Australian Government

Australian Transport Safety Bureau

Loss of control and collision with terrain involving Angel Aircraft Corporation 44, VH-IAZ

near Mareeba Airport, Queensland, on 14 December 2019

ATSB Transport Safety Report

Aviation Occurrence Investigation (Defined)

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Addendum

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Safety summary

What happened

On 14 December 2019, two pilots were conducting a private flight in an Angel Aircraft Corporation Model 44 aircraft, registered VH-IAZ, at Mareeba, Queensland. An instructor seated in the right pilot seat was conducting a flight review of the pilot (and aircraft owner) in the left seat.

The aircraft took off from Mareeba Airport at 1058 Eastern Standard Time,[1] after which witnesses reported hearing one of the engines hesitating and backfiring, accompanied by a sooty smoke trail from the right engine. The aircraft operated in the training area until returning to the airport circuit area at 1112. Witnesses observed the aircraft touch down on the runway, accelerate and take off again. After take-off, the aircraft climbed to about 100-150 ft above ground level before entering a right descending turn. The aircraft was airborne for about 20 seconds before witnesses observed it rolling rapidly to the right and impacting terrain in a cornfield 475 m north of the runway. The pilots sustained fatal injuries and the aircraft was destroyed.

What the ATSB found

Based on the witness reports of abnormal engine sounds and because the instructor had planned to conduct a simulated engine failure after take-off, the ATSB assessed whether the accident occurred following a simulated or real engine failure.

Examination of the fuel system found that two of the fuel injectors in the right engine showed evidence of partial blockage by corrosion particles. Such blockage would have resulted in the over-fuelling of the other injectors and the engine running overly rich; reducing the maximum power available from that engine. There was, however, no evidence of a complete power loss, with both engines producing power at the time of impact.

The ATSB found that shortly after take-off, the flight instructor very likely conducted a simulated failure of the right engine in environmental conditions and a configuration in which the aircraft was unable to maintain altitude with one engine inoperative. Power was not immediately restored to the right engine to discontinue the exercise and the pilots were unable to maintain altitude or heading, particularly with the aircraft banked towards the inoperative engine. The pilots did not reduce power and land ahead, as required by the *Airplane Flight Manual*, resulting in a loss of directional control and roll. The loss of control occurred at a height too low to recover and the aircraft impacted terrain.

The instructor had limited experience in multi-engine aeroplanes with retractable landing gear and only one short flight in the Angel 44 aircraft several years earlier. Therefore, the instructor was likely unfamiliar with the time necessary for the landing gear and flaps to retract (significantly longer than other aircraft the instructor had flown) and the associated detrimental effect that extended flaps and landing gear had on the aircraft's single-engine climb performance. This likely influenced the decision to initiate a low-level simulated engine failure and diminished the instructor's ability to interpret and manage the situation.

Additionally, the pilot (in the left seat) had not flown for 3 years prior to the accident flight, which likely resulted in a decay of skills at managing tasks such as an engine failure after take-off. The pilot probably over-estimated their self-assessed competency for the planned task and did not demonstrate proficiency at a safe height before the low-level simulated engine failure.

The ATSB found that the right-side altimeter was probably set to an incorrect barometric pressure, resulting in it over-reading the aircraft's altitude by about 90 ft.

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

The aircraft had not been flown regularly for more than 2 years and the engines had not been preserved in accordance with the manufacturer's procedures. Both engines had mild internal corrosion and the right engine had signs of water contamination within the fuel system, including in the engine-driven fuel pump and fuel injection servo. Corrosion particles in the fuel injection servo likely originated from the fuel tank. These particles lodged in two of the fuel injection nozzles and contributed to the right engine running overly rich, backfiring and a reduction in maximum power available.

Safety message

Flight reviews

Flight reviews that are conducted without the oversight of a training organisation remove the opportunity to include training. Due to the known limitations of self-assessed competency, pilots who choose this option should have recent demonstrated proficiency in all of the required exercises.

Simulated engine failures

In light twin-engine aeroplanes, loss of power on one engine shortly after take-off poses a high risk due to low altitude, low airspeed and generally limited single-engine climb performance. The asymmetric thrust can lead to a loss of directional control that, if mishandled, will likely result in an accident due to insufficient height above the ground to recover.

The regulatory requirement to use simulators for conducting engine failure after take-off exercises has eliminated the risk for those aircraft where simulators are available. However, where simulators are not available, there is still a requirement to perform the exercise in the aircraft. In those situations, it is essential to understand the risks and ensure effective controls are in place to prevent the simulation turning into a loss of control at low level, where recovery will probably not be possible. Consideration of these risks should include:

- the method of simulating engine failure
- instructor/check pilot training, experience and proficiency specific to the aircraft make and model
- ensuring the pilot/student has first demonstrated the ability to maintain asymmetric control at a safe height and understands handling one engine inoperative flight and associated risks
- thorough pre-flight briefing including minimum control speed, configuration including flaps and landing gear, safe intentional single-engine speed, one engine inoperative climb performance and limitations
- ensuring the aircraft is in a configuration and at an airspeed at which climb with one engine inoperative is possible
- criteria for aborting the procedure including airspeed, height above terrain/obstacles, directional control and bank angle
- effect of, and time required to restore power to the simulated inoperative engine
- understanding when a reduction in power and landing ahead may be ultimately necessary to avoid a loss of control.

Attempting to continue flight with one engine inoperative in a multi-engine aeroplane when directional control cannot be maintained, carries a high risk of an accident and fatal injuries.

Airframe and engine preservation

If an aircraft is not flown regularly, the airframe and engine/s should be preserved in accordance with the manufacturer's procedures. Incorrect or inadequate preservation can increase the likelihood of in-flight failures, with the associated safety risks.

Contents

The occurrence

On 14 December 2019, at 1046 Eastern Standard Time,[2] an Angel Aircraft Corporation Model 44 aircraft, registered VH-IAZ (Figure 1), commenced taxiing at Mareeba Airport, Queensland. On board the aircraft were two pilots. The pilot in the left seat ('the pilot') owned the aircraft and was undertaking a flight review,[3] which was being conducted by the Grade 1 flight instructor in the right seat ('the instructor'). The planned flight was to operate in the local area, as a private flight and under visual flight rules.[4]

Figure 1: VH-IAZ (when formerly registered as VH-IOZ)

Source: Aircraft maintainer

As the aircraft taxied towards the runway intersection, the pilot broadcast on the common traffic advisory frequency (CTAF)[5] that VH-IAZ was taxiing for runway 28.[6] The pilot made another broadcast when entering and backtracking the runway, then at 1058, broadcast that the aircraft had commenced the take-off roll.

Witnesses who heard the aircraft during the take-off reported that it sounded like one of the engines was hesitating and misfiring. An aircraft maintainer who observed the aircraft take off, reported seeing black sooty smoke trailing from the right engine. The maintainer then watched the aircraft climb slowly and turn right towards the north. Another witness who heard the aircraft in flight soon afterwards, reported that it sounded normal for that aircraft, which had a distinctive sound because the engines' exhaust gases pass through the propellers.

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

3 Flight reviews are required to ensure pilots continue to be competent in exercising the privileges of their licences and ratings.

4 Visual flight rules (VFR): a set of regulations that permit a pilot to operate an aircraft only in weather conditions generally clear enough to allow the pilot to see where the aircraft is going.

5 The CTAF is the frequency on which pilots operating at a non-controlled aerodrome should make positional radio broadcasts.

6 Runway number: the number represents the magnetic heading of the runway. Runway 28 at Mareeba was on a magnetic heading of 283°.

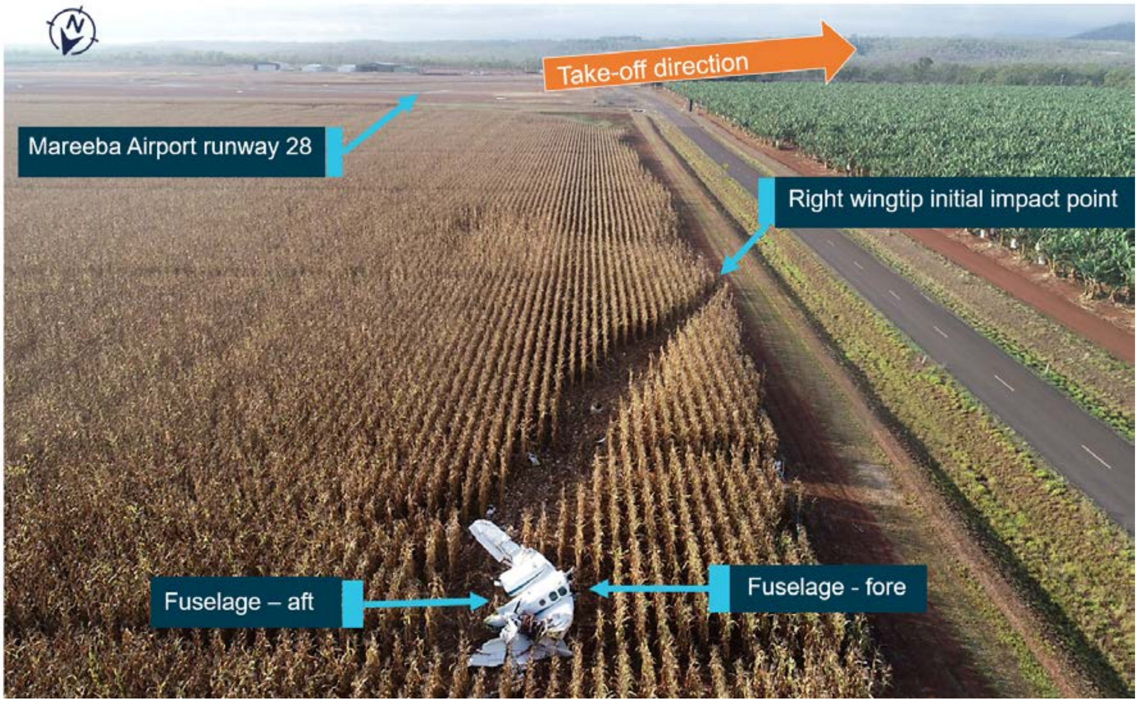
Once airborne, the pilot broadcast that they were 'making a low-level right-hand turn and then climbing up to not above 4,500 [feet] for the south-west training area.'

About 2 minutes later, the instructor broadcast that they were just to the west of the airfield in the training area at 2,500 ft and on climb to 4,000 ft, and communicated with a helicopter pilot operating in the area. After 8 minutes in the training area, the pilot broadcast that they were inbound to the aerodrome.

At 1112, the aircraft's final transmission was broadcast by the pilot, advising that they were joining the crosswind circuit leg for runway 28.

Witnesses then saw the aircraft touch down on the runway and continue to take off again, consistent with a 'touch-and-go' manoeuvre, and heard one engine 'splutter' as the aircraft climbed to an estimated 100–150 ft above ground level. At about 1115, the aircraft was observed overhead a banana plantation beyond the end of the runway, banked to the right in a descending turn, before it suddenly rolled right. Witnesses observed the right wing drop to near vertical and the aircraft impacted terrain in a cornfield. Both pilots were fatally injured and the aircraft was destroyed (Figure 2).

