Loss of control and collision with terrain involving Diamond DA40, VH-YPQ

1 km south of Port Macquarie Airport, New South Wales, on 8 September 2017

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Addendum

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Safety summary

What happened

On the evening of 8 September 2017, an instructor and student from the Australian International Aviation College were preparing to conduct night training circuits at Port Macquarie Airport, New South Wales, in a Diamond DA40 NG aircraft, registered VH-YPQ. As it was the student's first time conducting night circuits, once lined up on the runway, the instructor took the aircraft controls for the take-off.

After take-off, as the aircraft climbed, the instructor heard and felt the engine and propeller surging. Propeller speed and engine power fluctuations occurred from about 200 ft above the runway and increased in amplitude as the aircraft climbed to about 400 ft. Recorded data showed that the engine was producing full power despite the fluctuations. The instructor interpreted the fluctuations as a partial engine power loss and commenced a left turn, aiming to return and land on the runway in the opposite direction to the take-off. The instructor had considered landing straight ahead but assessed that there was power available to turn and that they would be unable to see and avoid trees or to be sure to land in a suitable clearing ahead.

In the 10 seconds that the instructor was assessing and making decisions about a perceived partial power loss, the airspeed reduced from 75 to 69 kt due to the aircraft's nose-up pitch attitude. Then, at the same time as commencing the turn back towards the runway, the instructor reduced engine power to 30 per cent, while maintaining a nose-up attitude, and the airspeed reduced rapidly.

During the turn, the aircraft aerodynamically stalled resulting in a loss of control. Although the aircraft pitched down and the instructor subsequently increased the power, control was not regained. The aircraft descended and collided with trees, coming to rest inverted. The student and instructor were seriously injured, and the aircraft was destroyed.

What the ATSB found

After reducing the power, the instructor did not maintain adequate airspeed during the turn. This resulted in an aerodynamic stall, loss of control and collision with terrain.

The aircraft manufacturer could not determine the reason for the engine speed fluctuations. Propeller speed fluctuations had occurred in other aircraft, and either resolved without pilot input or by moving the power lever.

Although not contributing to this occurrence, in the course of the investigation it was found that engine cylinder heads for the aircraft type were cracking prior to reaching their service life.

What's been done as a result

After the accident, the Australian International Aviation College:

- added a requirement to the take-off safety briefing to include setting partial power safety speed in the event of a partial power loss
- conducted partial engine failure after take-off training for instructors and students, comprising pre-flight planning and self-briefing, ground training, and flight training
- performed flight simulator tests for partial engine failure after take-off conditions in each single engine aircraft model operated by the flying school to assess the power required to maintain altitude in the event of a partial power loss.

Safety message

In this accident, the instructor perceived there was a partial power loss. The ATSB research report *Avoidable Accidents No. 3 – Managing partial power loss after take-off in single-engine aircraft* provides information to assist pilots maintain aircraft control in the event of an emergency or abnormal situation after take-off. The report prescribed initial actions to be considered including:

- Lower the nose to maintain the glide speed of the aircraft. If turning is conducted, keep in mind an increased bank angle will increase the stall speed of the aircraft.
- Maintain glide speed and assess whether the aircraft is maintaining, gaining or losing height to gauge current aircraft performance.
- Fly the aircraft to make a landing, given the aircraft's height and performance, and the pre-planned routes for the scenario.

Contents

The occurrence

On the evening of 8 September 2017, an instructor and student from the Australian International Aviation College (AIAC) planned to conduct night circuits at Port Macquarie Airport, New South Wales, in a Diamond DA40 NG aircraft, registered VH-YPQ. The student taxied the aircraft to runway 21, then, as it would be the student's first time conducting circuits at night, the instructor took over the controls for the take-off.

It was dark and the moon had just risen above the horizon when the aircraft commenced the take-off roll at 1957:12 Eastern Standard Time[1] (Figure 1). During the initial climb, about 20 seconds after lift-off, while still above the runway and passing 200 ft, the instructor noticed changes in the engine sound, felt acceleration changes and saw fluctuating indications on engine load and propeller RPM gauges, despite maintaining the power lever in the fully forward maximum power position.

The fluctuations increased over the next 20 seconds as the aircraft climbed. During that time, the aircraft pitched up to about 8 degrees, consistent with the normal attitude for initial climb and to achieve the best rate of climb speed, and the vertical speed increased to more than 900 ft per minute. The instructor assessed that the fluctuations were due to an engine problem and considered the options for landing.

The instructor considered landing straight ahead, however, while there were two fields that may have been suitable for a landing, they were not visible at night and the instructor was concerned the aircraft may land beyond the field in trees. While still above the runway and climbing through about 400 ft, and as the engine was still producing power, the instructor elected to conduct a left turn, aiming to land on the reciprocal runway, 03. The left turn commenced at 1957:58 and 1 second later, the instructor moved the power lever aft, reducing the engine load to about 30 per cent, where it remained for the next 10 seconds.

At 1958:01, the instructor broadcast on the common traffic advisory frequency[2] that they had engine problems and would land on 'runway 21,' although actually intending to land on runway 03.

The instructor recalled concentrating on trying to maintain adequate speed—not 'nosing up too much getting closer to the stall speed or nosing down and not being able to make the runway.' As the aircraft turned and the runway came into sight, the instructor assessed that the aircraft was not going to make it back as the runway was too far away and the airspeed was too slow. The instructor also recalled looking down and all that could be seen was the trees.

The instructor made changes with the power lever to see if the fluctuation issue improved. Engine data showed the power lever position moving to maximum power for 3 seconds, back to 25 per cent engine load for less than 2 seconds then to full power for the final 4 seconds. The instructor also noticed signs of an impending aerodynamic stall[3]—buffeting and sloppy controls, followed by a left wing drop. The aircraft entered uncontrolled flight, descended rapidly and impacted trees and terrain.

The aircraft collided with trees about 18 seconds after the left turn commenced, 325 m abeam the runway 03 threshold, and came to rest inverted (Figure 1). Both occupants were seriously injured and the aircraft was destroyed.

