a pro-forma to calculate the aircraft's take-off weight, may have meant that the pilot was unaware of the overweight operation.

The owner/operator's misunderstanding that the MTOW of the aircraft was 3,600 lbs (1,633 kg) suggested that the aircraft may have routinely been operated above its MTOW since being placed on the Australian aircraft register. The cumulative effect of those operations on the aircraft's structural integrity could not be quantified.

The conflicting witness statements meant that the investigation could not conclusively establish whether the pilot completed a pre-take-off magneto drop-off check prior to the accident flight. In addition, the investigation could not confirm that the pre-take-off magneto drop-off check, if completed, would have identified any pre-take-off anomaly with the engine. In any event, the action by the pilot to conduct the takeoff appeared to indicate that, either there was no problem with the engine at that time, or that any anomaly, if present, remained undetected.

The pilot's decision to conduct a no flaps takeoff was consistent with the guidance received from the aircraft's owner/operator and with the aircraft Owner's Manual.

2.3 Aircraft take-off performance

The configuration of the highly-modified aircraft, and the limited information available on the effects of those modifications, meant that the pilot had to rely upon aircraft operational information that was published for the aircraft prior to the incorporation of the modifications. However, as indicated by the supporting supplemental type certificate supplement for the turbocharged engine, the enhanced engine performance possible from that engine should have ensured aircraft performance equal to or greater than that published for the unmodified aircraft.

The investigation determined that, in isolation, the operation of the aircraft in excess of its published MTOW, while contrary to the regulations and other relevant guidance, probably had no noticeable effect on the aircraft's take-off performance. However, the limited information for the aircraft meant that the effect on the aircraft's controllability and the predictability of the operation, if any, following the suspected engine anomaly, could not be determined.

2.4 Pilot management of a partial engine failure after takeoff

A pilot faced with an engine power loss in a single-engine aircraft at a critical phase of flight such as during takeoff, is confronted with a particularly difficult situation to handle. In the event of a complete engine failure after takeoff (EFATO), it is obvious that there will be no alternative but to force-land the aircraft in the best manner possible. In the event of a partial EFATO, it may appear that sufficient power is available to allow the flight to proceed, to the extent that a safe emergency landing can be carried out. A pilot will typically have only a short period of time in which to assess the situation, and to make a decision, possibly based on limited and uncertain information.

The uncertain availability of reduced or intermittent power may be a significant risk factor in pilot decision-making. The increased and varying number of options confronting a pilot in response to the availability of incomplete engine power increases the complexity of the event, and makes it harder for a pilot to process information and act appropriately in a time-critical situation. This can result in pilots attempting manoeuvres that increase the risk of aerodynamically stalling, and of losing control of an aircraft.

In deciding how to handle a partial EFATO, it is possible that a pilot may compare the almost certain damage and possible injury that would result from a forced landing with the possibility that, if they continue the flight, then they may be able to land without either damage or injury. That is, to the pilot, the decision may seem to be one between an almost certain loss, and the possibility that they can conclude the flight without either damage or injury. The risk is that the pilot may focus on the negative consequences of a forced landing, and therefore try to avoid a forced landing at all costs, even when it would be the safest course of action in the circumstances.

Given that the pilot had not undertaken any recent emergency training, and the lack of any history of the conduct of any practical partial EFATO training, the accident flight was most probably the pilot's first exposure to such a difficult after take-off emergency. His apparent decision to attempt to maintain the aircraft airborne was in response to an unenviable emergency situation to which it was likely that varying responses could be expected from individual pilots. In an instant, the pilot had to assess and act on the potential need for an emergency landing, and/or the possibility that the available engine power may have initially appeared adequate to attempt to manoeuvre the aircraft for a low-level circuit and return to the aircraft landing area, or to another suitable area for landing.

In any event, had the pilot chosen to force-land the aircraft in the area directly ahead of the runway, or in the emergency areas that were reported to have been discussed with the pilot by the owner/operator, there may have been a higher possibility of a successful forced landing. The advice provided to the pilot by the owner/operator during the emergency, although an attempt to assist the pilot, might have distracted the pilot during the consideration of his response to the power loss. The effect could have been that the opportunity to use those landing areas had passed, or that an unintentional right bank developed prior to the impact with the tree.

Although the high number of variables in a partial EFATO event makes it a difficult competency for which to train and assess, the development of a standard emergency procedure would make it easier for pilots to perform appropriately in time-critical situations. It would also allow a pilot to self-brief for a partial EFATO event before commencing a takeoff, an important factor in successfully dealing with such events. Training to ‘cognitively prime’ pilots in how to best handle this difficult emergency could provide a significant safety benefit. Such a program could be simulator-based, allowing pilots to be exposed to realistic scenarios in a safe environment.