Figure 2: Accident site showing the take-off direction, initial impact point and fuselage resting position



Source: ATSB

Context

Flight crew information

Pilot medical status, qualifications and experience

The 73-year-old pilot's Class 1 aviation medical certificate had expired in February 2017. Although the pilot had attended a general practitioner and completed a Class 2 medical examination on 12 August 2019, the requirements to be issued with a medical certificate had not been completed at the time of the accident.

The pilot held a commercial pilot licence (aeroplane) and had accrued over 20,000 flying hours, approximately 300 of which were in VH-IAZ. When purchasing the aircraft, the pilot had completed aircraft type training in the Angel 44 aircraft with the manufacturer in the United States (US). The pilot had operated the aircraft for commercial passenger-carrying charter flights and had previously been authorised by the Civil Aviation Safety Authority (CASA) to perform training in it, although that authority had lapsed.

In 2015, the pilot had completed flight instructor and instrument rating proficiency checks, but those ratings were no longer current. The pilot had last flown in June 2016, in VH-IAZ (which at the time was registered VH-IOZ). Also in 2016, the pilot had completed a flight review, valid for 2 years, which expired in February 2018.

Instructor medical status, qualifications and experience

The 63-year-old instructor had a valid a Class 1 medical certificate, and was in the process of renewing it, as it was due to expire in January 2020.

The instructor held an air transport pilot licence (aeroplane), current multi-engine aeroplane class, instructor and instrument ratings, and had accrued 5,029.5 hours of aeronautical experience.

According to the instructor's logbooks, most of the recorded 976 hours of multi-engine command time was obtained in Vulcanair (formerly Partenavia) P68 C and Britten-Norman Islander aircraft, both aircraft types having fixed (non-retractable) landing gear. The instructor had also recorded limited hours in several multi-engine aeroplanes with retractable landing gear, including Piper PA34, PA31 and Cessna 421 aircraft. The instructor's most recent experience in an aeroplane with retractable landing gear was in January 2018, when the instructor conducted flight training in a Piper PA34 aircraft.

From available evidence, the instructor's only Angel 44 experience was 'a circuit' in VH-IAZ with a senior pilot on board, about 4 years prior to the accident flight. At that time, the instructor was assessed as 'not ready' to be employed as a charter pilot operating the aircraft.

The day before the accident flight, the instructor had satisfactorily completed a multi-engine instructor rating proficiency check[7] in a P68 C aircraft with the chief flying instructor (CFI) of a flight training school based at Mareeba Airport. The CFI reported that the proficiency check involved the instructor giving a briefing on asymmetric operations and a pre-flight briefing on single-engine (simulated one engine inoperative) circuits. The flight included upper airwork in the training area near Mareeba followed by simulated engine failures in the aerodrome circuit including after take-off, which were initiated between 400 and 500 ft above ground level (AGL).

The CFI reported that the instructor came across as quite professional, with handling skills slightly above average and 'really good' non-technical skills.

[7] A proficiency check is an assessment of a pilot's skills and knowledge in a particular operational area. Pilots are required to undertake proficiency checks to ensure they continue to be competent conducting particular kinds of operations. After gaining a qualification, it is normal for some skills to deteriorate over time.

Post-mortem and toxicology results

Post-mortem examination established that both pilots received severe, non-survivable injuries as a result of the accident.

The examination also found that the pilot had 75 per cent narrowing of one of the major coronary arteries and the instructor had 75 per cent narrowing of two of the major coronary arteries. The instructor also had significant heart enlargement with thickening of the major heart chamber, and stiffening and hardening of the aortic heart valve. However, neither the pilot nor the instructor had any features to indicate a recent heart attack.

The forensic pathologist reported that:

> both pilots had a sufficient degree of coronary artery narrowing (atheroma) that is associated with a significant increase in the possibility of a potentially lethal heart rhythm disturbance that might render a pilot (or passenger) unconscious, or have onset of chest pain or shortness of breath that might incapacitate a pilot.

It is possible that this may have led to some level of incapacitation of either the pilot or the instructor during the accident flight, however, this can be neither confirmed nor excluded on the basis of autopsy examination.

Toxicology results included the presence of a blood pressure lowering medication in the pilot's blood, which was consistent with that prescribed by the pilot's general practitioner.

Aircraft information

Angel 44, VH-IAZ

The Angel Aircraft Corporation Model 44 is an eight-seat, twin-engine aeroplane with retractable tricycle landing gear (Figure 1). It was designed as a utility aircraft, with short take-off and landing capability. The aircraft is powered by two Lycoming IO-540-M1C engines with 'pusher-configuration' aft-mounted Hartzell three-blade constant speed feathering propellers.[8]

The occurrence aircraft, serial number 004, was manufactured in the US in 2008. It was the only Angel 44 aircraft in Australia, where it was first registered in January 2010 as VH-IOZ. It was deregistered in November 2017 for sale and international export. The sale did not proceed and the aircraft was re-registered, this time as VH-IAZ, in March 2019. VH-IAZ was approved to operate under instrument flight rules[9] and in the charter category, and was fitted with dual flight controls. The aircraft had a maximum gross weight for take-off and landing of 2,630 kg (5,800 lb).

Aircraft maintenance history

The aircraft was to be maintained as per the CASA maintenance schedule, with a periodic inspection required every 100 hours or 12 months, whichever came first. Table 1 details the recent maintenance and operational history of VH-IAZ.

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8 Feathering: the rotation of propeller blades to an edge-on angle to the airflow to minimise aircraft drag following an in-flight engine failure or shutdown.

9 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.

Table 1: Recent maintenance and operational history

Date	Flight hours	Description of event
28 June 2016	0.2	Left engine replaced due suspect oil analysis – factory overhauled engine fitted. Maintenance release issued.
29 June 2016	0.9	Flight
4 September 2016	0.9	Flight
12/14/15 October 2016	5.1	Three flights over 3 days
22 February 2017	0.5	Flight
30 May 2017	0.5	Right engine replaced, no reason for change noted – factory overhauled engine fitted
13 September 2017	0.5	Periodic inspection and maintenance release issued and flight
30 September 2017	0.6	Flight (last recorded flight hours)
1 November 2017		Airworthiness Directive 2017-0788 *Identification of connecting rods with non-conforming small end bearings*, which referenced Lycoming service bulletin 632B, carried out on left engine (not applicable to right engine) and other minor maintenance tasks.
14 November 2017		VH-IOZ removed from Australian register
29 March 2019		Aircraft registered as VH-IAZ
26 April 2019		Certificate of airworthiness issued
30 April 2019		Current maintenance release issued. Right fuel tank water contamination – both fuel tanks drained, flushed, 70 litres AVGAS[10] uploaded into the fuel tanks, ground run carried out and fuel lines flushed.
5 December 2019		'All fuel drains removed, cleaned of wasp nests and refitted. Both tacho cables removed, lubed, flushed outer cables, refitted and ops check off.'
10 December 2019		Two new spark plugs fitted to right engine No. 3 cylinder due magneto drop, ground run okay.
14 December 2019		Accident flight: nothing recorded on maintenance release, no daily inspection signed. No flight hours recorded since 30 September 2017.

Source: Aircraft maintainer

The two licenced aircraft maintenance engineers who maintained VH-IAZ reported that the aircraft had been ground run a few times since it was last flown, but not to a specified schedule. These ground runs were not recorded, nor were they required to be.

The last recorded flight time was on 30 September 2017 and no flights had been recorded since the aircraft was reregistered in March 2019.

A certificate of airworthiness is issued when CASA, or an authorised person, has assessed that the aircraft complies with applicable airworthiness requirements and has been satisfactorily maintained, ensuring the aircraft is in a condition for safe operation. VH-IAZ was issued with a certificate of airworthiness on 26 April 2019. This involved a review of the aircraft logbooks and continued airworthiness requirements, a visual inspection of the aircraft, and verification that engine and airframe serial numbers were in accordance with the documentation.

The authorised person reported that, at the time of the inspection, they were aware the aircraft had not been flown for some time. Therefore, the authorised person sought confirmation from the maintainers that the engine fuel components had been assessed for serviceability and that the engine internals had been checked for evidence of corrosion. Following discussion with the

10 The aircraft had a total fuel capacity of 840 litres.

maintainers, the authorised person was satisfied these items had been addressed and did not identify any issues regarding the engines' serviceability.

The current maintenance release, issued on 30 April 2019, recorded that the aircraft had accrued 1,803.5 hours total time in service. Records show that evidence of water contamination was found in the right engine fuel system at that time. Therefore, both fuel tanks were drained and flushed, filters were cleaned and the fuel lines were flushed. After draining the tanks, 70 L of fuel was uploaded into them. They were then stored until the accident flight with significantly less fuel than the total capacity of 840 L. No flights, or additional maintenance, had been recorded on the maintenance release and the required daily inspection had not been endorsed prior to the accident flight.

Weight and balance

The aircraft was operating within the approved weight and balance envelope during the flight, at a take-off weight of 2,344 kg (5,169 lb) and a centre of gravity (CG) forward of mid-range.

Hydraulic system

The hydraulic system operates the nose, left main and right main landing gear and flaps. Hydraulic pressure is provided to the gear and flap control valves by an electric pump located in the nose of the aircraft. The landing gear and flaps were held up by hydraulic pressure and when fully extended, the landing gear was locked down by a mechanical stop and springs.

The Airplane Flight Manual (AFM) stated:

> 9.4.8 It is normal for the landing gears not to retract simultaneously. Since all 3 landing gears are interconnected hydraulically, the gear requiring the least pressure will retract first, then the next, and the one requiring the most pressure will be last.
>
> 9.4.9 When the landing gear and flap operations are selected simultaneously, their systems are interconnected. Since the flaps require less pressure, they will retract first. A check valve in the gear pressure line prevents the gear from going back down while the flaps are moving.

According to the aircraft manufacturer and pilots who had flown the aircraft, the landing gear took about 14 seconds to move from the extended (down) to fully retracted (up and locked) positions when selected up. As the gear and flap systems were interconnected, this time would increase if the flaps were selected up while the gear was retracting. If hydraulic pressure is lost, the landing gear will free-fall down and be locked over centre by springs.

Engine preservation

Unprotected surfaces in the engine, including cylinder walls, valves and fuel system components are susceptible to corrosion from moisture that naturally occurs in aviation fuels and the atmosphere. It is widely acknowledged that aircraft located in humid regions, and near the ocean and lakes, are at a greater risk of damaging corrosion than those in dry, low humid areas.

When a six-cylinder engine is stationary, generally at least one valve will be open in four of the six cylinders. With the day/night heating and cooling cycle, there is an exchange of air via the inlet or exhaust systems. If the air is warm and humid when it flows in and the engine then cools down, the water vapour can condense in the cylinders. This accumulation of moisture on the surfaces can lead to corrosion. Similarly, air exchange via the crankcase breather results in condensation in the oil. This can lead to formation of acidic compounds that promote surface corrosion.

In-service engines will generally self-purge the moisture through the combustion process and heating of the lubricating oil, which will provide a degree of protection to this corrosion. Engines in aircraft that are not flown frequently, and those that have flown less than 50 hours in total, are especially susceptible to corrosion. In this instance, effective storage procedures are required to ensure that the serviceability of the engine is maintained.

Storage procedures

The aircraft maintenance manual detailed three storage procedures when the aircraft is not expected to be flown for a period. For all three storage methods, the pitot[11] tube should be covered.

