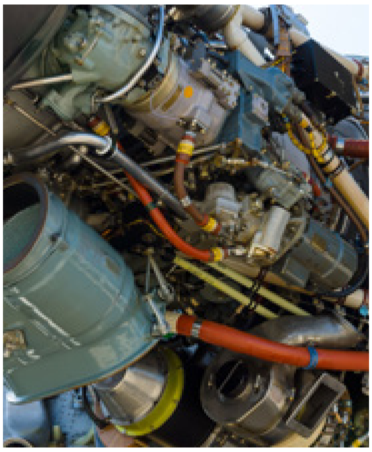
Australian Government

Australian Transport Safety Bureau

Power plant failures in turboprop-powered aircraft

2012 to 2016



Investigation

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Addendum

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Safety summary

Why the ATSB did this research

This is the second in a series of research investigations looking at technical failures reported to the ATSB. This report reviews power plant problems affecting turboprop-powered aircraft between 2012 and 2016.

By summarising power plant-related occurrences, this report provides an opportunity for operators to compare their own experiences with others flying the same or similar aircraft types, or aircraft using the same engines. By doing so, the ATSB hopes that the wider aviation industry will be able to learn from the experience of others.

What the ATSB found

A review of power plant-related occurrences reported to the ATSB showed that there were 417 occurrences involving turboprop-powered aircraft between 2012 and 2016 (83 per year on average). The subset of occurrences involving operators whose flight hours were known consisted of 314 occurrences in the four years between 2012 and 2015 (79 per year on average). With a combined total of just over 1.4 million flight hours for these aircraft in this timeframe, this subset equates to approximately 2.2 occurrences every 10,000 flight hours.

The vast majority of all the 417 occurrences (96%) were classified as 'low-risk rating' occurrences with a low or no accident outcome, however, there were four classified as 'medium-risk' and three as 'high-risk'. The three occurrences classified as high-risk occurrences all involved engine failures or malfunctions with forced/precautionary landings in single-engine Cessna 208 (Caravan) aircraft. There were no occurrences classified as 'very high-risk'.

The two occurrences in the set that resulted in any injury (both minor) were the result of engine failure or malfunctions and collision with terrain occurrences in aerial agricultural operations. The five occurrences classified as 'accidents' all involved aerial work operations, four in aerial agriculture and one in emergency medical services operations.

One aircraft type was found to have a rate of 13.9 power plant-related occurrences per 10,000 hours flown, more than double the rate of any other aircraft type. However, with only four occurrences between 2012 and 2015, the high rate is due to relatively very low flight hours for this aircraft. All four of these occurrences were classified as incidents (rather than accidents or serious incidents) and classified as low risk rating occurrences. Additionally, the sole operator of this aircraft type in Australia advised the ATSB that the fleet was retired in 2017 and replaced with a newer turbofan alternative.

Safety message

Timely and vigilant reporting of all technical problems is encouraged to ensure as much information as possible is collected so as to enable a better understanding of the failures. Of particular importance in technical occurrences are the follow-up reports from engineering inspections provided to the ATSB. These are often the only way that the root cause of the problem can be determined.

Contents

Context

When aviation safety incidents and accidents happen in Australia, or involve Australian-registered aircraft operating overseas, they are required to be reported to the ATSB. Accidents, as well as those incidents that pose a serious risk to the safety of aviation operations, are investigated. Most reports, however, are used to help the ATSB establish whether trends exist, if they are indicative of safety issues, and how these could affect different types of aviation operations.

Proactively reviewing all occurrences reported to the ATSB provides the opportunity to monitor many types of Australian operations before emerging safety issues manifest as accidents. By doing so, it is hoped that the wider aviation industry will be able to learn from the experience of others.

This report is the second in a series of aviation research investigations looking at technical failures reported to the ATSB. The first (*AR-2013-002, Power plant failures in turbofan-powered aircraft*) reviewed power plant problems affecting turbofan-powered aircraft. This report will review power plant problems affecting turboprop-powered aircraft, and the types of incidents with which they are associated.

Reporting of technical failures

Under the *Transport Safety Investigation Act (2003)* and *Transport Safety Investigation Regulations (2003)*, technical issues must be reported to the ATSB if they constitute a transport safety matter. While a transport safety matter can include anything that has affected, or has the potential to affect, the safety of an aircraft, power plant-related technical issues that occur from when the aircraft is being prepared for flight until all crew and passengers have disembarked after flight, must be reported to the ATSB when they include:

- a failure that has prevented an aircraft from achieving predicted performance during take-off or climb
- an uncontained or contained engine failure
- a mechanical failure resulting in the shutdown of an engine (precautionary or otherwise)
- any malfunction that affects the operation of the aircraft
- any technical failure that has caused death or serious injury, led to aircraft control difficulties, or that has seriously affected operation of the aircraft
- items becoming detached from an aircraft
- a failure that has caused fumes, smoke, or fire, or has led to crew incapacitation.