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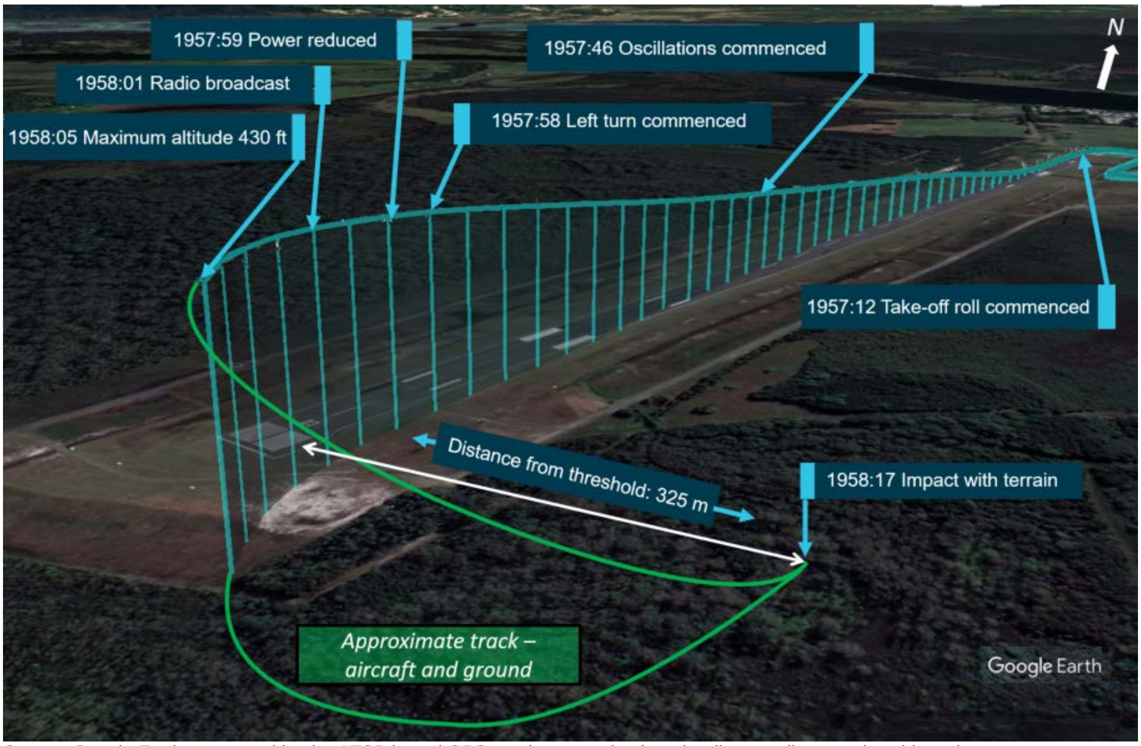
1 Eastern Standard Time (EST): Coordinated Universal Time (UTC) + 10 hours.

2 Common Traffic Advisory Frequency (CTAF): A designated frequency on which pilots make positional broadcasts when operating in the vicinity of a non-controlled aerodrome or within a Broadcast Area.

3 Aerodynamic stall: occurs when airflow separates from the wing's upper surface and becomes turbulent. A stall occurs at high angles of attack, typically 16˚ to 18˚, and results in reduced lift.

Figure 1: Aircraft flight path and key events



Source: Google Earth, annotated by the ATSB based GPS, engine control unit and radio recordings, and accident site assessment

Context

Operational information

Aircraft operator

The Australian International Aviation College (AIAC) was a flight training and charter organisation based in Port Macquarie, New South Wales. It conducted flight training for up to 90 Australian and international students, from initial training through to commercial pilot licence, and single and multi-engine aeroplane, instructor and instrument flight ratings. The AIAC operated a fleet of Diamond aircraft and an approved flight training device (simulator).

Instructor qualifications and experience

The instructor:

- held a commercial aeroplane pilot licence issued in April 2014
- held a valid Class 1 medical certificate issued in March 2017 with the restriction that distance vision correction must be worn
- held instrument and instructor ratings
- met the recency requirements for the planned night circuits
- satisfactorily completed flight crew emergency procedures training at AIAC in February 2017
- completed a flight instructor standardisation and proficiency check in January 2017 including attaining a Grade 2 instructor rating
- obtained an instrument rating training endorsement for single-engine aircraft below 5,700 kg in June 2017
- had accrued 1,160.9 hours total aeronautical experience, including 86.2 hours in command at night (73.7 in single-engine aircraft and 12.5 in multi-engine aircraft) and 680.7 hours instructing in single-engine aircraft
- logged 124 hours in the DA40 NG and DA42 NG (diesel-engine) aircraft in 2017.

Student pilot experience

The student pilot commenced flight training at AIAC in March 2017 and completed a recreational pilot licence test on 24 May 2017. The student had accrued a total of 85.4 hours flying time, of which 19.8 were as pilot in command.

Weather and environmental information

The weather was fine with light winds and little to no cloud. The time of the occurrence was past astronomical twilight and the nearly-full moon was just above the horizon. The township of Port Macquarie provided some light and a horizon reference to the east but the ground near the airport was dark apart from a few scattered dwellings. The instructor reported that the moon and town lights were below their field of vision during the initial stage of the flight.

The Bureau of Meteorology recorded the wind strength and direction at Port Macquarie Airport at 1-minute intervals. Nil wind was recorded at the aerodrome for the 20-minute period encompassing the short duration of the accident flight. Although the aircraft took off with nil wind at runway level, according to GPS data, it encountered an increasing tailwind of up to 8 kt during the climb and turn. As the aircraft climbed, the temperature increased from 12.5 °C at runway level to 16.5 °C at the maximum height reached.

Aircraft information

General information

The Diamond Aircraft Industries DA40 NG aircraft is a four-seat, low-wing, T-tail aircraft constructed from composite materials. The aircraft is factory-fitted with a turbo charged four-cylinder diesel Austro E4 engine, operated on aviation turbine fuel, and a three-bladed wooden composite variable-pitch MT-Propeller MTV-6-R propeller.

VH-YPQ

The aircraft serial number 40.N292 was manufactured in 2015 and placed on the Australian register in early 2016 as VH-YPQ (Figure 2).

The aircraft had a current certificate of airworthiness and maintenance release[4] with no outstanding maintenance or defects notated. The aircraft had a total time in service of about 906 flight hours before the accident flight. The logbook statement indicated that the aircraft was maintained in accordance with the Diamond Aircraft DA40 NG maintenance schedule. It was equipped and certified for operation under the instrument flight rules[5] and was maintained and operated in the Charter Class B category.