Flyable storage procedures – where the aircraft is not expected to be flown for an indefinite period but is kept in a condition to 'fly quickly' included:

- Turn each engine by hand at least 5 revolutions each week to redistribute the oil and ensure the engine does not 'end up in the same place each time.'
- Keep fuel tanks as 'full' as possible.
- The aircraft wheels should be chocked and the aircraft tied down securely, if stored outside.
- After 30 days, the aircraft should be flown for at least 30 minutes, or ground run until the oil reaches operating temperature.

Short-term storage procedures – where the aircraft is not expected to be flown for a period of up to 3 months included:

- The engine is to be inhibited by spraying a small amount of corrosion inhibitor through the spark plug holes and oil filler tube.
- Cover exhausts, pitot, static and cowl openings.
- Lock landing gear retraction linkage.
- Disconnect or remove the battery.

Long-term storage procedures – where the aircraft is not expected to be flown for an extended indefinite period included:

- The aircraft should be stored inside or under some type of cover if possible.
- Replace the engine oil with a defined lubricating mixture and fly the aircraft for 15-30 minutes, then spray the lubricating mixture into the cylinders and replace upper spark plugs with blanks. Respray the cylinders and interior of the engine at least every 6 months.
- An alternate method is as per short-term storage, but de-inhibit the engine and run it every 90 days, before reapplying corrosion inhibitor.

The engine manufacturer, Lycoming, also had procedures for corrosion prevention in engines that will be inactive for a period up to 30 days. These were similar to the aircraft maintenance manual procedure for short-term storage, in that the engine is sprayed with corrosion preventative oil. In addition, the engine manual had the note:

> Ground running the engine for brief periods of time is not a substitute for the following procedure; in fact, the practice of ground running will tend to aggravate rather minimise this corrosion condition.

Lycoming Service Letter L180B *Engine preservation for active and stored aircraft* reinforced the requirement for short-term storage, of up to 30 days, and long-term storage practices, particularly in humid environments. Long-term storage also included the use of a desiccant,[12] which should be inspected at least every 15 days.

Further, CASA airworthiness bulletin 85-021 *Piston engine low utilisation maintenance practices* reinforces following the manufacturer's procedures to prevent corrosion.

The fuel injector manufacturer, Precision Airmotive also published short- and long-term storage requirements in their operation and service manual. In addition, this manual stated:

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[11] The pitot tube is part of the aircraft's pitot-static system, which is used to determine airspeed and altitude. A pitot tube blocked by insects or other foreign matter will result in erroneous airspeed indications.

[12] Desiccant: a hygroscopic substance used as a drying agent.

> A complete overhaul is mandatory regardless of any FAR [US Federal Aviation Regulation] operational category when the injector or fuel system component has been subjected to severe environment such as but not limited to…contaminated fuel such as water, rust sand, etc.

Recorded data

The aircraft was not equipped with a flight data recorder or cockpit voice recorder, nor was it required to be.

Post-accident examination and assessment

Accident site

The accident site was located in a cornfield about 475 m north of the runway at Mareeba Airport. Based on an analysis of the wreckage and ground marks, it was evident that the aircraft impacted terrain right wingtip first, while travelling in a northerly direction. The nose landing gear impacted the ground about 33 m beyond the initial impact point, after the right wing had fractured and collapsed under the weight of the aircraft. At that point, the fuselage was at, or slightly over, vertical, and the cockpit folded under and to the left.

The aircraft then slid on its left wing at about mid-span, until the left wingtip dug into the terrain, resulting in the fuselage lifting and clearing a section of corn, before coming to a halt, upright, and 67 m from the initial impact point.

An assessment of the area beyond the runway identified that obstacle-free forced landing areas were limited to a road which ran perpendicular to the runway (Figure 2).

On-site examination

From the accident site examination, there was no evidence of an in-flight breakup or discontinuity of the flight controls that may have contributed to a loss of aircraft control. The rudder trim lever was in the neutral position and the elevator trim was fully forward in the down position.

The left altimeter QNH was set to 1013[13] and the right altimeter QNH was set to 1009. Due to the design of the selector, these settings were unlikely to have moved during impact. An aerodrome forecast service for Mareeba Airport was available from the Bureau of Meteorology, which included forecast QNH. Additionally, an Aerodrome Weather Information Service was available by phone or VHF radio, which provided actual QNH. However, it could not be determined whether the pilots accessed either service prior to the flight.

Landing gear and flaps

The landing gear selector was in the up position. The nose landing gear was fully or almost fully retracted, the right main landing gear was partially extended and the left main landing gear was extended and on the mechanical (down) lock. However, the electric pump for the hydraulic system detached from the aircraft when the nose impacted the ground. This removed the hydraulic pressure required to hold the landing gear and flap up. After that, the main landing gear (and flap) was able to free-fall. As such, the main landing gear was either retracted and free-fell down during the impact sequence, or was not fully retracted before impact. From the observed flight path, the aircraft was airborne for about 20 seconds; for approximately 5 of those seconds after take-off, the landing gear remained extended. This left a maximum of about 15 seconds for all three wheels to retract to the up-and-locked position. As it took about 14 seconds for the landing gear to retract, and longer as the flaps also retracted (see section *Hydraulic system*), it was probable that the landing gear had not fully retracted prior to impact.

The normal take-off flap position was 20 degrees extension. At the accident site, the flap was extended 5-15 degrees, however, the associated paint transfer mark on the fuselage indicated

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[13] QNH: the altimeter barometric pressure subscale setting used to indicate the height above mean seal level.

that the flap was likely up or almost fully up prior to impact and was pushed down in the accident sequence. The flap selector lever was at about a 45-degree angle, indicative of the flaps selected in the fully extended position, but due to disruption of that part of the panel during the impact sequence, it was not indicative of the actual flap position.

Engines and propellers including controls and indications

Both of the fuel mixture levers were fully forward in the ‘rich’ position, with the fully aft position denoted ‘lean’. The propeller pitch levers were both fully forward in the full fine position, denoted ‘Hi RPM’, with the fully aft position denoted ‘feather’. The left throttle lever was fully forward in the ‘open’ position, with the aft position denoted ‘close’. The right throttle lever was at mid-travel and was likely at that position prior to impact, as the lever had been bent to the right during the impact sequence. That position was consistent with the right engine tachometer, which was stuck at about 1,300 RPM and was likely in that position immediately prior to impact.

For both a normal take-off and in response to an (actual) engine failure after take-off, the expected lever positions would be all six levers in the fully forward position.

Initial on-site examination found no evidence of pre-impact mechanical, electrical or other catastrophic failure to either engine or propeller assembly. The propeller blades indicated that both engines were making power at impact, with the right engine operating at lower power than the left. The propellers and engines were taken to specialist facilities for further examination.

Propeller examination

Chord-wise scoring and leading edge damage was present on both propellers, consistent with the propellers operating under engine power (not windmilling) during the impact sequence.

The left propeller had all three tips missing, one of which was severed twice and another had twisted during separation. This was consistent with the left engine producing significant power at the time of impact. The right propeller blade tips had not detached.

The location of the pusher-propellers and impact sequence, including the materials the blades passed through, likely affected the blade damage signatures. The right blades typically showed less substantial markings from having passed through soil, vegetation and the fuselage. The left propeller blades had more damage, due to impact with the airframe including the wings.

Engines and fuel system examination

There was no evidence of catastrophic failure of the engines or fuel system components. All magnetos and spark plugs were tested and found serviceable.

Mild corrosion was evident in cylinder bores of both engines. While the internal corrosion was consistent with inadequate preservation and storage of the engines, it was unlikely to have contributed to significant power loss or engine failure.

There was no evidence of water contamination in the left engine fuel system. The right engine-driven pump and right fuel injection servo unit carried a black residue – consistent with water contamination. For this to occur, the right engine would have to have been run with water contamination in the fuel.

When tested, the fuel injector nozzles from cylinders No. 2 and 4 on the right engine had reduced flow due to particulate contamination. Partially obstructed fuel injectors had the potential to contribute to the unaffected cylinders running overly rich. This was consistent with carbon deposition observed in the No. 2 and No. 4 cylinder exhaust and witness reports of a dark sooty trail emitting from the right engine on the first take-off of the flight.

ATSB examination found the particulates were consistent with iron-oxide (corrosion). The contamination and deposits in the right engine had the possibility to reduce engine efficiency and performance, but the broader effect on the flight could not be determined.

Weather and environmental information

At 1115 EST, the temperature at Mareeba Airport was 34 ºC, the dewpoint 15 ºC, and the wind from 266º (westerly) at 6 kt gusting to 9 kt. There was no cloud and the QNH was 1012 hPa.

The aerodrome elevation was 1,650 ft and with the given temperature and QNH, the density altitude[14] was 4,440 ft.

Planned flight

Purpose

The purpose of the flight was to conduct a flight review so the pilot could exercise the privileges of a multi-engine aeroplane class rating.

Preparation

The ATSB obtained evidence to determine what opportunities the instructor had to gain familiarity with the aircraft prior to the flight. On 30 November 2019, the pilot contacted the instructor to ask whether they could do this flight review. The instructor responded being happy to do the review and would be qualified to do so following completion of an instructor rating renewal (proficiency check). The instructor anticipated needing about 1 hour on the ground to become familiar with the aircraft and reported having flown it previously, with an experienced pilot. On December 10, the instructor arranged to conduct the instructor rating renewal on December 13 and confirmed with the pilot that they would do the flight review on December 14.

Documents that the instructor carried immediately before and/or during the accident flight included information about the P68 C aircraft flown the previous day for the instructor rating renewal and regulations pertaining to flight reviews. There was no information about the Angel 44 aircraft.

Pre-flight planning

On the morning of the accident flight, the pilot departed from a friend's house at about 0800. A witness saw the pilot conducting engine run-ups in VH-IAZ at about 0915 and closed-circuit television (CCTV) footage showed the aircraft taxi and park near the maintainer's hangar at 0922.

CCTV footage showed the pilot and instructor walking past the hangar together in a westerly direction at 0950, both carrying flight bags. About 21 minutes later, they walked east towards the parked aircraft. It is probable that the plan for the flight was discussed between them during that time, and as they walked to the aircraft, the pilot can be heard to say 'right circuit', which was the circuit direction for runway 28. Another 35 minutes elapsed before the aircraft commenced taxiing.

In-flight exercises

Table 2 shows a transcription of a document found at the accident site, confirmed to be in the instructor's handwriting. The aircraft registration, model and date were written across the top of the page, followed by the numbers '10-58' and '10-44'. The pilot broadcast rolling on runway 28 at 1058, consistent with the instructor logging the time the aircraft became airborne. The second time (1044) may have been the engine start time, as the aircraft commenced taxiing at 1046.

The document listed items that were required to be demonstrated for a multi-engine flight review. Of the standards required to demonstrate competency for a flight review, the list represented what could be considered a bare minimum of the required procedures (see section *Flight reviews*). Of the listed exercises, some had been ticked, presumably to indicate they were complete. The item 'Missed approach' was ticked. The next item on the list was a short-field landing, which was consistent with witnesses observing the aircraft touch down just before commencing the second

[14] Density altitude is pressure altitude corrected for temperature. In layman's terms, it directly affects the performance parameters of any aircraft, and in effect it is the equivalent altitude of where, performance-wise, the aircraft 'thinks' it is. The higher the density altitude, the lower the aircraft performance, and vice versa. (Skybrary)

take-off, rather than a missed approach, where it would not be expected to touch down. A simulated engine failure after take-off was next in the sequence, which was to be followed by a single-engine approach and landing. A diagram that the instructor had drawn on the same document as the list, showed a missed approach followed by an engine failure after take-off in a single circuit pattern.