Many of these technical issues would be considered a ‘major defect’ or ‘other major defect’ by the Civil Aviation Safety Authority (CASA), and should be reported to CASA via the Defect Report Service. These reports can be submitted via the online portal at the CASA website.

Case Study: Collision with terrain involving Beech Aircraft Corporation B200, VH-MVL, Moomba Airport, South Australia, 13 December 2016

ATSB investigation AO-2016-170

On 13 December 2016, a Beech Aircraft Corporation B200 conducted a flight from Innamincka, South Australia (SA) to Moomba, SA for a medical clinic. On board the aircraft were the pilot and two passengers. On arrival at Moomba, the pilot configured the aircraft to join the circuit. At about the base turn point, the pilot observed the left engine fire warning had activated. The pilot decided to conduct the immediate actions for an emergency engine shutdown. The pilot retarded the left engine condition lever to the fuel shut-off position, paused, then closed the firewall shut-off valve and activated the fire extinguisher.

The pilot continued to fly the aircraft around base, but noticed it was getting increasingly difficult to maintain the right turn. The aircraft had flown through the extended runway centreline when the pilot sighted the runway out to the right side of the aircraft. The aircraft was low on the approach and the pilot raised the landing gear and retracted the flap to reduce the rate of descent. The pilot then lowered the landing gear and continued the approach to the runway from a position to the left of the runway centreline. The aircraft landed in the sand to the left of the runway threshold and after a short ground roll spun to the left and came to rest. There were no injuries, however the aircraft was substantially damaged.

VH-MVL accident site Source: Aircraft operator

Safety analysis

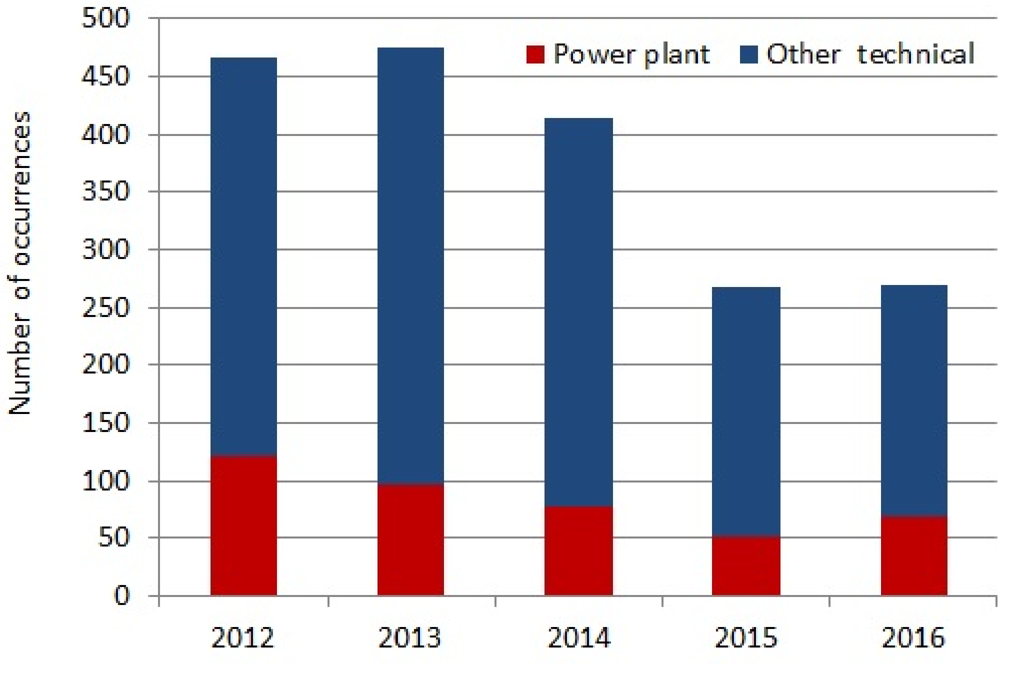
Review of occurrences reported to the ATSB

A review of the ATSB occurrence database[1] shows that between 2012 and 2016, there were 1,894 occurrences relating to technical failures[2] reported to the ATSB by flight crews and operators of Australian civil (VH-) registered turboprop-powered aircraft. In contrast, there were about 10,700 safety occurrences of all types that were reported to the ATSB over the same period involving the same types of aircraft. Within the technical failures occurrences, 417 were classified as being power plant/propulsion occurrences.

Each of these occurrences was characterised by one or more specific occurrence events. For example, a single occurrence may involve an engine failure or malfunction, followed by a diversion/return or forced/precautionary landing. Thus, from the 417 power plant occurrences, 464 occurrence events were derived. Each event has been coded using the ATSB occurrence type classification.

Although the total number of all safety matters reported to the ATSB has been generally increasing, Figure 1 shows that the number of reported occurrences relating to technical failures in turboprop aircraft has been generally decreasing from 467 in 2012 to 270 in 2016. The power plant sub-set (shown in red) has also decreased in the same time period, from 122 in 2012 to 69 in 2016. As a proportion of all technical failures, the percentage of power plant occurrences has remained quite consistent, only fluctuating between 19 to 26 per cent of the annual total of technical occurrences.