2.5 Engine power loss and engine examination

The impact forces, submersion of the aircraft, and recovery of the aircraft from the dam had the potential to alter the condition of the aircraft, the aircraft engine and its component parts. These events hampered the investigation’s ability to draw conclusions regarding the pre-impact engine condition.

The impact damage to the propeller pitch stops, and estimated glide distance from 100 ft above the upwind end of the runway showed that there had been a partial loss of engine power at that time. The disassembly and examination of the aircraft engine, and examination and testing of its components did not reveal any anomalies which would have contributed to the partial EFATO as described by the witnesses.

When tested in the as-found condition, nine of the engine’s 12 spark plugs failed to operate normally. Given that, after cleaning, all of the plugs were retested serviceable, and that engine operation was reported as ‘normal’ during the take-off roll, the investigation concluded that it was most likely that the oil fouling of the plugs was not representative of their pre-impact condition.

The sooting on a number of the spark plugs and engine pistons was consistent with a rich-running engine. That was corroborated by the reports from the witnesses at the ALA of black smoke and/or vapour emanating from the aircraft soon after takeoff. The investigation considered whether the use of cold heat range spark plugs could have resulted in the sooting noted. However, the reason for the rich-running of the engine, and any possible effects on engine performance, if any, could not be established.

The examination of the turbocharger, and examination and testing of the turbocharger components did not reveal any anomaly. In considering the effect of a turbocharger failure during initial climb, the investigation determined that the potential power loss of about 100 hp might have been consistent with the witness reports of a sustained, single action reduction in power. However, the investigation was unable to replicate any like power loss during the test of the turbocharger components on a comparable engine.

The investigation could not discount that a transient anomaly, or a coincidence of less significant anomalies, occurred in the engine or its associated components during the accident flight with the effect of interrupting the engine power to the extent reported by the witnesses. In either case, the transient nature of the anomaly may have rendered it not discoverable during the disassembly, examination and test of the engine and its components.

2.6 Aircraft fuel quality

2.6.1 Introduction

Laboratory examination of the fuel used to fuel the aircraft was negatively affected by a number of factors. However, the recovered fuel sample from the drum that was used to fuel the aircraft was determined by an approved National Association of Testing Authority laboratory to be outside specification and would have affected engine combustion.

The results of that laboratory examination were forwarded to the engine manufacturer, an international investigation agency and a number of industry and aviation fuel experts in an effort to clarify the potential for the quality of the fuel to have affected the engine's performance. The advice received from those companies, agencies and bodies varied, including that there would have been no likely effect on engine performance, that the fuel was unsuitable for use and that there was the risk of blockage of the aircraft's fuel filters.

The disparate opinion amongst the laboratory, fuel quality, industry and investigation experts regarding the results of the fuel tests appeared to indicate that, on balance, it was unlikely that the quality of the fuel negatively affected the engine's performance.

2.6.2 Fuel density

The investigation was unable to conclusively establish the reason for the change in the density of the fuel. One industry expert indicated that the change in density would only have affected engine starting in cold temperatures and not engine performance. As a result of the varying scientific and professional advice, and lack of opinion provided by the engine manufacturer, the investigation could not conclusively determine the potential effect of the change in the density of the fuel on the aircraft engine's performance.

2.6.3 Evaporation

The observed evaporation of the 'light ends' was consistent with the fuel's storage and handling following delivery. The investigation concluded that there was minimal potential for the evaporative changes to the fuel to have negatively affected engine performance.

2.6.4 Existent gum

The lack of any existent gum residue or visible solid matter in the fuel system components that were examined by the investigation indicated that the potential for the fuel's elevated existent gum values to have affected the engine's performance during the takeoff was minimal.

2.6.5 Vaporisation

It was possible that the high ambient temperature, the heat generated as a result of the previous flight, and the heat generated during the prolonged period between the flights with the engine idling combined to significantly increase any heating of the fuel lines in the forward firewall area at the rear of the engine. The result would have been to increase the likelihood for fuel vaporisation to have occurred. The erratic idling that was reported before the takeoff may have been the result of fuel vaporisation.

The owner/operator's report of the normality of the takeoff and climb until 100 ft above ground level suggested that any fuel vaporisation, if present, was insufficient to have affected the takeoff and initial climb. The lack of any physical or witness evidence of engine backfiring or surging, which would have been consistent with a fuel vaporisation problem, suggested that fuel vaporisation was, in isolation, insufficient to have explained the engine power loss.