Table 2: Transcribed copy of handwritten plan for the flight

IAZ ANGEL 44 14/12/19	
	10-58 10-44
Short field take-off	
Stall and recovery	✓
Steep turn	✓
500’ turn	✓
1 full circuit	
Missed approach	✓
Short field landing	
Engine failure take-off (EFATO)	
Single engine approach and land	

Source: Retrieved from the accident site by Queensland Police, transcribed by ATSB

Flight reviews

Flight instructor requirements

The instructor held grade 1 training and multi-engine aeroplane training class rating endorsements, and was authorised to do the flight review in accordance with Civil Aviation Safety Regulations (CASR) including 61.1175. However, the instructor was not authorised to include any training, as the review was not being conducted under the oversight of a training organisation.

General competency requirement

To operate an aircraft, pilots are required to be competent. CASR 61.385 *Limitations on exercise of privileges of pilot licences—general competency requirement*, included:

> 1. The holder of a pilot licence is authorised to exercise the privileges of the licence in an aircraft only if the holder is competent in operating the aircraft to the standards mentioned in the Part 61 Manual of Standards for the class or type to which the aircraft belongs, including all of the following areas:
>
> a) operating the aircraft’s navigation and operating systems;
>
> b) conducting all normal, abnormal and emergency flight procedures for the aircraft;
>
> c) applying operating limitations;
>
> d) weight and balance requirements;
>
> e) applying aircraft performance data, including take-off and landing performance data, for the aircraft.

Flight review requirements

CASR 61.745 *Limitations on exercise of privileges of aircraft class ratings—flight review,* required a pilot to complete a flight review within the previous 24 months to exercise the privileges of a rating, in this case a multi-engine aeroplane class rating. As the pilot had not completed a flight review within the 24 months prior to the accident flight (or completed CASA medical requirements), the instructor was the pilot-in-command for the flight.

The CASA publication *Flight crew licensing—Flight reviews*, described a flight review as

> an opportunity to receive training that refreshes your flying skills and operational knowledge.

It stated that the instructor

> is responsible for designing appropriate content for your flight review. A flight review should include training, so it is not just an assessment.

It explained that if the review includes training, it must be done under an approved training organisation.

However, while CASA strongly encourages pilots to include training within their flight reviews, flight reviews could be conducted as a private flight, not under the oversight of a training organisation, as long as training was not included.

The publication further stated that the

> requirements of a flight review are met when the instructor conducting the review is satisfied you have demonstrated competency for the rating according to the Part 61 Manual of Standards (MOS).

If on initial assessment, the instructor deemed that the pilot needed training, that would then have to be conducted with the oversight of a training organisation.

CASR 61.400 *Limitations on exercise of privileges of pilot licences—flight review*, required the pilot to demonstrate in the flight review, that they are competent in each unit of competency mentioned in the Part 61 MOS for the rating.

Relevant standards

Of particular relevance to this occurrence, the Part 61 MOS standards required to demonstrate competency for a multi-engine aeroplane class rating flight review, included:

> 2.6 FR-MEAC.6 – Manage non-normal and emergency conditions
>
> (a) manage a simulated engine failure in the take-off segment;
>
> (b) manage a simulated partial engine failure;
>
> (c) manage a simulated complete engine failure and execute a simulated asymmetric approach and landing;
>
> (d) manage aircraft system malfunctions.

CASA does not provide a definition of the 'take-off segment' or what maximum height above the runway this extends to. However, CASA guidance recommends that instructors consider not conducting simulated engine failure in the take-off segment exercises below 400 ft (see *Simulated engine failures after take-off*).

Comparison flight review requirements

The US Federal Aviation Regulations also required a flight review every 2 years with an instructor, with some exemptions. A US flight review must consist of a minimum of 1 hour of ground training and 1 hour of flight training. The FAA did not permit flight reviews to be conducted without including training. The US Federal Aviation Administration (FAA) advisory circular (AC) 61-98D – *Currency requirements and guidance for the flight review and instrument proficiency check*, provided the intent of a flight review as 'a training event in which proficiency is evaluated.' The AC advised that flight reviews should always include abnormal and emergency procedures.

Regarding instructor qualifications, the FAA AC advised that:

> For aircraft in which the flight instructor is not current or with which he or she is not familiar, he or she should obtain recent flight experience or sufficient knowledge of aircraft limitations, characteristics, and performance before conducting the review.

Additionally, US Federal Aviation Regulation 61.195 stipulated that a flight instructor may not give training in a multi-engine aeroplane, unless they have at least 5 flight hours of pilot-in-command time in the specific make and model aeroplane.

Transport Canada provides several means for private pilots to remain current and proficient, including a biennial component, of which one option is a flight review conducted by an instructor. The alternative options to a flight review include attending a seminar or completing on-line study.

The European Union Aviation Safety Agency's multi-engine piston rating for aeroplanes was valid for 1 year. To revalidate the rating, a pilot must pass a proficiency check with an approved examiner, in a multi-engine piston (single-pilot) aeroplane or an approved simulator. During the rating validity period, the pilot must have completed at least one route sector of a single-pilot multi-engine aeroplane with an examiner.

Multi-engine class rating and the Angel 44

The Angel 44 aircraft was included in the multi-engine aeroplane class rating. This means that CASA assessed it as not having unusual performance or handling characteristics compared with other light (under 5,700 kg) twin-engine aeroplanes. International Civil Aviation Organization Annex 1 recommended (2.1.3.1.1) that class ratings should be established for aircraft for single-pilot operations which have 'comparable handling, performance and other characteristics.'

The last pilot to fly the aircraft prior to the accident flight had about 30 hours of experience in it. That pilot reported that the controls were all familiar but slightly unusual. Having previously conducted a simulated engine failure after take-off at about 500 ft above the ground, the pilot reported that the aircraft handled normally when the yaw was corrected, the standard actions performed and blue-line speed (see section *Key speeds* below) was maintained. While that pilot would not recommend a pilot flew it without any training, the pilot's expectation was that any commercial multi-engine rated pilot should be able to manage a circuit with both engines operative.

A pilot with extensive experience flying Angel 44 aircraft advised that the aircraft was more 'docile' than other twin-engine aeroplanes and had less propeller torque effect due to the geometry of the engines and propellers. That pilot reported that during take-off, unlike other twin-engine aeroplanes, it yaws right (rather than left), so left rudder is needed to keep straight. However, with one engine inoperative, it is the same as other twin-engine aeroplanes in that opposite rudder (to the inoperative engine) is used to counteract the yaw. That pilot confirmed that the initial actions following an engine failure are the same as for other twin-engine aeroplanes.

The experienced pilot further commented that if a pilot was new to the aircraft, it would take several hours in the aircraft to be competent and 5 to 12 hours to get comfortable with it. The pilot advised that in the US, although the regulations require an instructor to have 5 hours before they can instruct in an aircraft, insurers generally require 12 hours experience in the aircraft make and model.

Asymmetric flight

Asymmetric control

In light twin-engine aeroplanes, with one engine inoperative, the asymmetric thrust will cause the aeroplane to yaw (rotate about its vertical axis) towards the inoperative engine. As a secondary effect of yaw, it will also roll. The yawing needs to be countered by deflection of the rudder and a small aileron deflection to raise the inoperative engine wing in order to maintain straight flight or 'directional control'. The amount of rudder deflection needed increases as the operative engine power increases and airspeed reduces, to a minimum control speed, below which the rudder is ineffective in maintaining directional control. Angle of bank has a large effect on the minimum control speed, and if the aeroplane is banked towards, instead of away from the inoperative engine, the minimum control speed increases significantly.

Below the minimum control speed, the pilot must reduce power on the operative engine to reduce the asymmetric force, and/or lower the aircraft nose to increase airspeed, to prevent a loss of control. If directional control is lost, the aircraft will yaw and then roll rapidly. While controlled flight can be recovered if enough height is available, reducing power and lowering the nose when close to the ground may result in a landing. The US FAA *Airplane Flying Handbook* Chapter 12 stated:

> Landing under control is paramount. The greatest hazard in a single-engine takeoff is attempting to fly when it is not within the performance capability of the airplane to do so. An accident is inevitable.

Performance requirement

Subsection 8 of Civil Aviation Order 20.7.4 required multi-engine aeroplanes below 5,700 kg to be able to climb at a gradient of 1 per cent, or to maintain height, as follows:

> 8.1 Multi-engined aeroplanes engaged in charter operations under the Instrument Flight Rules or aerial work operations under the Instrument Flight Rules must have the ability to climb with a critical engine inoperative at a gradient of 1% at all heights up to 5 000 feet in the standard atmosphere in the following configuration:
>
> (a) propeller of inoperative engine stopped;
>
> (b) undercarriage (if retractable) and flaps retracted;
>
> (c) remaining engine(s) operating at maximum continuous power;
>
> (d) airspeed not less than 1.2 V_S [stalling speed].
>
> 8.2 Multi-engined aeroplanes (other than those specified in paragraph 8.1) must have the ability to maintain height at all heights up to 5 000 feet in the standard atmosphere in the configuration specified in subparagraphs 8.1 (a), (b), (c) and (d).

Key speeds

Three key 'V' speeds critical to understanding the accident flight were specified in the Angel 44 AFM. They are stalling speed, best rate of climb speed with one engine inoperative, and minimum control speed.

These reference V speeds are published for specific configurations and the actual V speeds will be different in any other configuration. The ATSB investigation considered the published V speeds and the likely actual V speeds associated with the aircraft's probable configuration when the loss of control occurred.

The aircraft configuration was:

- approximately 5,100 lb (2,313 kg) weight
- CG slightly forward of mid-range
- flaps up or nearly up
- landing gear partially retracted
- 15 degrees right wing down angle of bank
- left engine at full power
- right engine between idle and 1,300 RPM
- right propeller not feathered.

Stalling speed

Stalling speed (V_S) is defined as the minimum steady flight speed at which the aeroplane is controllable in a given configuration. V_{SO} is the stalling speed in the landing configuration.

The AFM specified V_{SO} as 57.5 kt calibrated airspeed (KCAS)[15] for the aircraft in 1G flight at maximum gross weight, most forward CG, power off and in the landing configuration (flaps and landing gear fully extended).

[15] According to the AFM, the calibrated airspeed was within about 1 kt of the indicated airspeed.

However, an aircraft will stall when the critical angle of attack is exceeded, regardless of airspeed. To this end, the AFM provided a table from which to derive stalling speeds including:

- at weights less than the maximum gross weight
- flap at 0°, 20° and 37° (fully extended)
- landing gear up and down
- 0°, 15°, 30°, 45° and 60° angle of bank
- aft CG.

The stalling speed in the probable configuration at the point of loss of control was about 68 KCAS. Flight testing for aircraft certification found that full power (on both engines) reduced stalling speed by about 12 kt. Therefore, the stalling speed with 1,300 RPM on the right engine may have been 4–6 kt lower, that is, 62–64 kt.

As increase in power reduces the stalling speed, asymmetric thrust will also produce asymmetric stall characteristics, with the inoperative engine side wing stalling at a higher airspeed than the operative engine wing.