Figure 1: The number of technical occurrences involving turboprop aircraft, 2012 to 2016



1 Date of last occurrence reviewed was 27/09/2017.

2 This does not include approximately 120 reports submitted to the ATSB over this period relating to technical issues that were considered as 'non-reportable events' under the Transport Safety Investigation Regulations 2003.

Operations and aircraft involved

These power plant-related occurrences originate from eleven different operational groups:

- commercial air transport operation:
  - air transport high capacity[3]
  - air transport low capacity[4]
  - charter[5]
- aerial work
- private
- general aviation-unknown
- flying training
- business
- sports aviation
- other
- unknown.

Figure 2 shows the distribution of the power plant occurrences for each operation type.

Air transport high capacity

Many (184, or 44% of the total) occurrences originated from aircraft in the air transport high capacity group. Over three-quarters (140) of the aircraft in this group were Bombardier DHC-8's (300 and 400 series). Fokker F27 Mk50's were involved in 27 occurrences, followed by ATR-72's (13 occurrences) and Convair 580's[6] (4 occurrences).

Air transport low capacity

Air transport low capacity made up nearly a quarter of all occurrences with 100 occurrences reported (24% of the total). Of these, the Fairchild SA226/227 was the most prevalent with 31, followed by SAAB 340's 24 occurrences and 22 involving Bombardier DHC-8's (100 and 200 series). The Bombardier DHC-8 is the only aircraft in this study to overlap the weight category which defines the border between low capacity and high capacity air transport. The DHC-8 100 and 200 series fall into the low capacity category, while the 300 and 400 series fall in the high capacity category. The rest of the low capacity air transport group was made up of Embraer EMB-120's (10 occurrences), British Aerospace 3200/4100 (7), Beech 200's (3), Cessna 441's (2) and one Cessna 208.

Charter

The 58 (14% of the total) occurrences from charter aircraft came from a mix of aircraft types, many of which are also found in the high and low capacity air transport groups. These included the Fairchild SA226/SA227 (11), Beech 200 (10), Cessna 441 (9), Bombardier DHC-8 (8), Embraer EMB-120 (5), Cessna 208 (4) and Fokker F27 Mk50 (3). There were also one each of Piper PA-42, Pilatus PC-12, Fairchild SA226/227, Beech 1900, British Aerospace 3200/4100, SAAB 340, Dornier 228 and Rockwell 690.

3 High capacity aircraft are certified as having a maximum capacity exceeding 38 seats, or having a maximum payload capability that exceeds 4,200 kg.

4 Low capacity operations are conducted in aircraft other than high capacity aircraft, that is, aircraft with a maximum capacity of 38 seats or less, or having a maximum payload capability of 4,200 kg or below.

5 Charter operations involve the carriage of passengers and/or cargo on non-scheduled flights by the aircraft operator, or by the operator's employees, for trade or commerce.