2.7 Aircraft maintenance issues

The inspection of aircraft airframe items on an annual basis was consistent with the regulatory requirements for an aircraft in the Private category. Although no discrepancies were found with the engine or airframe, that practice did not appear to accord with the conclusion by CASA Airworthiness Bulletin AWB 02-3 Issue 2 that 'the CASA maintenance schedule *does not relax* the manufacturer's maintenance schedule'.

The apparent disparity between the requirements of AWB 02-3 Issue 2 and guidance in CAAP 42B-1(0), and the Schedule 5 maintenance requirements, may lead to confusion among aircraft operators in the Private category regarding required inspection intervals on aircraft airframe items.

2.8 Survivability issues

2.8.1 Structural damage and survivability

An analysis was carried out of the structural damage to the aircraft, the impact signatures, and resulting deceleration forces imposed upon the aircraft in order to evaluate the survivability of the impact and subsequent aircraft exit.

The investigation determined that several conditions may have negatively affected the survivability of the accident.

2.8.2 Briefing of parachutists

The owner/operator reported that briefings on aircraft emergencies were given to Tandem Students and parachutists. However, witness reports and video evidence indicated that the briefings were related to exiting the aircraft and landing after the parachute jump. The provision of a pre-flight brief to parachutists or passengers in an aircraft that includes the actions in the event of an aircraft emergency has been demonstrated to increase survivability in such an emergency.

2.8.3 Use of harnesses/restraints

Parachuting aircraft are configured to permit parachutists with cumbersome equipment easy exit from the aircraft. That normally requires the removal of an aircraft's standard configuration seats and seat belts.

Although there was a less than adequate number of floor restraints available, the non-use of those restraints increased the risk of injury to the parachutists' during impact. Any injury would have decreased the likelihood of their successful exit from the immersed aircraft. Had the cabin occupants been suitably-restrained, there was the possibility that their injuries may have been less severe.

2.8.4 Use of protective equipment

Post-mortem information indicated that several of the occupants suffered head injuries with the potential to have rendered them unconscious.

The Tandem Students were not wearing head protection for the accident flight. The non-use of helmets by the parachutists may have increased the risk of head injuries, and decreased the likelihood of their exit from the submerged aircraft.

2.8.5 Harnessing together of tandem parachutists

A Tandem Master and a Tandem Student were found to be harnessed together when recovered from the aircraft wreckage. Their harnessing together prior to the takeoff would have adversely affected the ability of one or both of them to successfully exit the submerged aircraft.

Parachutists often consider themselves to have a better safety margin than passengers on an aircraft because they have parachutes. However, aircraft emergencies before the parachutist safe release point[66] restrict the options available to parachutists because they are effectively passengers and unable to exit the aircraft until landing.

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66 The lowest altitude from which a parachutist can exit the aircraft and deploy their parachute successfully.

2.9 Organisational issues

2.9.1 Self-administration of sports parachuting

While the self-administration of sports parachuting delegated the oversight of the operation to the Australian Parachute Federation (APF), the funding provided by the regulator for that oversight was reported insufficient to meet the organisation's operating costs. That could be expected to have impacted on the APF's ability to employ or train auditors with the expertise to thoroughly audit all aspects of sports parachuting operations, particularly in regard to aircraft operations and airworthiness aspects. The funding issue could conflict with CASA Notice of Proposed Rulemaking NPRM00007MS comments about self-administering organisations being better able to audit members of the APF than would CASA because of CASA's limited resources.[67]

The APF Area Safety Officer's (ASO) knowledge of parachuting operations was significant, as would be expected for one in that position. However, knowledge of aircraft operations and airworthiness would also be prudent in an individual conducting such audits. In addition, there is the potential that the provision of formal audit training to prospective APF auditors other than just the APF Technical Officer would also lead to the conduct of more robust audits of sports parachute operators.

Previous audits of the operator by APF ASOs did not uncover a number of operational anomalies that were established during this investigation, such as:

- the operation of the aircraft in excess of its MTOW
- insufficient aircraft emergency procedures and performance information available to the pilot in the aircraft's operational documentation
- insufficient information available to the pilot in the aircraft's operational documentation supplement concerning the engine modification and operation of the auxiliary fuel pump
- insufficient numbers of aircraft cabin floor harness attachments for the number of occupants.

It would appear that APF audits of its members were limited in their capacity to assess and address the level of regulatory compliance in regards to aircraft operational and engineering issues. The understanding by the APF of the non-mandatory effect on members' parachuting operations of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* may have influenced the conduct of federation audits against the requirements of those publications.