Figure 2: VH-YPQ

Source: Simon Coats

[4] Maintenance release: an official document, issued by an authorised person as described in Regulations, which is required to be carried on an aircraft as an ongoing record of its time in service (TIS) and airworthiness status. Subject to conditions, a maintenance release is valid for a set period, nominally 100 hours TIS or 12 months from issue.

[5] Instrument flight rules (IFR): a set of regulations that permit the pilot to operate an aircraft to operate in instrument meteorological conditions (IMC), which have much lower weather minimums than visual flight rules (VFR). Procedures and training are significantly more complex as a pilot must demonstrate competency in IMC conditions while controlling the aircraft solely by reference to instruments. IFR-capable aircraft have greater equipment and maintenance requirements.

System description and information

Engine and propeller control

The constant speed propeller has a governor, which changes the blade pitch to maintain a constant RPM, regardless of the amount of engine torque, airspeed or altitude. The aircraft's maximum take-off propeller speed was 2,300 RPM.

The engine and propeller were controlled by a single electronic engine control unit (ECU) with dual-redundant hardware that performed continual self-testing. A single power lever provided command input via two separate channels to the ECU and the ECU controlled the engine fuel injection to match the power lever command. For redundancy, there was a cockpit switch for selecting ECU channels in case of a fault.

Integrated instrument and avionics system

VH-YPQ was factory-fitted with a Garmin G1000 integrated avionics system, which consolidated all communication, navigation, surveillance, automatic flight control system, primary flight instrumentation, engine indication, and annunciation systems on two liquid crystal display units (DU) and an audio panel. The two DUs consisted of a primary flight display on the left (student pilot side), and the multi-function display (MFD) on the right (instructor side). The audio panel was located between the two display units. The aircraft was not fitted with the optional terrain awareness and warning system.

Recording capability

The G1000 avionics system was capable of storing up to 60 flight and engine parameters on a data memory card. Data was logged to a new file that was created each time the MFD was powered on. All parameters were recorded at 1-second intervals. The electronic ECU was capable of storing significant amount of engine data and had a backup battery for redundancy.

Aircraft weight and balance

The aircraft was assessed as being within the weight and balance limits throughout the accident flight, with a take-off weight of 1,143 kg.

Relevant speeds

Best glide speed is used to achieve the greatest distance for the height in case of engine failure. At any airspeed faster or slower than the best glide speed, the aircraft will travel less distance over the ground.

According to the *Airplane Flight Manual*, the best glide speed ('airspeed for best glide angle') for the aircraft with flaps up was 88 kt, and 'airspeed for emergency landing' with engine off and flaps in the take-off position was 78 kt.

The best rate of climb speed (V_Y) was 72 kt with take-off flaps set. Therefore, in the event of a power loss when in the climb at V_Y, the pilot would need to lower the aircraft nose to achieve the best glide speed, and the airspeed for emergency landing.

Accident site examination

The aircraft initially impacted trees causing significant structural damage to the wings, after which it impacted terrain inverted and at a nose-down angle of about 25°. The cockpit was partially collapsed, with the airframe resting on the instrument panel and seat backs. Both wings and the tail detached during the impact sequence (Figure 3).

Figure 3: Wreckage of VH-YPQ, which was partially disturbed during rescue of the occupants

Source: ATSB

Examination of the aircraft wreckage found no pre-existing airframe issues. The flap actuator was found in the take-off position. The aircraft's fuel tanks were breached and there was evidence of fuel spillage. A small quantity of fuel was drained from the tanks and matched the characteristics of aviation turbine fuel. It tested negative to water content. Previous fuel records and the engine data both indicated that there was sufficient fuel on board the aircraft for the intended flight.

The engine was examined externally with the cowls removed and there was no noted fluid leakage or pre-impact defects identified. During removal of the engine and control parts, no defects were identified. The propeller blades were fragmented, consistent with the engine driving the propeller when the aircraft impacted with terrain. The propeller and propeller control unit were removed from the aircraft for function testing.

The G1000 avionics unit data memory card and electronic ECU memory module were removed from the aircraft and transported to the ATSB technical facilities for examination and download.

Component testing

Propeller hub and propeller control

The propeller hub and controller were sent to the propeller manufacturer for testing. No faults were identified during function testing or visual examination.

Manufacturer data analysis

The aircraft and engine manufacturers analysed the recorded data and could not determine the cause of the propeller speed fluctuations. The engine manufacturer reported that

> the oscillation was still in a normal range and did neither create an ECU warning nor a reduction of power. There are lots of possible reasons for RPM oscillation but in this case they were not engine related.

They advised that at the propeller speeds that were recorded during the last 40 seconds before the accident, the propeller should have been sitting on the fine pitch limit stops. Whether the propeller was at full fine pitch during the fluctuations could not be determined as the actual propeller blade pitch angle was not sensed or recorded. Fuel injection quantity and timing were not recorded on the ECU, but fuel quantity and fuel flow were recorded on the Garmin system. In the recorded Garmin data, the fuel flow rate increased and decreased in step with the propeller RPM and in response to the changes in power lever position.

Assessment of possible causes of RPM fluctuations

Figure 4 is an extract from the aircraft maintenance manual, which provided troubleshooting for fluctuating propeller RPM from a list of possible causes.

Figure 4: Extract from the aircraft maintenance manual

Trouble	Possible Cause	Repair
Propeller RPM fluctuating.	Engine gearbox oil level low.	Replenish gearbox oil level. Refer to Chapter 72.
	Engine gearbox oil contaminated.	Replace engine gearbox oil. Refer to Chapter 72.
	Electrical connection between engine EECU system and governor.	Do a continuity check of the wiring between the EECU system and the governor. Replace/repair faulty wiring. Refer to Chapter 92 for the wiring diagrams.
	Governor defective.	Replace the governor.

Source: Diamond Aircraft

From the listed possible causes, the post-accident inspection found the following.

- The engine gearbox oil level was not measured, but the ATSB assessed its quantity as unremarkable. There was no sign of an oil leak on or around the engine that would have depleted the oil quantity.
- No defects or metal debris were identified in the gearbox oil filter or magnetic chip detector.
- No faults were identified with the electrical wiring harness.
- The propeller governor was satisfactorily tested by the propeller manufacturer and all measurements and adjustments were found to be within tolerances.