6 These aircraft are a turboprop conversion of the Convair 340 powered by two Allison 501 turboprop engines.

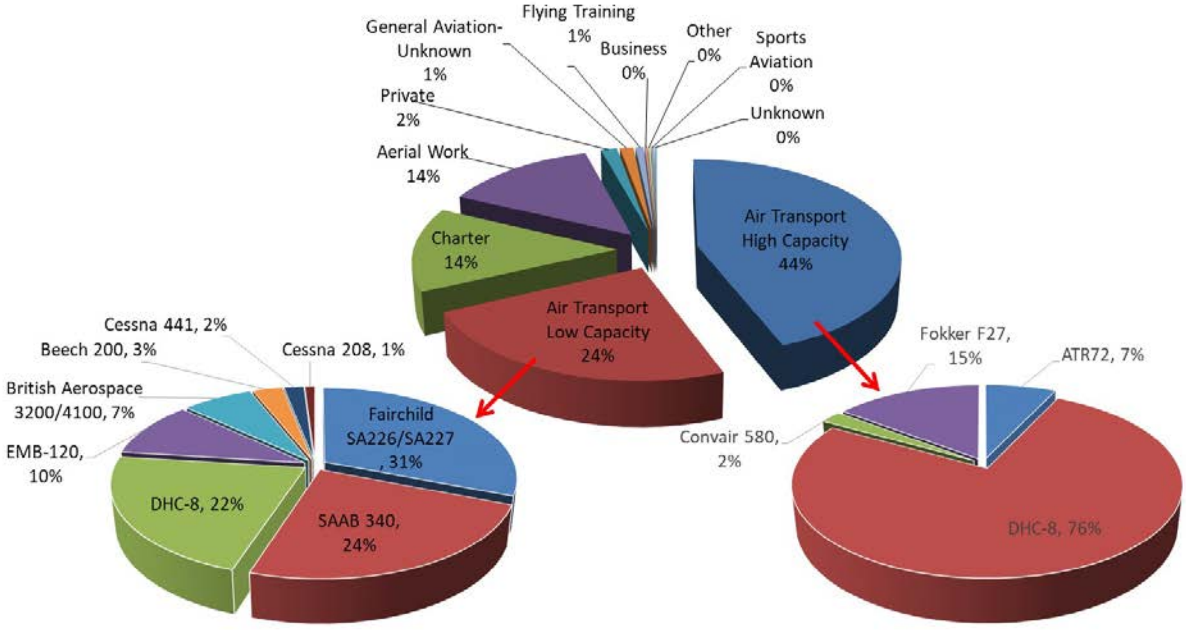
Aerial work

Occurrences in the aerial work group numbered 57 (14% of all occurrences) and involved operations such as search and rescue, test and ferry, aerial agriculture, survey and photography, and emergency medical services flights. Accordingly, the aircraft in this group were quite varied, and included the Bombardier DHC-8 (14), Beech 200 (14), Pilatus PC-12 (11), Air Tractor AT-802 (3) and AT-502 (1), Cessna 441 (3) and 208 (1), PAC 08-600 (2), Ayres S2R (2), Dornier DO228 (1) and DO328 (1), Embraer EMB-120 (1), Remis F406 (1) and Government Aircraft Factories (GAF) N22 (1) and Beech 1900 (1).

Other

There were a further 18 aircraft distributed between Private Operations (6), General Aviation-Unknown (5), Flying Training (3), Business (1), Other (1), Sports Aviation (Parachute Operations) (1), and Unknown (1).

Figure 2: The proportion of power plant occurrences from each operation type between 2012 and 2016.



Common occurrence events

The ATSB Occurrence type taxonomy and coding manual are available from the ATSB web site at www.atsb.gov.au/avdata/terminology/. The ATSB classifies the power plant set of technical occurrences into six occurrence types as follows:

Abnormal engine indications

'Abnormal engine indications' occurrences include:

- abnormal engine instrument readings, such as engine power output or temperature, oil pressure or temperature, fuel pressure, etc.
- general reports of engine trouble without further specific information
- engine overspeed or over-torque warnings (without an accompanying mechanical fault).

Auxiliary power unit (APU)

'Auxiliary power unit' occurrences include:

- fires
- fumes and smoke events where the APU was identified as the source.

Engine failure or malfunction

A technical fault that results in an 'engine failure or malfunction' occurrence includes:

- reports of total power loss of an engine whether single or a multi-engine aircraft
- a loss of power that limits aircraft performance (Note: loss of power due to environmental issues such as air density, icing, are also to be coded under the applicable environment occurrence type)
- a rough running engine (coughing, spluttering, etc.)
- observation of abnormal sights, sounds or vibrations by a crew member
- any mechanical issue that results in an engine shutdown, irrespective of phase of flight. (Note: engine shutdowns based solely on abnormal engine indications are coded only as 'Abnormal engine indication'.).

Propellers/rotor malfunction

'Propeller/rotor malfunction' occurrence type includes the:

- failure of associated propeller accessories, such as feathering mechanisms, constant speed units, and reduction gearboxes
- reported damage to a propeller or rotor blade including delamination
- general reports of damage to a propeller or rotors without further specific information.

Transmission and gearboxes

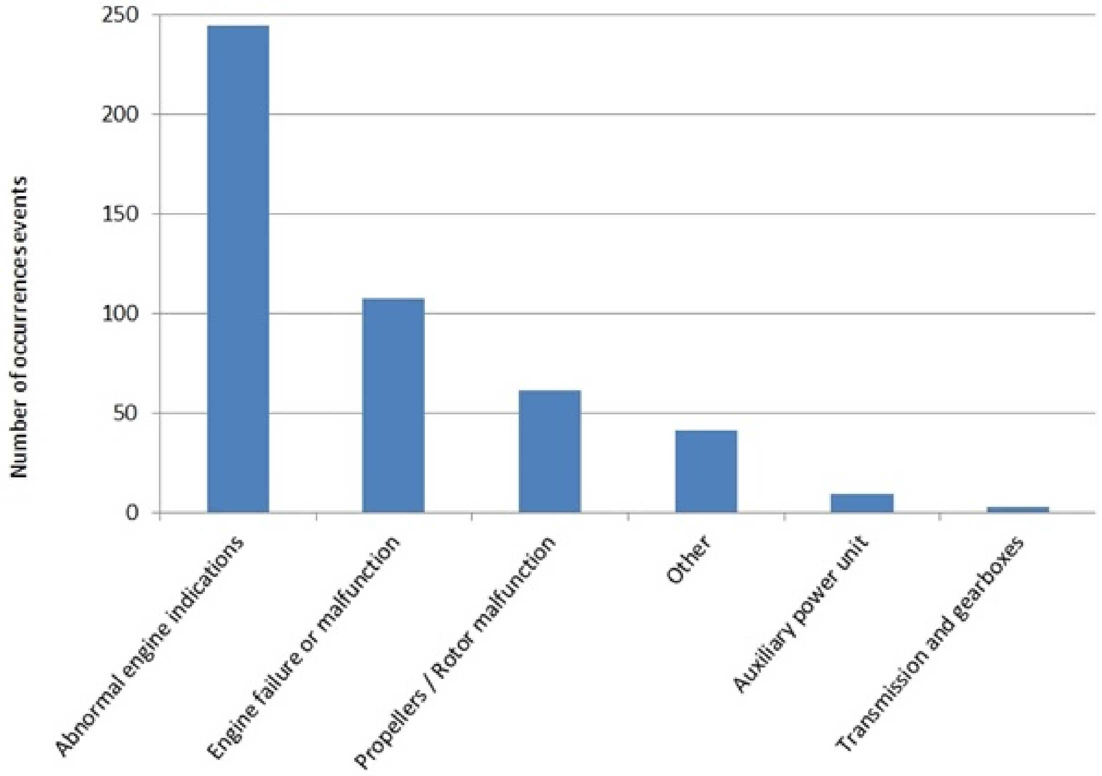
This technical occurrence type can apply to any transmission or gearbox in the power train of either an aeroplane or helicopter.