The AFM also stated that when recovering from single-engine stall, an altitude loss of 800 ft could be expected.

Best rate of climb speed with one engine inoperative

The best rate of climb speed with one engine inoperative (single-engine) (V_{YSE}) is marked on the airspeed indicator with a blue radial line and is therefore also known as the 'blue-line speed'. In the Angel 44 aircraft it was a thick line or 'sector' marked from 90–92 KIAS (Figure 3). This represented the single-engine best rate of climb speed at maximum weight, with the lower value of 90 KIAS for 5,000 ft AMSL and the higher value of 92 KIAS for sea level. According to the AFM, the single engine best rate of climb is established in the following configuration:

- gear and flaps up
- the critical (left) engine[16] feathered [note that the flight test data detailed in the next section states that the *right* engine was the critical engine but that the difference was not significant]
- full power on the right engine
- the inoperative engine wing up about 1°.

The AFM *Climb performance summary* table specified single-engine climb performance in feet per minute (fpm) and the associated best rate of climb speed. These were provided for gross weights of 5,800 lb (2,631 kg) and 4,800 lb (2,177 kg) and altitudes at the associated international standard atmosphere (ISA) temperatures from sea level to 20,000 ft AMSL.

Interpolating from the AFM table for the 4,500 ft density altitude (at 100 ft above ground level on the accident flight) and the aircraft weight (which was less than maximum weight), the single engine climb rate was approximately 169 fpm at a single engine best rate of climb speed of 89 KIAS. Note this equates to a climb gradient of about 1.87 per cent. Therefore, a positive rate of climb could have been expected on the accident flight if the aircraft had been configured for the best rate of climb as above.

However, compared with the configuration for best single engine climb performance, at the time of the loss of control on the accident take-off, the landing gear was probably not fully retracted, the right engine was probably simulated inoperative and the propeller was not feathered (although an engine speed of 1,300 RPM may have been selected to simulate the reduced drag from a feathered propeller) and the right wing was banked down about 15 degrees rather than up 1 degree. Therefore, the aircraft was not configured to achieve the expected rate of climb.

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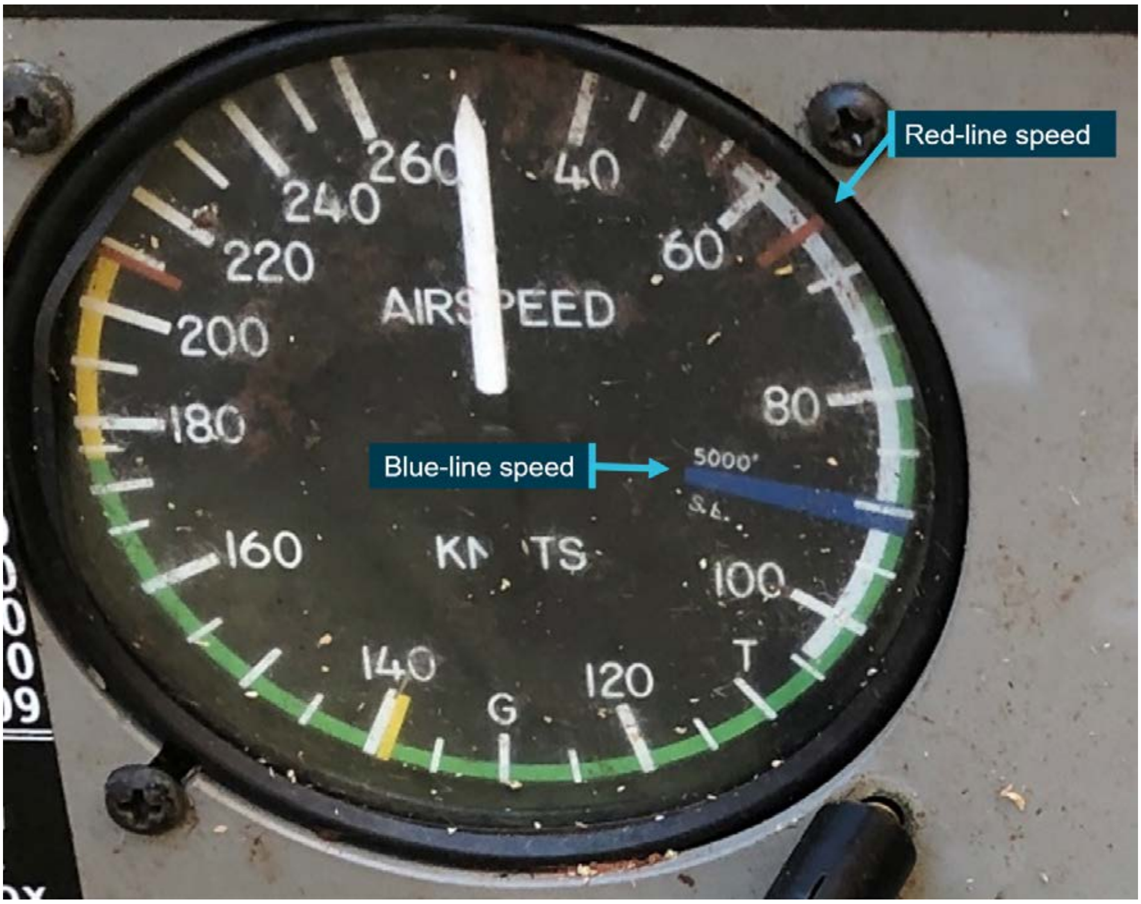
16 The critical engine of a multi-engine fixed-wing aircraft is the engine that, in the event of failure, would most adversely affect the performance or handling abilities of an aircraft. (Skybrary)

Moreover, in the environmental conditions and with the landing gear extended, the aircraft was almost certainly unable to maintain altitude. This was specified in the AFM, which warned:

> *The airplane will not maintain altitude at most weights, altitudes and temperatures with gear or flaps extended.*

Figure 3: Airspeed indicator from VH-IAZ showing red-line (V_{MC}) and blue-line (V_{YSE}) speeds



Source: VH-IAZ annotated by ATSB

Minimum control speed

Definition

The CASA Civil Aviation Advisory Publication (CAAP) 5.23-1(2) *Multi-engine aeroplane operations and training*, defined minimum control speed (V_{MC}) as:

> a speed that is associated with the maintenance of directional control during asymmetric flight. If the pilot flies below this speed the tail fin and rudder are unable to generate enough lift to prevent the aircraft from yawing. If uncorrected, the yaw causes roll, the nose drops, the aircraft rapidly assumes a spiral descent or even dive, and if the aircraft is at low altitude, it will impact steeply into the ground. This type of accident is not uncommon in a multi-engine aircraft during training or actual engine failure.

Flight test and published figure

Minimum control speed (V_{MC}) is published in the AFM and obtained from testing in a specific configuration. There is both a ground value (V_{MCG}) and an airborne value (V_{MCA}), but for simplicity, V_{MC} usually refers to V_{MCA}. V_{MC} is marked with a red line on the airspeed indicator, and often referred to as 'red-line speed' (Figure 3).The AFM specified the aircraft's minimum control speed (V_{MC}) as 65 KIAS and stated:

> This is the minimum speed at which the airplane is controllable with takeoff power on one engine, the other engine suddenly made inoperative, 5° bank toward the operating engine, takeoff flaps (20°), and the landing gear retracted.

At the time of the Angel 44's certification, V_{MC} was tested in accordance with US Federal Aviation Regulations (FAR) 23.149 *Minimum control speed*. This has since been replaced with FAR 23.2135 *Flight characteristics - Controllability*, which includes:

> (c) V_{MC} is the calibrated airspeed at which, following the sudden critical loss of thrust, it is possible to maintain control of the airplane. For multiengine airplanes, the applicant must determine V_{MC}, if applicable, for the most critical configurations used in takeoff and landing operations.

The aircraft manufacturer provided details about the V_{MC} flight testing for the aeroplane. Because aircraft weight does not appreciably affect V_{MC} but does affect V_S, it is conducted at a light weight (and aircraft loaded to aft CG) to demonstrate that V_{MC} does not exceed 1.2 V_{S1}[17] (which was 69 KCAS).

There were two steps to determining V_{MC}. These were conducted in the take-off configuration with flap extended 20° and landing gear down, full power on the left engine, right engine inoperative and propeller windmilling in the fully fine pitch setting.

Step 1: The aircraft was gradually slowed until directional control (heading) could not be maintained with the right wing raised 5°. This was done at various altitudes and extrapolated to sea level. For the Angel 44 aircraft, the V_{MC} obtained was about 61 kt and the published V_{MC} value was 65 kt.

Step 2: Engine cuts were performed (by pulling the mixture control) at 65 kt. The ability to maintain control (heading) and not allow speed to decay below 61 kt was verified.

The flight data computed V_{MC} obtained from testing decreased linearly from 65 kt at mean sea level to 54 kt at 10,000 ft, so at 5,000 ft the V_{MC} would be 60 kt.

The manufacturer advised that the pusher-propeller configuration significantly reduced some of the asymmetric effects of single-engine operation. While the amount of yaw was still large, the amount of roll was much less (than for a normal 'tractor' propeller aeroplane).

Actual minimum control speed

The published V_{MC} is for the specified configuration. The actual V_{MC} that a pilot will experience in flight varies depending on weight, altitude, rudder, thrust settings, configuration and, most significantly, on bank angle. Flight testing is generally not performed at bank angles other than with the inoperative engine wing raised 5°, as it is not required. Therefore, there is limited published data to show the effect of different configurations.

The CASA CAAP 5.23-1(2), stated that flight tests conducted in a Cessna Conquest aircraft, which had a published V_{MCA} of 91 kt, found that if the wings were held level instead of the inoperative engine wing raised 5°, the actual minimum control speed was 115 kt – an increase of 24 kt. Further, the testing found that lowering the wing towards the failed engine (instead of raising it), increased the minimum control speed by about 3 kt per degree of bank.

Other light twin-engine aeroplanes would similarly show an increase in actual minimum control speed with bank.

In the accident flight, witnesses assessed the aircraft's bank angle during the right turn at 15-30 degrees. That is, 20-35 degrees in the wrong direction of bank from the published V_{MC}. The density altitude, some power on the right engine and flap retracted, would have reduced the actual V_{MC} but would not diminish the bank angle effects. Additionally, as the right main landing gear was likely last to retract, due to the forces during the right turn, it would have further compounded the asymmetric drag, increasing the actual V_{MC}.

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[17] V_{S1}: The stalling speed with power off, at the maximum take-off weight with gear and flaps up.

The US FAA *Airplane Flying Handbook* Chapter 12 – *Transition to multiengine airplanes*, stated:

> The first consideration following engine failure during takeoff is to maintain control of the airplane. Maintaining directional control with prompt and often aggressive rudder application and STOPPING THE YAW is critical to the safety of flight…At least 5° of bank should be used initially to stop the yaw and maintain directional control. This initial bank input is held only momentarily, just long enough to establish or ensure directional control.

At speeds below the actual V_{MC}, the aircraft will lose directional control – yaw and then roll towards the inoperative engine. Transport Canada's Instructor Guide: *Multi-engine class rating (TP 11575)* stated:

> It cannot be too strongly emphasized that control will be regained only by a reduction in power of the good engine or by increasing airspeed through a change in pitch attitude, or both.