Recorded data

Recorded data from the G1000 memory card and ECU memory module was analysed. The data from the two sources correlated to within about 2 seconds. Selected data is displayed in the graph in Figure 5. In this graph, the altitude, airspeed, ground speed, pitch and roll were retrieved from the G1000 and the propeller speed (RPM), power lever position and engine load were from the ECU. The altitude is accurate to within 30 ft.

Propeller speed fluctuations

According to the data, the aircraft lifted off at 1957:26. Twenty seconds later, the aircraft climbed through 200 ft at an airspeed of 74 kt. The propeller RPM began fluctuating about 10 RPM per second above and below 2,250 RPM. The power lever remained constant in the maximum power position and the engine load made small fluctuations around 98.5 per cent power, consistent with the RPM fluctuations.

The RPM and engine load fluctuations increased in amplitude as the aircraft climbed. The engine manufacturer advised that fluctuations up to ± 20 RPM were acceptable, although no normal operating range of fluctuations was defined. That ‘acceptable’ change in amplitude was first exceeded at 1957:47, 218 ft above the runway.

The fluctuations continued to increase in amplitude over the next 10 seconds to a maximum variation of 73 RPM in 1 second (which equated to about 3 per cent of an average 2,250 RPM) as the aircraft climbed to 361 ft.

Figure 5: Plot of selected engine and aircraft GPS data parameters

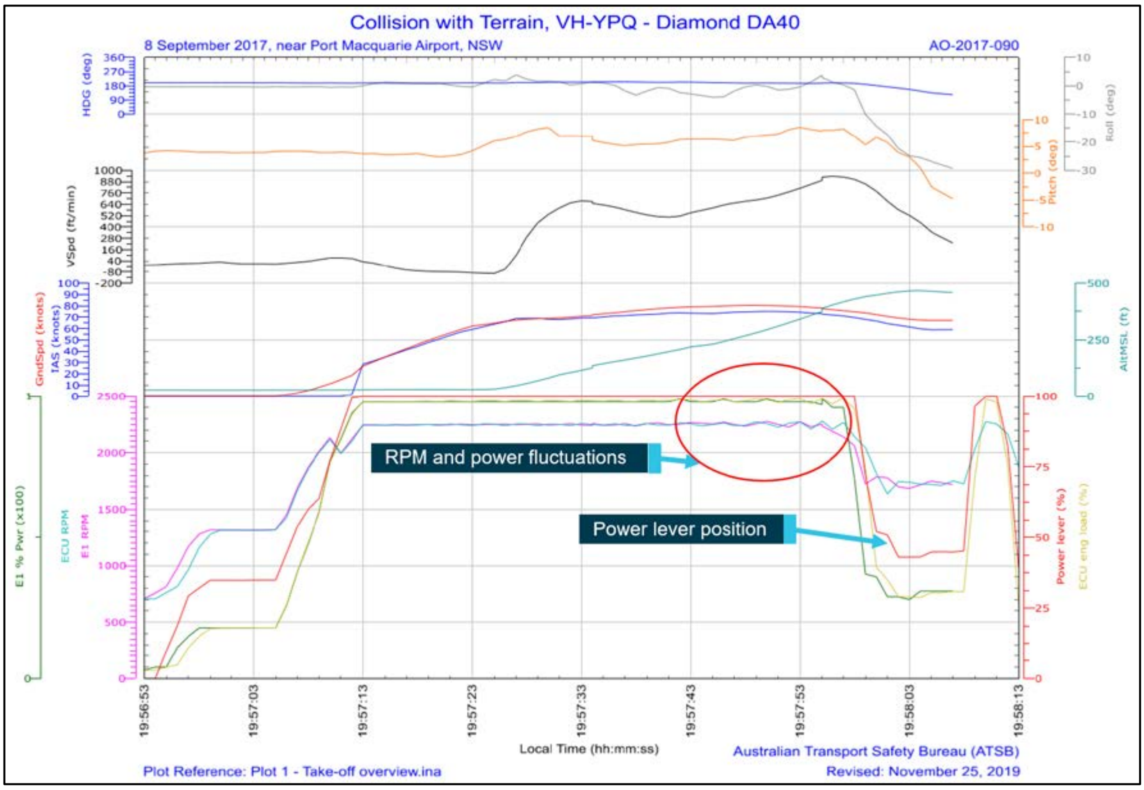


Image shows increasing fluctuations in propeller RPM and engine load, followed by a sequence of power lever movements with corresponding RPM and load variations.
Source: Austro Engine and Garmin 1000 data analysed by ATSB

Manoeuvring

As the aircraft climbed through 300 ft above the runway, the airspeed reached 75 kt, which was the maximum achieved on the flight. Over the next 10 seconds the airspeed decreased to 69 kt as the pilot maintained a pitch-up attitude of about 8 degrees, and the aircraft climbed at a rate of up to 938 ft per minute. After reaching a peak pitch-up of 8.3 degrees and still climbing at 928 ft per minute, the pilot started to reduce the aircraft’s pitch attitude.

At 1957:58, as the aircraft was climbing at 904 ft per minute through 389 ft, the airspeed had reduced to 69 kt and a left bank (roll) commenced. At that time, the aircraft was still pitched up about 7 degrees. One second later, the power lever was moved to a lower power setting that corresponded with an engine load reduction to about 30 per cent and the propeller speed decreased to about 1,750 RPM.

Over the next 4 seconds, the aircraft continued to climb albeit at a reducing rate, the airspeed continued to decrease and the angle of bank increased. At 1958:05, the maximum altitude of about 430 ft was reached, airspeed was 59 kt and the aircraft nose then pitched down. The aircraft then started to descend. The last Garmin data recorded was at 1958:07 with the airspeed at 59 kt (which it had been for 4 seconds), a 29 degree angle of bank and a propeller speed of 1,720 RPM.

The ECU data indicated that at 1958:09, the power lever was moved forward for 3 seconds, back for 2 seconds then forward for the final 4 seconds and the engine load increased and decreased correspondingly. The last recorded ECU data at 1958:17 was consistent with the aircraft colliding with terrain.

Uncontrolled descent

The G1000 memory card was missing approximately the last 12 seconds of data. This was likely due to the unit's power being cut abnormally during the accident sequence, instead of a normal system shutdown. Consequently the aircraft's final descent and flight path were not recorded. Based on alignment between the accident site location, direction of travel and the final recorded position, the left turn and steep descent continued until impact. The aircraft descended from 428 ft in 10 seconds, which was an average descent rate of 2,568 ft per minute.