Other

The 'Other' occurrence type includes mechanical faults involving associated engine components.

The distribution of power plant occurrences in turboprop-powered aircraft over the five years 2012 to 2016 is shown in Figure 3.

Figure 3: The number of power plant-related occurrence events between 2012 and 2016 involving turboprop-powered aircraft in Australia.



Abnormal engine indications

About half (52.5%) of all the power plant events involved an abnormal engine indication, which numbered 244 over the five-year study period. This type of occurrence relates to any abnormal engine instrument readings, such as engine power output or temperature, as well as engine over-speed or over-torque warnings. Additionally, reports of abnormal engine indications included any general reports or observations of abnormal sights or sounds by a crew member. These included smoke or fumes in the cabin/cockpit or excessive engine vibration (further detail regarding common abnormal engine indications is provided below in an analysis broken down by aircraft and engine type). This type of occurrence is often associated with other occurrence events, with 190 of the 244 involving additional occurrence events. For example, 101 of the abnormal engine indication occurrences were also associated with a diversion or return and 47 also involved a rejected take-off.

Of the 244 occurrences that involved an abnormal engine indication, only one was classified as an accident. The ATSB investigation report (AO-2016-170) for that accident is summarised on page 2 of this report. An engine fire warning was the abnormal indication, and it was also associated with a loss of control and collision with terrain occurrence types. Another abnormal engine indication was classified as a serious incident, summarised on page 17 of this report. The other 242 occurrences involving abnormal engine indications were classified as incidents and not investigated by the ATSB.

Engine failure or malfunction

Following from abnormal engine indications, 'Engine failure or malfunction' was the next most commonly reported occurrence type with 107 reported during the study period. This represented nearly a quarter (23.1%) of the occurrence events. This occurrence type is potentially the most serious, with 33 involving an in-flight shut down of the affected engine. Of the five occurrences classified as accidents in the data set, four involved an engine failure or malfunction. Notably, all four involved aircraft undertaking aerial agricultural activities.

Propellers/rotor malfunction

The third most commonly reported technical occurrence event was 'Propellers/rotor malfunctions' with 61 reports (13.1%). These were mostly issues with the auto-feather systems (25), followed by faulty propeller control units (11) and torque signal condition units (6), propeller anti-icing system issues (4) and propeller governor problems (3). The remaining 12 occurrences were all reports of one-off failures of a variety of components. All 61 propellers/rotor malfunctions were classified as incidents; there were no accidents or serious incidents associated with this occurrence type.

Auxiliary power units

Although an auxiliary power unit (APU) is not technically part of the propulsion system, they are a turbine in themselves with similar components, operating temperatures/pressures and failure mechanisms to the turbines used for propulsion. Over the five-year period there were nine occurrences involving issues with APUs reported to the ATSB. Four of these occurrences were associated with smoke and/or fumes in either the cabin or cockpit. In one occurrence the APU was left on after engine start; the subsequent warning distracted the flight crew long enough to receive a landing gear overspeed warning. Another occurrence involved an unsecured APU access panel while three occurrences described unspecified APU failures.

Transmission and gearboxes

There were only two occurrences reported that related to problems with transmission or gearboxes. One occurrence, the result of a seized gearbox, led to the crew shutting down the engine and returning to land. The other occurrence involved an engine failure due to a failure of the propeller reduction gearbox.

Other

There was very little commonality between any of the 41 occurrences classified as 'Power plant/propulsion – Other'. These occurrences included a diverse range of failures and faults ranging from unsecured oil caps to failed oil vent valve O-rings. None of the occurrences involved any accidents or serious incidents (all were classified as incidents), none involved any injuries to crew or passengers and none were investigated by the ATSB.