There was a lack of clear guidance in Schedule A of the Deed of Agreement between the APF and CASA in regard to what constituted an 'applicable' manual. That may have explained the APF's understanding that compliance with the contents of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* was not mandatory. However, it appeared that the manual could be

67 The APF's resources, particularly in relation to the audit of operational and airworthiness aspects of their members' operations, could have been expected to have been more limiting than those affecting CASA's ability to oversight sports parachuting.

considered an applicable manual in accordance with the schedule. The clarification of the intent of Schedule A has the potential to mandate the adoption of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* by APF members. In turn, that would enhance the safety and efficiency of APF members' parachuting operations.

2.9.2 Classification of operations

The classification of sports parachuting operations as a Private category operation, and the belief by the self-administering organisation that it had no actual authority to influence or guide the safe operation of aircraft used for parachuting operations, appeared less than ideal. At the same time, one witness indicated a perception that the level of safety of aircraft engaged in these operations was comparable to regular fare-paying passenger (RPT), Charter or Aerial Work operations.

However, it appears that the operation of sports parachuting aircraft entails a higher potential level of risk than other categories because:

- CASA auditors, who are highly-trained in aircraft operations and engineering matters, do not audit sports parachuting operators on a regular basis as is done for Aerial Work, Charter and RPT operations
- CASA auditors are unlikely to conduct frequent examinations of Private category parachuting aircraft for airworthiness (ramp checks) as is done for Aerial Work, Charter and RPT operations
- sports parachuting pilots are not required to hold more than a Private Pilot (Aeroplane) Licence (PPL(A)), with a Class 2 medical certificate
- sports parachuting pilots are not held to the same standard regarding experience, recency, currency and medical fitness to fly as Aerial Work, Charter and RPT pilots
- sports parachuting aircraft may not be maintained or inspected as frequently as aircraft engaged in Aerial Work, Charter and RPT operations.

2.9.3 Pilot aircraft type transition

In addition to the licence and other requirements held by the pilot, Civil Aviation Order (CAO) 40.1.0 section 4.4 required the pilot to be familiar with the aircraft normal and emergency flight manoeuvres, and to have sufficient training and recent experience on the aircraft type, or on a comparable type. There was no evidence that the pilot received training in the aircraft or in a comparable type before he commenced operations with the operator in 2005, and the pilot's level of familiarity with the Cessna 206 normal and emergency manoeuvres could not be established.

More specifically, the investigation was unable to determine the pilot's exposure to the normal and emergency procedures in the highly-modified Cessna 206 aircraft prior to the conduct by the pilot of parachuting operations in that aircraft. The apparent lack of any formal emergency checklists or procedures in the aircraft operational documentation, may have adversely affected the ability of the owner/operator or the pilot to prepare for those eventualities.

Although there was no evidence that the pilot's lack of training on the aircraft type contributed to the accident, the completion of transition training in a Cessna 206, particularly the modified turbo charged engine variant, or comparable, would have provided a higher level of assurance that the pilot had acquired the appropriate knowledge and skill to safely manage such emergency situations. Implementation of the advice contained in Appendix 1 and 2A of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* by the parachuting owner/operator would have facilitated that assurance.

The investigation considered that the provision of formal guidance regarding compliance with the requirements of CAO 40.1.0 section 4.4 could emphasise the need for a risk-based approach to a pilot's transition to new aircraft types and provide the means for an operator to develop appropriate ground and flight training.

2.9.4 Emergency procedures

The content of the various ab-initio flying training syllabi, and CASA competency standards and assessments, generally addressed the pilot actions following an EFATO.

The absence of specific emergency procedures in the aircraft's operational documentation increased the likelihood of the pilot experiencing difficulty in responding effectively to after take-off emergencies. That meant the pilot would have had to rely upon the emergency actions and procedures learnt from his previous experience in other aircraft types, including the actions in the event of a full power loss during the take-off roll, the takeoff or during flight.

It appeared that the pilot did not receive, nor was there a requirement to receive, practical flying training in response to a partial EFATO. The pilot's exposure to the management of a partial EFATO was limited to a general discussion during his ab-initio training of what actions to take in the event of such an emergency situation.

There was the possibility that, in ideal circumstances, the partial EFATO information provided to the pilot in the flying school syllabus could have been applied to the emergency. However, the time-critical nature of the occurrence, and absence of recent specific practical training, meant that it was unlikely that the pilot would have been able to recall and apply that consideration to the current emergency situation in the time available.

Contrary to advice given in the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual*, the aircraft owner/operator relied upon the newly-engaged pilot's knowledge and skills that were acquired during his commercial pilot licence training, in particular, those skills relating to emergency flight actions and manoeuvres. The risk for the owner/operator was that the pilot may not in fact have retained sufficient recency and/or proficiency to respond appropriately to an emergency.