The stalling speed with power off (V_S) for the aircraft weight and take-off flap was 58 kt indicated airspeed (KIAS) at 0° angle of bank, and 62 KIAS at 30° angle of bank. The last recorded airspeed was 59 KIAS when the bank angle was about 30°, below the power-off stalling speed.

No ECU faults were recorded.

Aircraft performance testing

Following the accident, the AIAC conducted in-flight performance testing of partial engine failure scenarios. With an aircraft weight of 1,156 kg (similar to the accident flight), a DA40 NG aircraft maintained level performance (occasional 100 ft per minute climb) and airspeed at a safe margin above the stalling speed, with 30 per cent power, flaps in the take-off position and glide attitude set, including in a turn.

Regulatory requirements

The Civil Aviation Safety Regulations (CASR) Part 61 Manual of Standards (MOS) detailed competency standards for all flight crew qualifications as well as proficiency checks, flight reviews and flight test standards.

Competencies specified for private and commercial aeroplane pilot licence and single-engine aeroplane class ratings included managing a simulated engine failure after take-off in the circuit area, but not partial power loss. Underpinning knowledge of the competencies included 'engine failure scenarios and procedures for partial and complete power loss.'

Competencies specified for the night visual flight rules (NVFR) rating included skills and knowledge required for managing emergency situations at night including that '(in simulated conditions) aircraft control is maintained.' The Airservices Australia Aeronautical Information Publication En Route 1.1 did not permit simulated engine failures to be conducted below 1,500 ft at night in the circuit area.

The Part 61 MOS Unit A5 – *Advanced stalling*, included that a pilot is required to demonstrate recovery from a stall with full or partial loss of engine power. The Civil Aviation Safety Authority's (CASA's) *Flight instructor manual* stated:

> Before carrying out any advanced stalling exercise it is important that sufficient height is gained to ensure recovery by 3,000 feet above ground level…

CASA advised that competency in this standard 'should mitigate [against the] risk of partial power loss in the take-off.'

Operator procedures

Managing partial power loss after take-off

The AIAC syllabus of training was in line with the Part 61 MOS requirements and did not reference partial engine failure after take-off or in the circuit. However, the AIAC standard operating procedures included expanded procedures for engine failure immediately after take-off with insufficient/partial engine power. It listed the following considerations in managing a partial power loss after take-off:

- When faced with a partial power loss, the pilot in command should not try to diagnose the engine problem at the expense of maintaining aircraft control;
- Climbing at the aircraft's best rate of climb speed will maximize options if a partial power loss or total power loss occurs;
- Lower the nose to maintain the glide speed of the aircraft (if unable to climb);
- If a partial power loss has occurred with remaining runway, the earlier a decision is made to cut remaining engine power, the greater landing distance is available; the immediate extension of landing flaps is recommended as this will also help to reduce the aircraft groundspeed prior to ground contact;
- Conduct the Phase One checks as outlined in the QRH. However, this should only be done if there is sufficient time;
- Maintain best glide speed and assess whether the aircraft is maintaining, gaining or losing height to determine current aircraft performance. This will assist in making decisions in the available options for landing.
- Fly the aircraft to make a landing, given the aircraft's height and performance, and the pre-planned routes for the situation. If any turning is conducted, be mindful that an increased bank angle will increase the stall speed of the aircraft. Keeping the aircraft in balance will also minimize rate of descent in any turn.
- Re-assess landing options throughout any manoeuvers. Be decisive but be prepared to modify the plan if required.
- Maintain glide speed up to the point of landing flare; this will ensure that when flaring there is enough energy to arrest the vertical descent rate.

Circuits under the night visual flight rules

At the time of the accident, the AIAC NVFR training syllabus included 5 hours of night circuits. Prior to commencing night circuits, students were given a briefing by an instructor. The briefing included human factors, illusions that can occur at night, lighting and flight with reference to instruments. It did not include emergencies, but students received a briefing on circuit emergencies earlier in their training. Additionally, at night, company pilots were required to conduct the climb after take-off at the best rate of climb speed.

Quick reference handbook

Emergency and non-normal procedures were detailed in the AIAC *Quick Reference Handbook* (QRH). These were derived from the emergency procedures detailed in the *Airplane Flight Manual*. The QRH included 'Phase 1 checks' that were printed in bold type. The Phase 1 checks were 'recall items' required to be committed to memory. The other, 'Phase 2' checks were not memory recall items and the QRH checklist was required to be used when carrying out these checks.

Two QRH procedures were relevant to the accident flight: the checklist for partial or full engine failure after take-off and the 'defective propeller RPM regulating system' checklist. The first of these is depicted in Figure 6. Nearly all the items were in bold and were therefore memory recall items. The first (memory recall) item was to achieve an airspeed of 88 kt with flaps up, or 77 kt with flaps in the take-off position. The second item, if time permitted, was to check the power lever was at maximum.

Figure 6: QRH checklist for partial or full engine failure after take-off

ENGINE FAILURE IMMEDIATELY AFTER TAKEOFF

ENGINE FAILURE

INSUFFICIENT ENGINE POWER (PARTIAL or FULL ENGINE FAIL)

Airspeed..........83 KIAS (Flaps UP)
77 KIAS (Flaps T/O)

If Time Permits:

Power Lever..........check MAX
Alternate Air..........ON
Fuel Pump..........check ON
Voter Switch..........check AUTO

WARNING

IF ADEQUATE ENGINE PERFORMANCE CANNOT BE RESTORED IMMEDIATELY, PREPARE FOR A EMERGENCY LANDING. IF POSSIBLE LAND STRAIGHT AHEAD, AVOIDING OBSTACLES. TURNING BACK CAN BE FATAL

SHORTLY BEFORE LANDING (ENGINE STOPPED)

Engine Master..........OFF
Fuel Pumps..........OFF
Fuel Transfer Pump..........OFF
Fuel Tank Selector..........OFF
Communications..........Transmit on monitored freq. Set 7700, ELT

When certain of reaching landing area:

Flaps..........T/O or LDG (as required)
Approach Speed..........see table below

Approach Speeds – KIAS				
Flaps	1000kg	1100kg	1200kg	1280kg
T/O LDG	68 KIAS	72 KIAS	76 KIAS	77 KIAS

Electric Master..........OFF
Safety Belts..........SECURED
After Touch Down..........APPLY BRAKES

END OF CHECKLIST

Source: AIAC

In this occurrence, the instructor assessed the speed fluctuations as symptomatic of a partial power loss, although the engine was still producing maximum power. The instructor reported confirming the power lever was in the full power position.