Case Study: Engine failure and forced landing involving Cessna 208, VH-TYV, Darwin Airport, Northern Territory, 11 November 2016

ATSB investigation AO-2016-149

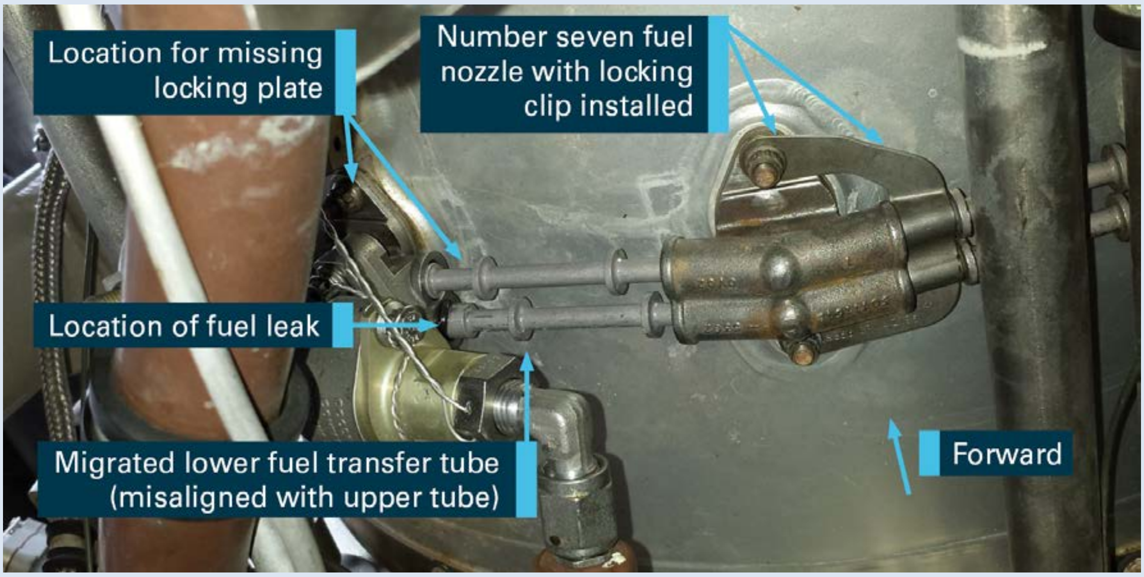
On 11 November 2016, at about 1546 Central Standard Time, a Cessna 208B aircraft entered runway 29, at the intersection of taxiway E2 at Darwin Airport, Northern Territory for an aircraft type re-familiarisation training flight. On board were an instructor and trainee pilot.

After take-off, at an altitude of about 500 ft above ground level, the instructor noted the climb speed reducing while the trainee continued to maintain the nose attitude for best angle of climb. At the same time, the instructor heard the engine lose power and a thin film of fuel partially obscured the windscreen.

As the airspeed reduced to 60 knots, the instructor took control of the aircraft. The pilot identified an area to the left of the aircraft as the most suitable for a forced landing and began a left turn towards that clear area at the target glide speed of 85 kt. As the aircraft turned, he assessed that sufficient height remained to continue the turn back towards Darwin Airport. At the completion of the turn, he selected 30 degrees of flaps to provide a short climb, which allowed the aircraft to clear two hangars and an area of trees.

After clearing the hangars and trees, the instructor observed taxiway A in line with the aircraft and elected to land on the taxiway A. The aircraft landed on taxiway A without further incident.

A post-incident examination of the engine found the number eight fuel nozzle locking plate missing (see below). This allowed the fuel transfer tube to migrate out of the number eight fuel nozzle adaptor. There was no damage to the locking plate mounts.



VH-TYV fuel transfer tube and location of the fuel leak

Source: Aircraft operator, annotated by ATSB

Occurrences by engine model

The number of power plant occurrences for turboprop-powered aircraft between 2012 and 2016 for each engine model is shown in Figure 4. Nine APU occurrences have been removed from that figure since an APU is a completely separate system to the engine. In all subsequent figures, where the individual occurrence types are presented, the APU occurrences are included. Also note that data in this section are non-normalised counts which do not take into account either fleet size or hours flown and thus do not represent rates of occurrence.

The Pratt & Whitney Canada PW100/150 family of engines were associated with the most power plant occurrences (236), followed by the Honeywell International Inc. TPE331 (72), the Pratt & Whitney Canada PT6A (69), and the General Electric Co. CT7 (25). The Allison Gas Turbines 501 and 250 engine types had five and one occurrence, respectively.

Most of these engine models are used in a number of different aircraft. Table 1 outlines the different engine and airframe combinations that are found for the occurrence aircraft in this report.