V_{YSE} as a safety margin above V_{MC}

In the accident flight, banking towards the inoperative engine significantly increased the actual V_{MC} to the extent that it probably exceeded the V_{YSE} (blue-line) speed (90-92 KIAS). This is important as pilots often use blue-line speed as a safety margin above V_{MC} for initiating a simulated engine failure, and assume that if blue-line speed is maintained, there is sufficient margin above red-line speed (published V_{MC}) to prevent an asymmetric loss of control.

However, for aircraft certification, the configurations used to determine the V_{MC} (red-line) and V_{YSE} (blue-line) speeds are different. For V_{MC}, the inoperative engine propeller is windmilling and wing raised 5°, the landing gear is down and the flaps are extended 20°. For V_{YSE}, the inoperative engine propeller is feathered and wing raised 1°, the landing gear and flaps are retracted. Even with the propeller feathered and landing gear and flaps retracted, if the pilot turns towards the inoperative engine, actual V_{MC} can exceed V_{YSE}. As it is essential to achieve and maintain an airspeed above actual V_{MC} in order to maintain directional control, understanding the effect of bank angle is vital to maintaining asymmetric control; particularly during take-off.

Rudder trim

Rudder deflection will be needed to control the yaw for the duration of the asymmetric flight. The rudder force that the pilot must apply can be reduced by adjusting the rudder trim. In the accident flight, the rudder trim was in the neutral position at the time of impact, however there was limited time to adjust the rudder trim before the loss of control and impact with terrain.

Engine failure procedures

The AFM contained the following emergency procedure for engine failure during take-off:

> After Airborne, Gear and Flaps Still Extended:
>
> a. Airplane Control……………….MAINTAIN
>
> b. Action………………………….LAND STRAIGHT AHEAD
>
> **WARNING**
>
> *The airplane will not maintain altitude at most weights, altitudes and temperatures with gear or flaps extended.*
>
> *If airspeed is below 65 KIAS, reduce power on operative engine as required to maintain lateral & directional control.*
>
> After Gear & Flaps Retracted:
>
> a. Airplane Control……………..…MAINTAIN
>
> b. Airspeed…………………..........VYSE OR GREATER
>
> c. Throttle (inoperative engine)…..CLOSE
>
> d. Propeller (inoperative engine)…FEATHER
>
> e. Throttle (operative engine)……..AS REQUIRED

f. Enroute Checklist……………….COMPLETE AS ABLE

Point a. *Airplane Control*, is maintained with use of rudder to counteract yaw and aileron to raise the inoperative engine wing 5°. The warning that 'if airspeed is below 65 KIAS…' only applies in the demonstrated V_{MC} configuration. If the inoperative engine wing is not raised 5°, a speed higher than 65 KIAS will be needed to maintain directional control.

Consistent with the warning in the published procedure, the FAA *Airplane Flying Handbook* stated:

> When operating near or above the single-engine ceiling and an engine failure is experienced shortly after lift-off, a landing must be accomplished on whatever essentially lies ahead…
>
> Remaining airborne and bleeding off airspeed in a futile attempt to maintain altitude is almost invariably fatal. Landing under control is paramount. The greatest hazard in a single-engine takeoff is attempting to fly when it is not within the performance capability of the airplane to do so. An accident is inevitable.

The manufacturer reported that on take-off, the Angel 44 aircraft accelerates to the 90 kt take-off safety speed 'pretty quickly.' In case of engine failure below that speed, a pilot would need to lower the aircraft nose and descend to achieve the required speed.

The Angel 44 AFM did not contain guidance for conduct of simulated engine failures (after take-off), provide a safe intentional single-engine speed,[18] or specify a safe altitude at which to conduct them. At the time of the aircraft certification, it was not required to provide this information.

Simulated engine failures after take-off

Civil Aviation Safety Authority guidance for simulated engine failures

Civil Aviation Advisory Publication (CAAP) 5.23-1(2) – *Multi-engine aeroplane operations and training* was produced by CASA in part, to provide advice on multi-engine training following 'a number of multi-engine aeroplane accidents caused by aircraft systems mismanagement and loss of control by pilots, flight instructors and persons approved to conduct multi-engine training'.

The CAAP specified risks associated with multi-engine training as:

- inappropriate management of complex aircraft systems
- conducting flight operations at low level (engine failures after take-off)
- conducting operations at or near V_{MCA} or V_{SO} with an engine inoperative[19]
- errors
- asymmetric operations including:
  - inadequate pre-take-off planning and briefing
  - decision making
  - aircraft control
  - performance awareness and management
  - operations with feathered propellers
  - missed approaches and go-arounds
  - final approach and landing
  - stalling.

[18] Safe single-engine speed (V_{SSE}): a speed above both VMC and the stall speed, selected to provide a margin of lateral and directional control when one engine is suddenly rendered inoperative. An intentional failing of one engine below this speed in not recommended. [Source: Transport Canada]

[19] See definitions in section *Key speeds*

To mitigate these risks, it suggests that:

> Instructors should consider not simulating engine failures below 400 ft above ground level (AGL) to provide a reasonable safety margin. The use of simulators has reduced the perils of this activity. Other mitigating factors are:
>
> - well trained instructors
> - complete knowledge of the theoretical factors involved during asymmetric operations
> - proven procedures, provided these are strictly adhered to
> - comprehensive pre-flight and pre-take-off planning and briefings
> - ongoing training
> - situation awareness
> - flying competency.

Section 6.5 of the CAAP, *Simulating engine failures*, advised instructors to 'be aware of the implications and be sure of their actions,' before simulating an engine failure. Further, that they 'must ensure that the aircraft is not in a dangerous situation to start with, such as the aircraft is flying too slow, too low, is in an unsuitable configuration or hazardous weather (wind, ice or visibility) is present. There is no benefit introducing more risks than the emergency being trained for.'

A CASA subject matter expert provided the following comments regarding simulated engine failures after take-off.

- The risk of not doing practice engine failures after take-off exceeded the risk of doing them. However, CASA had not conducted a risk assessment and were not required to do so by legislation for historical regulations.
- The suggested 400 ft AGL minimum height in CAAP 5.23-1(2) is general in nature and not specific to a particular aircraft type. This suggested minimum is consistent with a common point in the take-off path utilised in the certification. [US Federal Aviation Regulation 23.2120 for level 3 (7-9 passengers) low speed (V_{NO} and V_{MO} less than or equal to 250 KCAS)[20] aeroplanes requires a 1 per cent climb gradient at 400 ft above the take-off surface with the landing gear retracted and flaps in the take-off configuration. This was not in effect at the time VH-IAZ was certified and no similar criteria then applied to the aircraft. Based on data provided in the AFM, in the accident environmental conditions, and in the stated configuration, VH-IAZ would have met (and exceeded) this criterion.]
- Simulating engine failures after take-off is necessary because it is representative of what may occur. At lower density altitudes the operative engine will have better performance and the aircraft will have better climb performance.
- Conducting these at a higher altitude such as 3,000 or 5,000 ft AGL would still not ensure recovery in all instances, such as from a V_{MCA} departure. However, altitude provides an opportunity to regain speed [by lowering the aircraft nose and descending].
- The drills and hand and muscle movements should be practised at height then that skill and muscle memory taken to the after take-off scenario, where there is potential for the 'startle effect'. Conducting engine failures after take-off invokes an emotional response necessary to train for a real engine failure at low height above the ground.
- The competency check must be done in the environment where the skill is going to be used.

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[20] VNO – normal and VMO – maximum operating speeds

US Federal Aviation Administration

The US Federal Aviation Administration (FAA) *Flying light twins safely* brochure included the following training recommendation:

> Low-altitude engine failure is *never* worth the risks involved. Multiengine instructors should approach simulated engine failures below 400 feet AGL with extreme caution, and failures below 200 feet AGL should be reserved for simulators and training devices.

The US FAA *Airplane Flying Handbook Chapter 12 Addendum* included the following guidance regarding altitude and speed for simulating engine failures.

> When training in an airplane, initiation of a simulated engine inoperative emergency at low altitude normally occurs at a minimum of 400 feet AGL to mitigate the risk involved and only after the student has successfully mastered engine inoperative procedures at higher altitudes. Initiating a simulated low altitude engine inoperative emergency in the airplane at extremely low altitude, immediately after liftoff, or below V_{SSE} creates a situation where they [sic] are non-existent safety margins.

US National Transportation Safety Board

Due to a number of fatal accidents in the US where pilots did not maintain control following a loss of power in one engine while flying multi-engine aeroplanes, the US National Transportation Safety Board issued safety alert SA-081 – *Maintain airplane control with one engine inoperative*. It stated:

> These accidents demonstrate that having a multiengine rating alone may not be enough to avoid the risk of loss of aircraft control with one engine inoperative (OEI), especially if engine failure occurs during a critical phase of flight.

Recommendations in the safety alert included:

- Be thoroughly familiar with the recommended procedures and checklists for OEI operations—particularly the memory checklist items—in the airplane flight manual and pilot operating handbook.
- Ensure that you have a multiengine rating and establish multiengine proficiency.
- Seek training in any new multiengine airplane model you fly to ensure that you fully understand the relationship between OEI and VMC for each phase of flight and the proper recovery techniques for that airplane.

Flight training organisations

Based on the assessment that a large number of simulated engine failures after take-off are conducted every day in Australia without incident, the ATSB spoke to flight instructors from several flight training organisations to see what risk controls were used. Instructors usually used 400 ft AGL as a minimum height, but would start higher until the student was proficient. The aircraft would be accelerated to the manufacturer-recommended minimum safe intentional one-engine inoperative speed or blue-line speed before simulating the engine failure. As soon as the student either did not maintain heading or airspeed, the instructor would restore power and discontinue the exercise.

Related occurrences

Training accidents

A review of the ATSB occurrence database revealed that in the 10 years between 2008 and 2017, there were 24 accidents for twin-engine, VH-registered, aircraft under 5,700 kg[21] conducting training or checking. Of these, three involved an asymmetric simulated engine failure on take-off or climb.

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21 The same light multi engine aeroplane as the Angel 44, with a maximum certificated take-off weight of 5,700 kg or less.

The only fatal training accident during that period occurred on 30 May 2017. An inductee pilot undergoing a proficiency check, a chief pilot conducting the check and a CASA flying operations inspector observing the flight were on board a Cessna 441 (Conquest II) aircraft. Shortly after take-off from Renmark Airport, South Australia, a simulated engine failure was conducted at about 400 ft above the ground. The expected single-engine climb performance and airspeed were not achieved and the exercise was not discontinued. Consequently, about 40 seconds after initiation of the simulated engine failure, the aircraft experienced an asymmetric loss of control, from which recovery was not made.

The aircraft impacted the ground, all on board were fatally injured and the aircraft was destroyed. (ATSB investigation AO-2017-057). The investigation's safety message was:

> Conducting a simulated engine failure after an actual take-off is a high risk exercise with little margin for error. For that reason, Cessna recommended practicing this sequence in the [Cessna] 441 aircraft at a height of 5,000 ft above ground level to allow the opportunity for recovery in the event that control is lost.
>
> A review of past accidents indicates that, while accidents associated with engine malfunctions are rare, training to manage one engine inoperative flight (OEI) after take-off is important. The ATSB recommends that such training should follow the manufacturer's guidance and, if possible, be conducted in an aircraft simulator. If the sequence is conducted in the aircraft close to the ground then effective risk controls need to be in place to prevent a loss of control as recovery at low height will probably not be possible. Such defences include:
>
> - defined OEI performance criteria that, if not met, require immediate restoration of normal power
> - use of the appropriate handling techniques to correctly simulate the engine failure and ensure that aircraft drag is minimised/OEI performance is maximised
> - ensuring that the involved pilots have the appropriate recency and skill to conduct the exercise and that any detrimental external factors, such as high workload or pressure, are minimised.