The engine manufacturer reported that the defective propeller RPM regulating system procedure had been in the airplane flight manual of the DA40 D aircraft, which had a different engine, since 2003. The procedure was introduced due to issues with the propeller control system of that engine type, but was still a valid procedure to be followed in case of oscillating RPM in the DA40 NG aircraft and in the DA40 NG flight manual.

The QRH defective propeller RPM regulating system checklist carried the following warning:

> IN CASE OF DEFECTIVE RPM REGULATING SYSTEM, REDUCED ENGINE PERFORMANCE SHOULD BE ANTICIPATED.

For oscillating RPM, the first action, was:

> POWER setting…………..CHANGE
>
> *If problem does not clear*;
>
> VOTER Switch……………Swap between ECU A and ECU B
>
> *If problem does not clear*;
>
> VOTER Switch……………AUTO
>
> Land at nearest suitable airport
>
> **Revise ENGINE FAILURE DURING FLIGHT checklist** (Page-322).
>
> **END OF CHECKLIST**

The instruction to change the power setting was not a memory recall item. The AIAC *Operations manual* section *QRH procedures* stated that 'the QRH should not be referred to unless flight crew workload is sufficiently low to operate the aircraft while the checks are conducted,' and that, in visual meteorological conditions, the pilot was not to refer to the QRH (for non-recall items), unless the aircraft was at or above minimum/lowest safe altitude, and/or other safe conditions could be met.

The aircraft manufacturer advised that changing the power lever angle in accordance with the procedure should fix a problem such as that encountered in the accident occurrence, because 'changing the operating state of the engine will typically stop periodic interactions of systems and thus stop RPM fluctuations.'

The AIAC head of operations considered that the engine fluctuations were 'very small' and should have been able to be remedied by changing power setting/moving the power lever slowly back and forth (then changing the ECU switches if necessary), in accordance with the QRH checklist. However, the instructor had not been aware of similar issues within the operator's aircraft fleet before the accident, and reported that similar events had not been discussed or trained for by the operator to a point of being memorable.

Decision making

Pilots operate in a safety-critical environment and need to be trained and supported to make the best possible decisions in challenging conditions. Orasanu (2010)[6] stated that

> in many high-risk consequential environments, time for making a decision is limited, information is incomplete, conditions change dynamically, and goals shift, rendering analytic decision-making impractical, if not impossible.

Orasanu detailed ways in which expert knowledge contributes to cockpit decision-making. These included quick and accurate interpretation of a problem and performing rehearsed responses. Where a pilot made an error or did not select the best solution, it may be due to an incorrect interpretation of the situation, or choosing an inappropriate course of action.

The instructor had not previously experienced propeller speed fluctuations and interpreted the problem as a partial power loss. The ATSB Avoidable Accidents No. 3 publication, *Managing partial power loss after take-off in single-engine aircraft*, stated that while following a complete engine failure, a forced landing was inevitable, a partial power loss required the pilot to make a decision whether to continue flight or land immediately. Research for the publication found that in 145 of 160 occurrences where a pilot turned back to the runway following a partial power loss, the aircraft made it to within the aerodrome grounds. However, the increase in stall speed during the turn and the associated potential for a loss of control meant that the consequences of a mishandled turn back were more serious than a controlled forced landing.

The publication suggested four main considerations when assessing if a turn back to the aerodrome is possible. These were:

- height available
- remaining engine power available – do you have enough power to climb?
- increased stall speed associated with any increase in angle of bank increasing the risk of an aerodynamic stall
- level of confidence in the remaining engine power – but assume the engine may fail at any moment.

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[6] Orasanu, J., 2010, Flight Crew Decision-Making, in Kanki, B., Helmreich, R. and Anca, J., Crew Resource Management, Elsevier, San Diego, USA

Take-off safety briefing

The ATSB Avoidable Accidents publication also stated that pilots should self-brief prior to each and every take-off. The take-off brief 'serves as a reminder of your planned actions in the event of an emergency such as a partial power loss.' Planning actions under non-stressful and controlled circumstances prepares pilots for a quick response, reducing mental workload and mitigating some effects of decision making under stress, such as reduced short-term memory, if an emergency situation does eventuate.

The AIAC operations manual specified that a take-off safety briefing must be given by the pilot flying[7] at the completion of pre-take-off checks.

The company take-off safety briefing was:

> 1. Any emergencies prior to V_R[8] I will reject the take-off.
>
> 2. Any emergencies at or after V_R I will reject and land on remaining runway or clearway.
>
> 3. Any emergencies airborne with no runway remaining I will pick a landing area 30° either side of the nose and conduct a forced landing.
>
> 4. Special considerations – unique airport information, weather conditions, terrain or obstacles on departure, other known risks and intentions.

The take-off safety briefing did not specify what events constituted an emergency.

The instructor recited their normal take-off safety briefing as:

> If there was anything on the ground, power to idle, brakes to come to a stop. Airborne with runway remaining, nose down land on the remaining runway. Airborne with insufficient runway remaining, pick an area either side of the nose, nose down, maintain glide speed, consider flap and then shutdown checks.

Related occurrences

Aircraft operator fleet events

After the accident involving VH-YPQ, the pilot of a twin-engine Diamond DA42 aircraft with a similar engine type to VH-YPQ and operated by AIAC, experienced a similar propeller RPM fluctuation event, where it varied about 50 RPM. In that event, the wind was gusting to 25 kt. During the take-off, there were some RPM changes due to wind gusting, but the pilot reported that was normal. Passing about 400 ft during the climb, fluctuation noise caught the pilot's attention. The pilot reduced the power to 85 per cent and after 5 to 6 seconds returned it to full power, and the fluctuations, noise and vibration ceased. The reasons for that fluctuation could not be determined from post-event examinations.