3 FINDINGS

Contributing safety factors

- At about 100 feet above ground level (AGL) during the climb after takeoff, the engine sustained an apparent partial engine failure after takeoff (EFATO).
- The aircraft impacted a tree about 1,200 m from the end of the runway, resulting in structural damage and departure from controlled flight.
- The aircraft impacted the water in a dam and totally submerged.

Other safety factors

Aircraft operations

- The existing cabin floor restraints were not utilised.
- The aircraft's operational documentation did not include emergency procedures in response to an EFATO.
- The aircraft's operational documentation regarding the use of the auxiliary fuel pump for takeoff was ambiguous.
- The aircraft was being operated in excess of its certified maximum take-off weight (MTOW).
- Two of the parachutists were harnessed together before takeoff, which would have adversely affected their ability to successfully exit the aircraft following its submersion in the dam.

Organisational

- The Civil Aviation Safety Authority (CASA) *Day (VFR) Syllabus – Aeroplanes* did not specifically address the management of a partial EFATO.
- There was a lack of formal guidance in support of the requirement for pilots and operators to comply with Civil Aviation Order 40.1.0 subsection 4.4 (a).
- The Schedule 5 maintenance guidance in Civil Aviation Advisory Publication 42B-1(0) for application to Private category aircraft appeared to conflict with the content of CASA airworthiness bulletin AWB 02-003 Issue 2.
- There was a lack of clear guidance in Schedule A of the Deed of Agreement between the APF and CASA in regard to what constituted an 'applicable' manual.

Aircraft

- There were insufficient floor restraints in the aircraft cabin for each occupant.

Other

- The fuel sample taken from the drum used to refuel the aircraft was tested and found not to conform to the specification for Aviation Gasoline.

- The Tandem Students were not wearing head protection, which increased the risk of their sustaining head injuries.

Other key findings

- The scope of the APF member audits, and the associated auditor skill sets, had the potential to limit the likely identification by APF Area Safety Officers of parachuting aircraft operational and engineering-related hazard.
- It was most likely that the oil fouling of the spark plugs was not representative of their pre-impact condition.
- The source of the rich-running engine, and any possible effects on engine performance, if any, could not be established.
- The reported engine or component anomaly, or its cause, was not apparent during the subsequent disassembly, examination and test of the engine and its components.

4 SAFETY ACTION

The section below details the safety actions communicated to the Australian Transport Safety Bureau (ATSB) during the investigation and in response to the draft investigation report. Where safety action was not forthcoming, or not considered sufficient, the ATSB has issued safety recommendations.

4.1 Australian Parachute Federation

During the course of the investigation, a number of meetings were held between the ATSB and the Australian Parachute Federation (APF) in order to share information regarding safety concerns identified by the investigation. As a result of those meetings, the APF took action to address the following items by way of their 2006 annual conference work groups:

- the conduct of aircraft emergency procedures briefings
- increasing the oversight of the parachuting aircraft during the conduct of APF audits
- consideration of tandem student parachutist ‘hooking up’ procedures, including at what stage of a parachuting flight that might occur
- consideration of single-point restraint requirements, and the need to ensure one restraint per person
- the use of helmets
- Cessna 206 control column protection
- pilot training requirements
- compliance with Civil Aviation Safety Authority (CASA) Airworthiness Directive AD/ENG/4 Amendment 9, specifically in respect of the engine compression check intervals.

In December 2006, the APF amended the APF *Operational Regulations* as follows:

> 5.2.9. Aircraft operated or hired by training organisations for the purpose of conducting parachuting operations must be maintained to a System of Maintenance or a Schedule which satisfies the requirements of Aerial Work, and the Operational Category on the Maintenance Release be Aerial Work or a higher category.

In December 2006, the APF amended the APF *Training Operations Manual* to include a requirement for briefing of Tandem Students on both ground and in-flight emergency procedures.

4.1.1 Use of helmets during sports parachuting operations

Safety issue

Parachutists are not required to utilise helmets while parachuting, thereby increasing their risk of head injury during parachuting and in the event of an aircraft accident. In the event of a head injury during an aircraft accident, their successful exit from an aircraft could be negatively affected.

ATSB safety recommendation 20070027

The Australian Transport Safety Bureau recommends that the Australian Parachute Federation establish the safety benefits of requiring parachutists to wear helmets during parachute operations.

4.1.2 Crash survivability of sports parachuting aircraft

Safety issue

The current configuration of some sports parachuting aircraft may not be conducive to occupant survivability in the event of an aircraft accident.