Figure 4: Power plant occurrences by engine model, 2012 - 2016

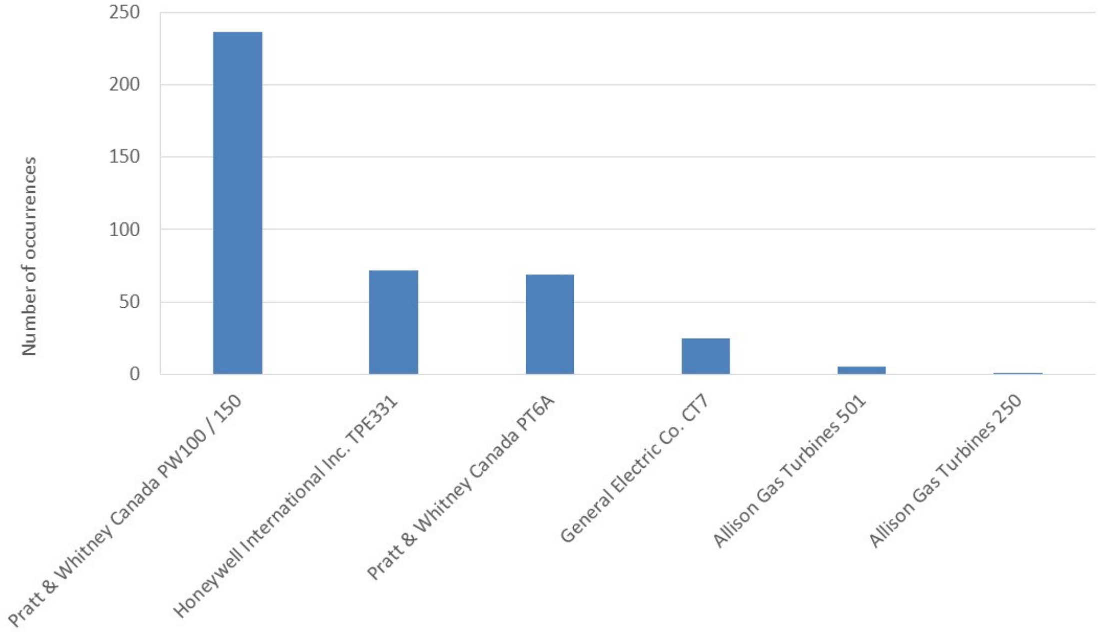


Table 1: List of possible engine/airframe combinations in Australian VH-registered turboprop aircraft.

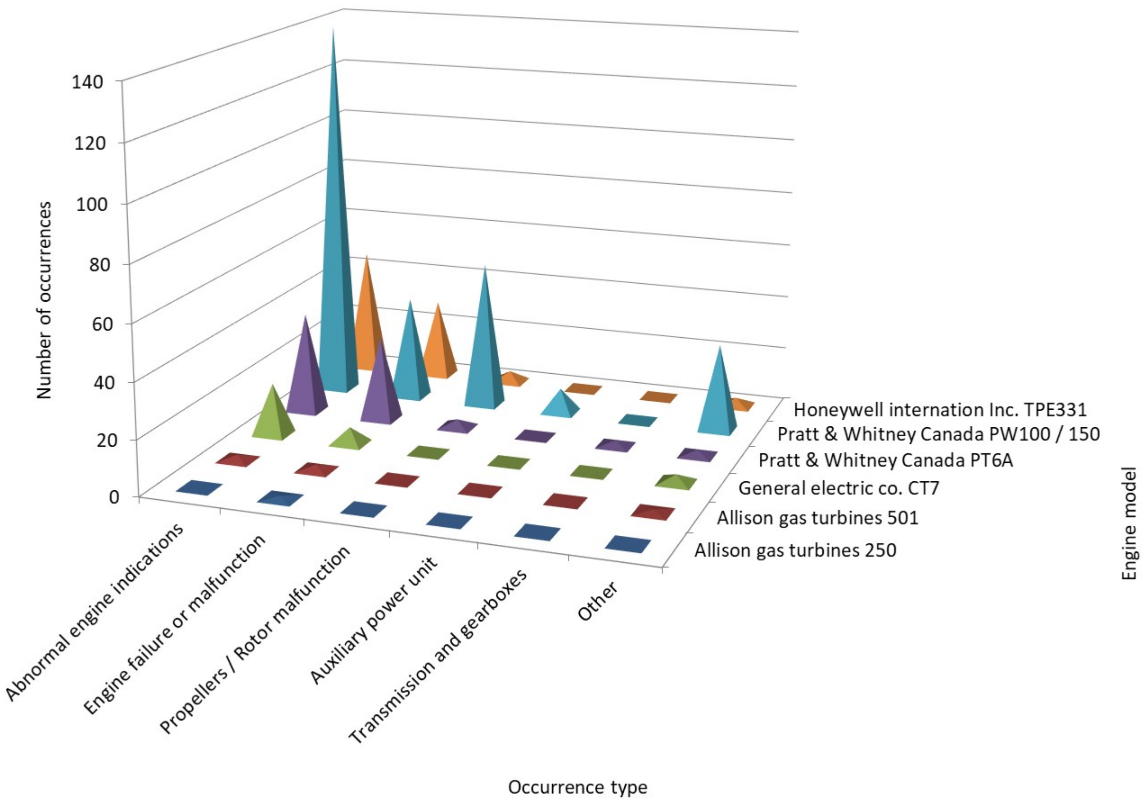
Engine manufacturer	Engine Model	Aircraft
Allison Gas Turbines	250	Government Aircraft Factories N22
Allison Gas Turbines	501	Convair 340 (580)
General Electric Co.	CT7	SAAB. Aircraft Co. 340
Honeywell International Inc.	TPE331	British Aerospace PLC 3200/4100 Cessna Aircraft Company 441 Dornier Werke GmbH DO228 Fairchild Industries Inc. SA226 Fairchild Industries Inc. SA227 Rockwell International 690
Pratt & Whitney Canada	PT6A	Air Tractor Inc. AT-502 Air Tractor Inc. AT-802 Ayres Corporation S2R Beech Aircraft Corp. 1900 Beech Aircraft Corp. 200 Beech Aircraft Corp. 300 Cessna Aircraft Company 208 Hawker Beechcraft Corporation 200 Pacific Aerospace Corporation 08-600 Pilatus Aircraft Ltd PC-12 Piper Aircraft Corp. PA-42 Raytheon Aircraft Company 200 Reims Aviation S.A. F406 SOCATA-Group Aerospatiale TBM
Pratt & Whitney Canada	PW100 / 150	ATR - Gie Avions De Transport Regional ATR72 Bombardier Inc. DHC-8 Dornier Werke GmbH DO328 Embraer-Empresa Brasileira De Aeronautica EMB-120 Fokker Aircraft B.V. F27