The aircraft maintainer provided extracted data of five similar fluctuation events from the aircraft operator's fleet. The last 3 hours of engine operating data were routinely downloaded from the ECU at each 100-hour maintenance event. Within that data, which represented 3 per cent of an aircraft's operating time, the maintainer found that oscillations/fluctuations in RPM were present 'quite a lot of the time.' Of the five sample events provided to the ATSB, four had fluctuations of greater magnitude than the accident flight. Only one of the five sample events was reported to the maintainer by the flight crew, and they reported 'hunting' of power and propeller RPM and that the aircraft was operating in turbulent conditions at the time.

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[7] Pilot Flying (PF) and Pilot Monitoring (PM): procedurally assigned roles with specifically assigned duties at specific stages of a flight. The PF does most of the flying, except in defined circumstances; such as planning for descent, approach and landing. The PM carries out support duties and monitors the PF's actions and the aircraft's flight path.

[8] VR: Rotate speed, is the speed at which the pilot begins to apply control inputs to make the aircraft nose pitch up, after which it leaves the ground.

The aircraft maintainer advised that the level of oscillation recorded in the ECU data for the accident flight was ‘quite common’ for the aircraft type (in the AIAC fleet) and believed they were generally introduced by an outside influence such as slight turbulence. The aircraft operator also reported that it was ‘common to observe and hear changes in propeller pitch on DA40 NG aircraft when flying in gusting wind conditions.’

The aircraft manufacturer advised that they were not aware of RPM fluctuations caused by windshear, gusts or turbulence, and that these would normally be eliminated by the governor. The AIAC chief engineer reported that in other previous occurrences of propeller fluctuations involving AIAC aircraft, the fluctuations had reached a maximum amplitude then reduced to near zero without pilot input.

Other aircraft events

In addition to the two events involving AIAC aircraft, the engine manufacturer reported that it was aware of 16 other events on aircraft fitted with the AE300 engine worldwide, involving fluctuations in propeller speed and load, none of which resulted in an accident. The engine manufacturer reported that in all cases, fluctuations ceased with a change in power lever position. Fifteen of these 16 occurrences were found to be the result of either a fuel pressure issue, propeller imbalance, or faulty electrical connection in the propeller governor and the cause of one was not found.

One additional event occurred in 2019, which was traced to excessive play in the alternator rotor. This was fixed by replacement of the alternator.

The reason for the fluctuations was found in all but three of the total of 19 reported occurrences.

Cylinder head cracking

On 25 May 2018, another DA40 NG aircraft in the AIAC fleet, VH-YPJ, had an occurrence where the engine coolant system over-pressurised and the coolant leaked. Inspection of that aircraft found cracking in six of the eight pairs of cylinder valve openings on the cylinder head.

Inspections were then carried out on the remaining aircraft in the operator’s fleet of five DA40 NG aircraft. The findings of the inspections are summarised in Table 1. The time between overhaul for the cylinder head was 1,800 hours.

Table 1: Cylinder head cracking in AIAC DA40 NG fleet

Aircraft	Cracking	Hours in service
VH-YPH	5 of 8 cylinder valves and cylinder head	1,358
VH-YPR	5 of 8 cylinder valves and cylinder head	1,409
VH-YPF	Cylinder head	1,356
VH-YPN	Cylinder head	1,555
VH-YPJ	6 of 8 cylinder valves and cylinder head	1,549
VH-YPQ	Cylinder head	901

Source: AIAC

After the accident and under the supervision of the ATSB, the operator examined the cylinder head fitted to VH-YPQ. Hairline cracks were identified in the cylinder head in the same location as VH-YPJ (Figure 7), however those cracks were assessed as insufficient in size to create engine problems at the time of the accident.

Figure 7: Cylinder cracks in VH-YPQ and another aircraft

Source: AIAC and ATSB

Safety analysis

Development of the accident

The aircraft experienced propeller speed fluctuations shortly after take-off, which although relatively small, the instructor had not experienced previously. The feel, sound and fluctuating engine indications were interpreted by the instructor as a partial power loss. The instructor considered landing ahead as for a complete engine failure. However due to darkness, obstacles in the path, the aircraft position and the perceived power available, the instructor decided to turn back to the runway.

During the 10 seconds that the instructor was assessing and decision-making prior to commencing the turn, the airspeed decreased 6 knots due to the aircraft's nose-up pitch attitude. At the same time as commencing the turn, the instructor reduced engine power, while maintaining a nose-up attitude.

Following the power reduction, the combination of nose-up pitch attitude and increasing angle of bank, resulted in an aerodynamic stall. The instructor recognised the signs of the impending stall and knew it was necessary to lower the aircraft nose to recover, but did not do so due to the perceived proximity of the trees below. This resulted in the loss of aircraft control and collision with terrain.

In-flight performance testing of a DA40 NG aircraft demonstrated that 30 per cent power was sufficient to maintain level flight including in a turn. Therefore, in this occurrence, had adequate airspeed above the stalling speed been achieved and maintained by lowering the aircraft's nose, it was likely aircraft control would have been retained, even following the power reduction commanded by the instructor.

Managing a perceived partial power loss

Although the engine did not sustain a partial power loss, the instructor perceived that there was an impending engine issue due to the noise and vibrations brought on by the propeller fluctuations. Therefore, the instructor managed the issue by dealing with it as a partial power loss. However, the instructor could not recall reducing the power at the same time as commencing the turn, or why.

Managing partial power loss after take-off in single-engine aircraft was not included in the units of competency within the Civil Aviation Safety Regulations Part 61 Manual of Standards (MOS) or the aircraft operator's training syllabus, other than as 'underpinning knowledge'. The instructor had previously demonstrated competence in managing simulated complete engine failure after take-off in single-engine and multi-engine aircraft and in managing simulated partial engine failure in multi-engine aircraft. The instructor was also required to have demonstrated competence in recovery from a stall with full or partial loss of engine power in accordance with the MOS.

Training for complete engine failure after take-off is straightforward and the trained response is primarily to lower the aircraft nose to achieve a safe airspeed and land ahead. Training for partial power loss is more complex as there can be significant variation in the power loss presentation. This includes anything from almost full to almost no power available, and the situation may resolve, worsen, or both. Following a partial power loss, a pilot will need to make an assessment of the power available, aircraft performance, suitable landing areas and other factors such obstacles and terrain. It may be that turning back to land on a runway is achievable. In any event, the first memory item stipulated in the aircraft's quick reference handbook in case of full or partial engine power loss, was to achieve the stated (best glide) airspeed, which is essential to avoid a loss of control.