ATSB safety recommendation 20070028

The Australian Transport Safety Bureau recommends that the Australian Parachute Federation conduct an audit of members' aircraft in order to identify and mitigate potential aircraft equipment-related crash survivability issues.

4.1.3 Compliance with APF operational documentation

Safety Issue

Compliance with the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* was understood by the APF to not be mandatory for members of the federation. However, it appeared that the manual could be considered an applicable manual in accordance with the schedule. The clarification of the intent of Schedule A has the potential to mandate the adoption of the APF *Jump Pilot's Handbook & Aircraft Operation Procedures Manual* by APF members. In turn, that would enhance the safety and efficiency of APF members' parachuting operations.

ATSB safety recommendation 20070029

The Australian Transport Safety Bureau recommends that the Australian Parachute Federation (APF) clarify with the Civil Aviation Safety Authority (CASA) the intent of Schedule A of the Deed of Agreement between the APF and CASA as it affects compliance by APF members with APF documentation.

4.2 Civil Aviation Safety Authority

4.2.1 Engine airworthiness directives

During the course of the investigation, a number of meetings were held between the ATSB and CASA. As a result of those meetings, CASA acted to amend AD/ENG/4 Amendment 9 to further clarify the compliance intervals that were outlined in Appendix A of the directive. Consequently, effective 26 October 2006, Amendment 10 of the directive was issued.

4.2.2 Airworthiness bulletins and advisories

Safety issue

Currently, Civil Aviation Advisory Publication (CAAP) 42B-1(0) and Airworthiness Bulletin AWB 02-003 Issue 2, are ambiguous regarding required inspection intervals for Private category aircraft airframe items. This may result in the items being operated past the specified aircraft manufacturer's inspection interval.

ATSB safety recommendation 20070030

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review Civil Aviation Advisory Publication (CAAP) 42B-1(0) and Airworthiness Bulletin AWB 02-003 Issue 2, in order to clearly define the required inspection intervals affecting Private category aircraft airframe items.

4.2.3 Harnessing together of tandem parachutists

Safety issue

The practice of harnessing tandem parachutists together during the take-off roll and climb out of the aircraft could negatively impact occupants' survivability in the event of an aircraft-related emergency.

ATSB safety recommendation 20070031

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority advise all self-administered sports parachuting organisations (other than the Australian Parachute Federation) to include instructions in their *Training Operations Manual*, or equivalent, to define when tandem parachutists should be harnessed together, with a view to optimising the likelihood of parachutists successfully exiting an aircraft in the event of an aircraft emergency, including when below the safe release point.

4.2.4 Crash survivability of sports parachuting aircraft

Safety issue

The current configuration of some sports parachuting aircraft may not be conducive to occupant survivability in the event of an aircraft accident.

ATSB safety recommendation 20070032

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority direct that non-Australian Parachute Federation sports parachuting organisations conduct a review of their aircraft in order to identify and mitigate potential aircraft equipment-related crash survivability issues.

4.3 US Federal Aviation Administration

4.3.1 Aircraft documentation supplement

Safety issue

The current US Federal Aviation Administration approved Supplemental Type Certificate SA2123NM supplemental operational documentation relating to usage of the auxiliary fuel pump in the Cessna U206 is ambiguous regarding the operation of the pump for takeoff. That ambiguity could result in the inappropriate use of the pump and subsequent engine operational issues.

ATSB safety recommendation 20070033

The Australian Transport Safety Bureau recommends that the US Federal Aviation Administration require Aeromods Incorporated to amend the aircraft operational documentation supplement for the Cessna U206 aircraft relating to Supplemental Type Certificate SA2123NM, to include information on the recommended use of the auxiliary fuel pump for takeoff.