The two other asymmetric training accidents were:

- On 23 December 2010, a flight instructor and student pilot departed Camden Airport, New South Wales on an instrument training flight in a Piper PA-30 (Twin Comanche) aircraft. Shortly after take-off, the instructor simulated an engine failure by moving the mixture control on the right engine rearwards at 400 ft above the ground. In response, the student reduced the engine control/s on the left engine. Shortly after, the airspeed decayed and the aircraft stalled. The aircraft rolled abruptly, with the right wing dropping to a 120° angle and the aircraft entered a spin. The instructor regained control of the aircraft at about 10 ft above ground level, with the aircraft in a relatively level attitude. As the nose of the aircraft was raised the airframe began to shudder, indicating that a stall was imminent. Consequently the instructor elected to reduce the throttles to idle and land the aircraft. The aircraft subsequently impacted the ground resulting in minor injuries to the instructor. The student was not injured. (ATSB investigation AO-2010-111).
- On 10 July 2009, a flight instructor and student were conducting asymmetric circuit refresher training in a Beechcraft Aircraft 76 at Bunbury Airport, Western Australia. During a go-around from a practice asymmetric landing, the flying pilot flared too high and bounced on one wheel. While the instructor said 'I have control', the student pilot applied power on the good engine, and (under 50 ft above the ground) the aircraft yawed right then impacted the ground in a flat attitude. The aircraft was seriously damaged but there were no reported injuries (ATSB occurrence number 200904058).

Engine failure and malfunction occurrences

For the same 10 year period (2008-2017) and types of aircraft, there were 405 actual engine failures or malfunctions reported to the ATSB. Of these, 43 per cent were in the take-off/climb phases of flight. Only 9 resulted in accidents (2%), but 78 per cent of accidents were in the take-off/climb phases of flight. Five accidents followed a single engine failure on take-off or climb that resulted in asymmetric thrust:

- On 6 February 2009, a Piper PA-31 aircraft was on a business flight departing from Darwin, Northern Territory. During the initial climb, the right engine gradually lost power. The aircraft failed to climb and the pilot shut the engine down and feathered the propeller. The aircraft did not maintain altitude and subsequently the pilot landed the aircraft on water. The pilot and five passengers walked to shore in knee deep water (ATSB occurrence number 200900366).
- On 23 March 2010, a Piper PA-30 was conducting a ferry flight to the United States. During the initial climb from San Francisco Airport, the left engine failed at 60 ft above the ground. The aircraft veered left and lost height until it struck the ground. The aircraft was seriously damaged but the pilot was not injured (ATSB occurrence number 201001978).
- On 15 June 2010, a Piper PA-31P aircraft, with a pilot and a flight nurse on board departed Bankstown Airport, New South Wales for a repositioning flight to Archerfield Airport, Queensland in preparation for a medical patient transfer flight. While the aircraft was climbing to 9,000 ft the right engine sustained a power problem and the pilot subsequently shut down that engine. Following the engine shut down, the aircraft's airspeed and rate of descent were not optimised for one engine inoperative flight. As a result, the aircraft descended to a low altitude over a suburban area and the pilot was then unable to maintain level flight, which led to a collision with terrain. Both occupants were fatally injured and the aircraft was destroyed (ATSB investigation AO-2010-043).
- On 14 November 2010, a Piper PA-31 aircraft was being operated on a passenger charter flight from Marree, South Australia. During the climb, at 2,500 ft, the pilot detected an unusual noise in the right engine followed by a gradual decrease in engine performance. The pilot returned to Marree Airport, however during the turn back the aircraft was unable to maintain altitude and elected to conduct a forced landing about 22 km south-east of the airport. The pilot did not feather the right engine as he assessed that the right engine was still producing some power. The aircraft was substantially damaged, however, the passengers and crew were able to exit the aircraft safely (ATSB investigation AO-2010-094).
- On 8 March 2015, the pilot of an Aero Commander 500 aircraft taxied for a charter flight from Badu Island to Horn Island, Queensland, with five passengers. The pilot commenced rotation and the nose and main landing gear lifted off the runway. Just as the main landing gear lifted off, the pilot detected a significant loss of power from the left engine. The aircraft yawed to the left, which the pilot counteracted with right rudder. He heard the left engine noise decrease noticeably and the aircraft dropped back onto the runway. The pilot immediately rejected the take-off; reduced the power to idle, and used rudder and brakes to maintain the runway centreline. Due to the wet runway surface, the aircraft did not decelerate as quickly as expected and the pilot anticipated that the aircraft would overshoot the runway. To avoid a steep slope and trees beyond the end of the runway, he steered the aircraft to the right towards more open and level ground. The aircraft collided with a fence and a bush resulting in substantial damage. The pilot and passengers were not injured (ATSB investigation AO-2015-028).

Risks associated with simulated and actual engine failures

While the risks associated with practice engine failures have mostly been eliminated for large air transport category aeroplanes through the use of simulators, accidents continue to occur worldwide as a result of simulated engine failures after take-off in flight in smaller (under 5,700 kg) multi-engine aeroplanes. The ATSB was unable to find any analyses or studies that had been conducted into the relative benefits versus risks of conducting simulated engine failures after take-off.

The above data on Australian accidents and incidents from 2008 to 2017 was used in the ATSB investigation into the fatal accident at Renmark in 2017 (described above) to conclude:

> A review of the ATSB occurrence database identified that there were three accidents during asymmetric training/checking flights in the last 10 years, with this accident being the only one with a fatal outcome.
>
> Over the same time period there were nine accidents associated with actual engine failures/malfunctions in 'small' aeroplanes like the Cessna 441, four of which followed a single engine failure on take-off/climb that resulted in asymmetric thrust but no injuries. One of the accidents was fatal and followed an engine failure at an altitude of about 7,500 ft. The nine accidents represented two per cent of the total number of engine failure/malfunction occurrences. However, 78 per cent of the accidents occurred during the take-off/climb phase of flight despite only 43 per cent of the total engine failures occurring during that flight phase.
>
> The data indicates that while accidents associated with engine malfunctions are rare, training to manage OEI flight after take-off is important.
>
> At present there is insufficient information available to accurately assess the accident rate associated with simulated engine failures, compared to the accident rate of actual engine failures occurring after take-off. Specifically, there is no data collected about the number of times asymmetric exercises are conducted in aircraft in Australia, in either flight training or company-based training and checking, which means the exposure is unknown.
>
> Without knowing the exposure rate and how the training exercises are being conducted, including whether they accurately represent the conditions of a real engine failure, the ATSB could not determine whether the benefits of conducting simulated engine failures at low level outweighed the risks. Further research in this area is required to answer that question.

Skill decay

A pilot's technical and non-technical skills decay when they are not used. To mitigate against this, pilots are subject to recency requirements to assess, practise and retain their skills.

Childs and Spears (1986) suggest that cognitive and procedural elements of flying skills decay more rapidly than control-oriented skills. Pilots whose skills had decayed, had difficulty correctly identifying cues and classifying situations, but once a situation was correctly classified, they remembered what to do.

Casner and others (2014) noted that hand-eye skills were quite resistant to forgetting, but decay was more significant for '…the set of cognitive skills needed to recall procedural steps, keep track of which steps have been completed and which steps remain, visualize the position of the aircraft, perform mental calculations, and recognize abnormal situations.' In addition, skill decay is more significant for procedural tasks with many steps and where the steps must be recalled in a specific order (Wisher and others 1999).

Simulated engine failures are predominantly procedural tasks, which require a set of actions to be completed. They are an abnormal situation and have serious consequences if not managed appropriately. These require well-rehearsed, proficient physical and mental skills as well as rapid cognition of the situation and decision making.

Safety analysis

Introduction

During a planned flight review, VH-IAZ touched down on the runway at Mareeba Airport and after accelerating, took off again. About 20 seconds after take-off, the aircraft rolled rapidly to the right and impacted terrain, fatally injuring the pilot and instructor.

Although post-mortem examination identified coronary atherosclerosis in the pilot and instructor, which increased the risk of incapacitation, there was no evidence that this occurred. The nature of the loss of aircraft control was consistent with the aircraft slowing to below the minimum control speed and as such, a medical event affecting the pilot flying was unlikely.

The following analysis will consider the operational factors associated with the development of the accident.

Development of the accident

Engine failure scenario

After the aircraft took off, witnesses observed it climb to 100–150 ft above ground level (AGL) and one witness heard an engine splutter. The aircraft was seen to turn and bank to the right, descend slowly then suddenly roll right wing down and impact the ground. Due to the low height reached and the abnormal engine sounds reported by witnesses, the ATSB analysed whether the loss of control occurred following an actual engine failure or an intentional simulated one.

Actual engine failure

Neither pilot declared an emergency on the common traffic advisory frequency, which would be expected following an actual engine failure but not a simulated one. In any case, however, there was very limited time available to make such a call.

Technical examination of the engines did not reveal any pre-impact failure that would have prevented the left engine from producing full power, and although the right engine was likely running overly rich,[22] there was no indication of an uncommanded power loss or complete engine failure.

Had the right engine actually failed shortly after take-off, when a witness heard spluttering, the immediate pilot actions called for the fuel mixture, propeller pitch and throttle levers to be pushed fully forwards, the landing gear and flaps selected up, and once the failed engine had been identified (as the right-hand engine) the right propeller feathered by moving the right pitch lever to the fully aft position. All of which could have been achievable within a few seconds.

However, at the accident site, the right propeller pitch lever was fully forward in the full fine pitch position, the propeller was not feathered and damage to the right propeller blades indicated that the right engine was making low power (and driving the propeller). These aspects were also consistent with the right engine's tachometer indication and mid-range throttle lever position; collectively suggesting a deliberate reduction in right engine power.

While an attempt to resolve or reduce rough engine operation may have involved movement of the right *fuel mixture* lever aft to a position lean of full rich, moving the right *throttle* lever aft would be very unlikely to do so. In this manner, the right throttle lever position was inconsistent with an attempt to resolve a partial power loss. Notably, witnesses reported similar engine sounds on the first take-off of the flight, after which there was no indication that the pilots had attempted or

[22] Overly rich mixture means there is incomplete combustion because the quantity of fuel injected exceeds the stoichiometric ratio, which is the correct fuel to air ratio where all fuel is burnt. This leads to soot visible in the exhaust and deposited in the cylinders.

needed to resolve any partial loss of power, nor considered it an issue that required a return to land.

Simulated engine failure

Unlike for an actual engine failure, feathering a propeller following a simulated engine failure after take-off is not recommended. Emulating the reduced drag from feathering is often accomplished by moving the throttle lever from idle to a 'zero thrust' position once the student or pilot has identified the correct simulated failed engine. This was consistent with the right throttle lever mid-range position.

In further support of the most likely scenario leading up to the loss of control being an intentional simulated failure of the right engine, was the requirement for a pilot to demonstrate management of a simulated engine failure after take-off as part of the flight review standards. Simulation of an engine failure by rapidly retarding the throttle was also consistent with the witness report of an audible 'splutter'. Additionally, the flight instructor's hand-written plan included a simulated engine failure after take-off, following a short-field landing, which had very likely just been conducted.