Research conducted for the ATSB publication *Avoidable Accidents No. 3 – Managing partial power loss after take-off in single-engine aircraft*, found proportionally more fatal accidents occurred following a partial power loss than a complete engine failure. In particular, loss of aircraft control occurred more often following a partial power loss, either during a turn back to the runway or as a result of pilot inaction to prevent airspeed decay. The consequences of these loss of control occurrences were more serious than landing ahead following a complete engine failure. The research identified that pilots generally used a take-off safety briefing that primed them for actions in case of complete engine failure after take-off but not for partial power loss.

The instructor's take-off safety briefing was consistent with that used across the general aviation industry and included instructions (paraphrased):

> In case of engine failure when airborne with no runway remaining, lower the nose to achieve best glide speed and land ahead.

As lowering the aircraft nose when close to the ground is counterintuitive, such priming may help the pilot resist pitching the nose up, thereby avoiding a stall and loss of control. However, in this occurrence, the instructor commenced the turn before lowering the aircraft nose to achieve a safe speed, and although knowing it was necessary to lower the nose, did not want to direct the aircraft towards the trees below.

In the *Avoidable accidents* publication, the ATSB assessed that including consideration of partial power loss in the take-off safety briefing by reminding the pilot to lower the nose to achieve best glide speed before assessing performance and decision-making, may improve outcomes following (actual or perceived) partial power loss after take-off.

Cylinder head cracking

While not contributing to this accident, engine cylinder head cracking in the aircraft operator's fleet of DA40 NG aircraft had occurred before the service life of 1,800 hours was exceeded. A crack in an engine cylinder head may develop to a size that results in loss of compression or power, foreign object damage or engine failure.

Findings

From the evidence available, the following findings are made with respect to the collision with terrain involving Diamond DA40 aircraft, registered VH-YPQ, 1 km south of Port Macquarie Airport, New South Wales, on 8 September 2017. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factors

- In response to increasing propeller speed fluctuations which were interpreted as a partial power loss, the instructor decided to attempt to turn back to land at the aerodrome. The instructor reduced power to 30 per cent and did not maintain adequate airspeed during the turn, resulting in an aerodynamic stall, a loss of control and collision with terrain.

Other factors that increased risk

- The aircraft manufacturer could not determine the reason for the fluctuations. Propeller speed fluctuations have occurred in other aircraft with the E4 engine and MTV-6-R propeller, and either resolved without pilot input or by moving the power lever.
- Cylinder heads for the aircraft type were cracking prior to reaching their service life.

Safety issues and actions

Additional safety actions

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Australian International Aviation College

The aircraft operator, Australian International Aviation College, reported to the ATSB that after the accident, they:

- added the following to their required take-off safety briefing:

  > In the event of a partial power loss, set partial power safety speed (DA40 NG – 78 kt take-off flap or 88 kt flap up), assess performance. If unable to maintain altitude find suitable place to conduct a forced landing.

- conducted partial engine failure after take-off training for instructors and students, comprising pre-flight planning and self-briefing, ground training, and flight training
- performed flight simulator tests for partial engine failure after take-off conditions in each single engine aircraft model operated by the flying school to assess the power required to maintain altitude.

General details

Occurrence details

Date and time:	8 September 2017 – 1959 EST	
Occurrence category:	Accident	
Primary occurrence type:	Collision with terrain	
Location:	1 km south of Port Macquarie Airport, New South Wales	
	Latitude: 31° 26.550' S	Longitude: 152º 51.678' E

Pilot details – Instructor

Licence details:	Commercial Pilot (Aeroplane) Licence, issued November 2015
Aircraft ratings and endorsements:	Manual Propeller Pitch Control; Retractable Undercarriage; Single Engine Aeroplanes less than 5,700 kg Maximum Take-off Weight; Multi Engine Aeroplanes
Ratings:	Multi Engine Aircraft Instrument rating; Instrument Approach 2 Dimensional and 3 Dimensional; Flight Instructor Rating Aeroplane Grade 2, Single Engine Aircraft, Night VFR Training, Design Feature Training, Instrument Rating Training
Medical certificate:	Class 1, valid to March 2018
Aeronautical experience:	1160.9 hours
Last flight review:	June 2017

Pilot details – Student

Licence details:	Recreational Pilot Licence, issued May 2017
Endorsements:	Nil
Ratings:	Nil
Medical certificate:	Unknown
Aeronautical experience:	85.4 hours flying time, of which 19.8 were as pilot in command.
Last flight review:	N/A

Aircraft details

Manufacturer and model:	Diamond Aircraft Industries DA 40	
Registration:	VH-YPQ	
Operator:	Australian International Aviation College	
Serial number:	40.N292	
Type of operation:	Flying Training - Training Dual	
Departure:	Port Macquarie Airport, New South Wales	
Destination:	Port Macquarie Airport, New South Wales	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 2 Serious	Passengers – 0
Aircraft damage:	Destroyed	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- instructor
- student
- flight training school/aircraft operator
- aircraft and engine manufacturer
- Civil Aviation Safety Authority
- Airservices Australia
- Bureau of Meteorology.

References

Orasanu, J., 2010, Flight Crew Decision-Making, in Kanki, B., Helmreich, R. and Anca, J., Crew Resource Management, Elsevier, San Diego, USA

Submissions

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

A draft of this report was provided to the aircraft operator, manufacturer and maintainer, the engine and propeller manufacturers, instructor and student pilot, the Civil Aviation Safety Authority, Austrian Federal Safety Investigation Authority and the German Federal Bureau of Aircraft Accident Investigation.

Submissions were received from the aircraft manufacturer, operator and maintainer, the Civil Aviation Safety Authority, Austrian Federal Safety Investigation Authority and the instructor. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within the ATSB's 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 operations involving the travelling public.

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 identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, 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 initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

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

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

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

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, current risk controls and organisational influences.

Contributing factor: a factor that, had it not occurred or existed at the time of an occurrence, 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 factor would probably not have occurred or existed.

Other factors that increased risk: a safety factor identified during an occurrence investigation, which did not meet the definition of contributing factor but was still considered to be important to communicate in an investigation report in the interest of improved transport safety.

Other findings: 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.