4.4 Australian Transport Safety Bureau

4.4.1 Engine power loss after takeoff

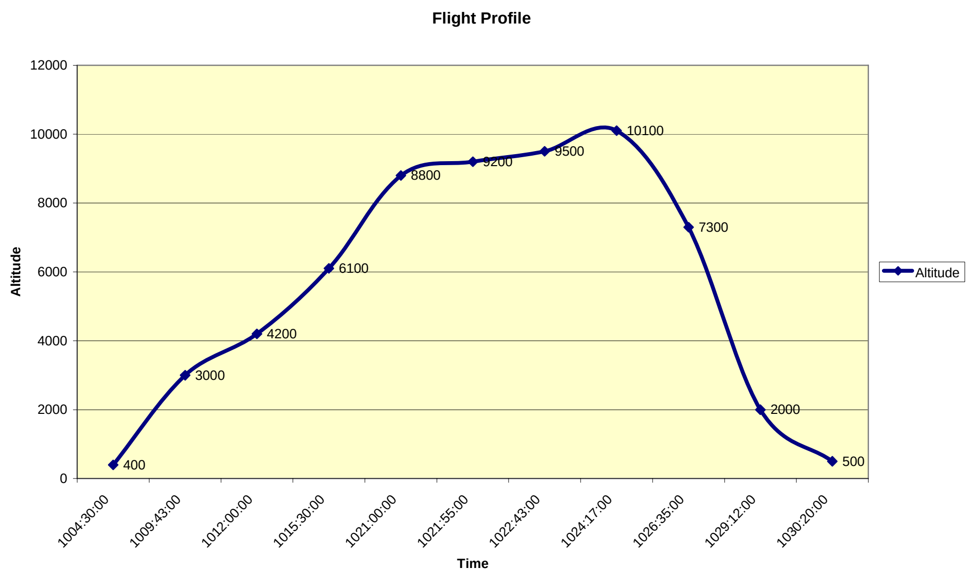
As part of its investigation into the circumstances of a partial engine power loss involving an amateur-built Lancair 360 aircraft, registration VH-ZNZ, the ATSB examined the aircraft normal and emergency familiarity requirements of Civil Aviation Order (CAO) 40.1.0. The results of that examination and a discussion of the ensuing safety action are included in ATSB Aviation Occurrence Report 200601688 at www.atsb.gov.au .

The ATSB has initiated a special investigation (ATSB investigation number 200603722) as a result of this and other occurrences, including the Cherokee Six accident at Hamilton Island on 26 September 2002 (ATSB investigation number 200204328). The bureau will investigate the factors that affect loss of control following engine power loss (including partial power loss) after takeoff.

APPENDIX A RADAR DATA

Radar information for the first flight was sourced from Airservices Australia and the nearby Royal Australian Air Force (RAAF) Base Amberley.[68] The recorded information indicated that the aircraft departed the Aircraft Landing Area (ALA) at Willowbank for the first flight at 1004:30. The aircraft climbed to Flight Level 110[69] for the parachutists' exit before descending back towards the ALA (Figure A-1). A tabulated representation of the radar data is at Table A-1.

Figure A-1: Flight profile for the first flight



68 There was the potential for the aircraft's low altitude and its distance from the radar head to have adversely affected the accuracy of the radar information.

69 Or 11,000 ft Above Mean Sea Level.

Table A-1: Radar data

Time	Altitude in feet mean sea level at radar contact	Note
1004:30	At 400 ft above and north-west of the ALA in a left turn.	
1009:43	At 3,000 ft.	Climbing at about 500 feet per minute (ft/min)
1012:00	At 4,200 ft.	Climbing at about 300 ft/min.
1015:30	At 6,100 ft.	Climbing at about 550 ft/min.
1021:00	At 8,800 ft.	Climbing at about 450 ft/min.
1021:55	At 9,200 ft.	Climbing at about 400 ft/min.
1022:43	At 9,500 ft	Climbing at about 400 ft/min.
1024:17	At 10,100 ft.	Climbing at about 400 ft/min.
1026:35	At 7,300 ft.	Descending at about 1,200 ft/min.
1029:12	At 2,000 ft 3 NM north-west of ALA.	Descending at about 1,890 ft/min.
1029:50	At 1,000 ft 2 NM north-west of ALA.	Descending at about 500 ft/min.
1030:20	At 500 ft 1.5 NM north-west of ALA.	Descending at about 500 ft/min.
1030:35	Radar contact lost at 400 ft due to ground shielding.	

APPENDIX B AVGAS CHARACTERISTICS, TESTING AND STORAGE

A fuel's ability to vaporise or change from liquid to vapour is referred to as its volatility. In Aviation Gasoline (Avgas), the distillation characteristics, together with the fuels vapour pressure, define and control:

- the ease of starting an engine
- warm-up requirements
- acceleration characteristics
- the risk of vapour lock
- crankcase oil dilution
- in part, the fuel economy and risk of sustaining carburettor icing.

Vapour lock occurs when excessive Avgas vapour accumulates somewhere in the fuel system such as the fuel pump, fuel line, fuel injectors or carburettor and interrupts the fuel supply to the engine. When the fuel supply is reduced as a result of any interruption in its flow, the fuel/air ratio becomes too lean, which may result in:

- loss of power
- knocking
- surging
- backfiring.

The tendency of a fuel to vaporise is also characterized by determining a series of temperatures at which various percentages of the fuel have evaporated (boiling temperatures), as described in American Society for Testing and Materials (ASTM) Standard D910-04a, *Standard Specification for Aviation Gasolines*. The temperatures at which 10 %, 50 %, and 90 % evaporation rates occur are often used to characterize the volatility of Avgas.