Aircraft performance

Given the density altitude at the time of the occurrence, the aircraft had minimal climb performance in the optimal one engine inoperative configuration, which included the propeller of the inoperative engine feathered, and the landing gear and flap retracted. However, while either the landing gear or flap were extended, the aircraft would not maintain altitude with one engine inoperative.

While the landing gear and flaps were probably selected up after take-off, the landing gear took 14 seconds to fully retract and gear retraction paused while the flaps retracted. Additionally, as the aircraft yawed and banked to the right, the right main landing gear would have experienced the greatest resistance and therefore would have been last of the three wheels to retract – principally as a result of gravitational forces and the inward landing gear retraction design. The extended right main landing gear would have increased the asymmetric drag and therefore the amount of rudder input required to counteract the yaw.

Therefore, commencing the simulated engine failure before the landing gear was fully retracted, likely resulted in the aircraft having insufficient performance to maintain altitude and reduced its ability to accelerate or maintain airspeed.

Response to simulated engine failure

With the aircraft unable to maintain altitude with one engine inoperative until the gear and flaps were fully retracted, a descent was necessary to maintain airspeed. Attempting to maintain altitude would have caused the airspeed to decrease. At the low height at which the simulated engine failure was commenced, this provided very limited time for the pilots to interpret the situation and abort the simulated engine failure exercise by restoring full power to the inoperative engine.

The fact that the aircraft was observed to turn and bank right and slowly descend, indicated that directional control was not achieved following the simulated engine failure.

The emergency procedure specified in the Angel 44 *Airplane Flight Manual* (AFM) for an engine failure after take-off with the landing gear and flaps extended, was to maintain control of the aeroplane and land straight ahead. There was, however, no obstacle-free area ahead for landing, because the simulated engine failure was commenced after a touch-and-go landing, in which the aircraft became airborne close to the end of the runway.

The next steps in the AFM emergency procedure were to be conducted after retraction of the landing gear and flaps. These required the pilot to maintain directional control and airspeed at or above the best rate of climb with one engine inoperative airspeed ('blue-line speed'). The procedure stated that if below the published minimum control speed (V_{MC} or ‘red-line speed’), ‘reduce power on the operative engine as required to maintain lateral and directional control.’

As the aircraft turned and banked right, towards the inoperative engine, the actual minimum control speed increased significantly above the red-line speed, due largely to the bank angle. Therefore, increased airspeed was needed to regain directional control; to be achieved by lowering the aircraft nose. The aircraft was then at very low height above the ground with the decreasing airspeed rapidly approaching the actual minimum control speed, which was significantly higher than the red-line speed and may also have exceeded the blue-line speed.

Without adequate height above terrain available to descend and increase airspeed, when airspeed reduction below the actual minimum control speed was imminent, preventing a ‘V_{MC} roll’ required the pilots to reduce power on both engines and land ahead. However, the aircraft departed controlled flight with no indication of a reduction in power on the left engine or an attempt to land. Once the aircraft departed controlled flight, there was insufficient altitude available to effect a recovery before the aircraft collided with terrain. The aircraft was at a height where reducing power and landing ahead would have resulted in a landing beyond the aerodrome confines and almost certain collision with vegetation. Landing ahead with the aircraft under control would almost certainly have resulted in a safer outcome. Despite this, it can be a difficult decision for a pilot to make, particularly when faced with a simulated, rather than actual engine failure.

The Angel 44 flight manual did not specify a safe altitude for conducting simulated engine failures, nor was it required to. The aircraft almost certainly did not reach the Civil Aviation Safety Authority’s (CASA’s) recommended minimum height of 400 ft AGL at which to simulate an engine failure. Even with the right-side (instructor’s) altimeter likely reading about 90 ft above the actual barometric altitude, it would have been indicating an altitude 190 to 240 ft above the aerodrome elevation when the simulated engine failure commenced.

Instructor experience and proficiency

The instructor had almost no experience in the aircraft make and model, and limited opportunity to prepare for the flight. While the accident flight had initially been discussed two weeks prior, there was no evidence that the instructor obtained a flight manual or had any information specific to the aircraft make and model. Given that the pilot owned the aircraft and had over 300 hours experience in it, the instructor may have assumed that the pilot was competent in the aircraft and would not have to intervene, particularly as the flight review was not to include training, as it was being conducted as a private flight. Had the instructor known the pilot had not flown for over 3 years however, it could be expected that the instructor would consider pilot recency when planning the flight.

On the morning of the accident flight, the pilot and instructor had the opportunity to discuss the flight for around 20 minutes at the airport then about 30 minutes in the aircraft prior to taxiing, however, it could not be known what was discussed during that time. During the 14 minutes that the aircraft was airborne before re-joining the aerodrome circuit, the pilot had demonstrated several items of the planned flight review. There was insufficient time for the instructor to also gain proficiency at operating the aircraft during the short flight.

The Angel 44 aircraft was included in the multi-engine aeroplane class rating as CASA considered that it did not have any unusual performance or handling characteristics. It also required the same standard actions in response to an engine failure as other aircraft in the same class. Although the instructor had the previous day demonstrated proficiency at managing engine failures after take-off in a twin-engine aeroplane with fixed landing gear, it had been nearly two years since the instructor had last flown one with retractable landing gear (the Piper PA-34). The Angel 44’s landing gear took twice as long to retract as that aeroplane’s, during which time it would not maintain altitude with one engine inoperative. With inexperience in the Angel 44 and limited preparation for the flight, the instructor was likely unaware how long the landing gear took to retract and the resultant negation of effective climb performance.

Pilot proficiency

The pilot had demonstrated proficiency in handling simulated engine failures in the Angel 44 and other aircraft types over many years and thousands of hours of flying experience. Additionally, because this was the only aircraft of its type in Australia, when it was operated by a charter company, the pilot had CASA approval to conduct check flights for company pilots in the aircraft—including managing simulated engine failures. Significantly however, the pilot had not flown at all for over 3 years before the accident.

Research shows that skills decay significantly after 1 year and then continue to do so, particularly for procedure-based tasks such as managing an engine failure after take-off. This decay probably increased the pilot's workload and the time taken to complete the required actions following simulation of the engine failure, and likely affected the pilot's ability to interpret the situation and act to prevent a loss of control.

Research has also established that people are generally poor at assessing their own competency. Under the general competency requirements, pilots must be competent for the planned flight. A meta-analysis showed that in general, people overestimate their abilities and performance – this can stem from being too optimistic and a belief they are above average (Dunning, Heath & Suls, 2004). In the medical industry, surgeons were found to be able to self-assess ability in technical skills, but less able to assess their own non-technical skills (Arora et al., 2011).

The pilot may not have appreciated the likelihood of skill decay and over-estimated their ability to manage a simulated engine failure. Regular demonstrated proficiency, including in abnormal and emergency procedures, is required in commercial aviation settings, which reduces the reliance on self-assessed competency.

To regain a level of proficiency following the absence from flying, it would have been prudent to spend time conducting familiarisation at a safe height prior to attempting low-level asymmetric exercises. As the aircraft was airborne for 14 minutes prior to the simulated engine failure, there was limited time for the pilot to become proficient.

Aircraft preservation

The aircraft's engines exhibited levels of internal corrosion inconsistent with their service life. In the years preceding the accident, the aircraft went through several periods of limited to no operation. While the aircraft's maintainers reported that the engines had been run on several occasions, there was no indication that prescribed periodic storage maintenance practices had been conducted. Additionally, the engine manufacturer advised that ground running the engines was not a substitute for flying and had the potential to worsen corrosion. Further, storing the aircraft with fuel tanks less than full increased the potential for water to enter the fuel system components.

The corrosion in the fuel system of the right engine indicated that the engine had been run with water contamination in the fuel. This may have occurred in April 2019 when the fuel contamination was found, or during engine ground runs conducted by the aircraft's maintainers. Where water contamination is evident, in addition to draining the fuel tank, it is necessary to disconnect the fuel lines before running the engine to ensure water is not introduced to the engine fuel system.

There was no evidence that inadequate engine preservation directly contributed to the accident, however, the corrosion-related debris located in the fuel system likely resulted in the right engine running overly rich, producing black smoke and backfiring, as well as a probable reduction in maximum power available. It is also likely that the service life of the engines would have been adversely affected, which had the potential to increase the risk of premature engine performance issues.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

From the evidence available, the following findings are made with respect to the collision with terrain involving an Angel Aircraft Corporation Model 44 aircraft, registered VH-IAZ, which occurred near Mareeba Airport, Queensland, on 14 December 2019.

These findings should not be read as apportioning blame or liability to any organisation or individual.

Contributing factors

- The flight instructor very likely conducted a simulated engine failure after take-off in environmental conditions and a configuration in which the aircraft was unable to maintain altitude with one engine inoperative.
- Having not acted quickly to restore power to the simulated inoperative engine, the pilots did not reduce power and land ahead (in accordance with the *Airplane Flight Manual* procedure) before the combination of low airspeed and bank angle resulted in a loss of directional control at a height too low to recover.
- The instructor had very limited experience with the aircraft type, and with limited preparation for the flight, was likely unaware of the landing gear and flap retraction time and the extent of their influence on performance with one engine inoperative.

Other factors that increased risk

- The pilot had not flown for 3 years prior to the accident flight, which likely resulted in a decay in skills at managing tasks such as an engine failure after take-off and in decision-making ability. The absence of flying practice before the flight review probably affected the pilot's ability to manage the asymmetric low-level flight.
- The aircraft had not been flown for more than 2 years and had not been stored in accordance with the airframe and engine manufacturers' recommendations. This very likely resulted in some of the right engine cylinders running with excessive fuel to air ratio for complete combustion and may also have reduced the expected service life of both engines' components.
- The right-side altimeter was probably set to an incorrect barometric pressure, resulting in it over-reading the aircraft's altitude by about 90 ft.

General details

Occurrence details

Date and time:	14 December 2019 – 1115 EST	
Occurrence category:	Accident	
Primary occurrence type:	Collision with terrain	
Location:	near Mareeba Airport, Queensland	
	Latitude: 17° 4.1520' S	Longitude: 145° 25.1520' E

Aircraft details

Manufacturer and model:	Angel Aircraft Corporation 44	
Registration:	VH-IAZ	
Serial number:	004	
Type of operation:	Private – Other	
Activity type:	General aviation – Instructional flying	
Departure:	Mareeba Airport, Queensland	
Destination:	Mareeba Airport, Queensland	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 2 Fatal	Passengers – 0
Aircraft damage:	Destroyed	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- aircraft maintainer
- witnesses
- aircraft, engine and propeller manufacturers
- Bureau of Meteorology
- Civil Aviation Safety Authority
- Queensland Police and forensic pathologist.

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Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section 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 following directly involved parties:

- the aircraft maintainer
- the aircraft, engine and propeller manufacturers
- the certificate of airworthiness issuer
- the Civil Aviation Safety Authority
- the US National Transportation Safety Board
- the UK Air Accidents Investigation Branch.

Submissions were received from:

- the aircraft manufacturer
- the certificate of airworthiness issuer
- the Civil Aviation Safety Authority.

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

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- 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, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

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

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining 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. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.