The Avgas manufacturer provided the investigation with a copy of the report on its own testing of the fuel that was completed on 10 March 2005, following the production of the fuel by the refinery. That report was compared with the results of the fuel tests that were carried out on 25 January 2006 by the National Association of Testing Authority (NATA)-approved laboratory. The results of that comparison are listed at Table B-1, with those parameters found outside the stipulated requirements highlighted in red.

Table B-1: Fuel test report comparison[70]

Test item	Fuel manufacturer test results - 10 March 2005	Approved testing authority results - 25 January 2006	Comments/requirements
Density at 15 degrees C	0.6911 kg/l	0.7242 kg/l	0.0331 kg/l difference, suggested limit was 0.0030 kg/l per movement.[71]
Initial boiling point	34 degrees C	51.4 degrees C	
Distillation range 10 % evaporated	68 degrees C	87.0 degrees C	Maximum 75 - to guard against carburettor icing and/or vapour lock.
Distillation range 40 % evaporated	95 degrees C	100.5 degrees C	Minimum 75 - to control density for fuel system metering characteristics.
Distillation range 50 % evaporated	99 degrees C	102.4 degrees C	Maximum 105 - to ensure average volatility/adequate evaporation in the induction system (prevent power loss).
Distillation range 90 % evaporated	106 degrees C	111.1 degrees C	Maximum 135 - to prevent too much fuel to the cylinders (power loss).
Final boiling point	118 degrees C	132.4 degrees C	Maximum 170 - to prevent unequal distribution of the fuel to the cylinders, spark plug fouling/power loss.
Sum of 10 % - 50 % boiling point	168 degrees C	189 degrees C	Minimum 135
Residual volume %	1.1	1.0	Maximum 1.5
Knock rating	108.5	107.7	Minimum 99.5
Existent gum	1 mg/100 ml	5 mg/100 ml	Maximum 3 mg/100 ml[72]

The NATA-approved laboratory did not test for specific energy and lead content. The determination of a fuel's specific energy relies on the fuel's density, distillation and aromatic data. As the 10 % evaporation distillation test failed at that laboratory, the specific energy of the fuel sample was not able to be checked. The laboratory

70 All maximum or minimum limits are as per the requirements of ASTM Standard D910-04a unless noted.

71 The drums were moved twice between the manufacturer of the fuel and its use at the Willowbank aircraft landing area.

72 Requirements per ASTM D381.

also advised that, since the test of the fuel sample had failed on its distillation range and existent gum, there was no need to test for lead content.

The proper storage of Avgas does not change the bulk properties or most of the performance characteristics of that fuel (excluding the characteristics that are affected by the presence of excessive existent gum). An article from a major petroleum producer cites the following:[73]

> For example, storage does not change the octane or energy content of the fuel. However, those properties will change if the means of storage contributes to any evaporative loss from the fuel. The evaporation of the light ends of Avgas decreases its octane index and increases its energy content.

The proper storage of drummed fuel stock would include maintaining the seal on the fuel drum when not in use.

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73 *Longer-Term Storage of Gasoline,* Chevron USA Inc., 2002-2006, San Ramon, CA, USA.

APPENDIX C MEDIA RELEASE

Final ATSB investigation report on 5-fatality parachuting accident

The ATSB's final investigation report into an aircraft accident near Willowbank in Queensland last year, resulting in five deceased persons and two seriously injured survivors, found that the aircraft's performance prior to impacting a large tree and crashing into a dam was consistent with an engine power loss.

The Australian Transport Safety Bureau report states that technical examination of the Cessna 206's engine and its associated components did not reveal anomalies with the potential to have individually contributed to the partial engine power loss and loss of climb performance about 100 feet above ground level.

The investigation could not discount the potential that a number of less significant anomalies that were identified, may have coincided on 2 January 2006 to reduce the available engine power.

Laboratory examination of the fuel used in the aircraft was found to be outside specification. However, fuel quality experts that were consulted during the investigation indicated that there was minimal potential for the quality of the fuel to have negatively affected the engine's performance.

The investigation determined that the aircraft was being operated in an overweight condition, but because of limitations in the available performance information on the highly-modified aircraft, the effect of that overloading could not be quantified.

The report outlines safety action taken by the Australian Parachute Federation (APF) and contains seven safety recommendations to the APF, the Civil Aviation Safety Authority and the US Federal Aviation Administration to enhance future safety.

As a result of this and a number of other accidents involving partial engine power loss, the ATSB has initiated a special investigation into the factors that affect loss of control following engine power loss (including partial power loss) after takeoff.