Occurrence types by engine model

To get further insight as to whether certain types of occurrences affected particular engine models, the occurrence types were graphed individually in Figure 5. As in Figure 3, most occurrences involved abnormal engine indications. Figure 5 however, shows that the majority of these occurrences derived from the Pratt & Whitney Canada PW100/150 family of engines.

It is difficult to draw any meaningful conclusions from the data in either Figure 4 or Figure 5 as there are a number of different possible airframe/engine combinations (see Table 1). Additionally, this data does not take into account either the number of these engines in the fleet or the hours that they have flown. In order to make any meaningful comparisons, occurrence data needs to be normalised by the number of hours flown. As the 'hours flown' data, however, pertains only to aircraft model, and due to the various airframe/engine combinations, there is currently no practical way of discerning actual engine hours. Thus, no quantitative conclusions can be made regarding the reliability of any particular engine model and these figures serve only as a qualitative insight into the types of issues associated with each engine model.

Figure 5: Power plant-related occurrences in turboprop-powered aircraft by engine model, 2012 – 2016.



Allison Gas Turbines 250

The one Allison 250 occurrence involved an engine failure in a GAF N22 (Nomad). That failure occurred on final approach and the aircraft continued to an uneventful landing. The failure was determined to be the result of blocked cross-feed fuel lines.[7]

Allison Gas Turbines 501

All five Allison 501 occurrences involved engines installed in Convair 580 aircraft. The two occurrences involving abnormal engine indications both related to abnormal oil pressure readings and both led to either a return to the departure location or a diversion. One was due to a rear turbine scavenge pump malfunction while the other resulted from a faulty engine oil cooler. Another two occurrences involved engine failures or malfunctions. One of these related to a faulty thrust reverser during the landing while the other involved a fire warning and inflight shut down due to a cracked exhaust flange. One occurrence, coded as a 'technical failure – other', involved a fire warning and smoke in the cabin during the taxi as a result of a separated exhaust pipe.

General Electric Co. CT7

The 28 technical failure occurrence events involving the General Electric Co. (GE) CT7 engine derived from 25 individual occurrences. The failed engines were installed in SAAB 340 aircraft operated by three different operators. The majority (19) were coded as abnormal engine indications. Of these, seven necessitated an air return or diversion while another three resulted in a rejected take-off and two led to a missed approach. Of the six engine failure or malfunction occurrences, two were due to faulty hydro-mechanical units. Another two were as a result of compressor stalls, one of which of investigated by the ATSB (AO-2016-104), while one was due to

7 Engine failures as a result of a fuel exhaustion are coded as 'fuel exhaustion' not 'engine failures'. Engine failures as a result of a fuel starvation, however, are coded as both 'fuel starvation' and 'engine failure or malfunction'.

a faulty torque sensor and one due to water ingress into the tailpipe heat detector. There were three occurrences coded as 'technical failure – other'. Two of these involved other occurrence events (abnormal engine indications and an engine failure or malfunction), while the third was an occurrence where the crew noticed oil leaking from an unsecured oil cap.

Pratt & Whitney Canada PT6A

There were 75 occurrence events (from 69 occurrences) involving aircraft fitted with an engine in the PT6A family of engines. These aircraft ranged from the Super King family (Beechcraft/Raytheon/Hawker 200/300 series) (30), Pilatus PC-12 (14), Cessna 208 (11), Air Tractor AT-802 (3) and AT-502 (1), Beech 1900 (3), Ayres Corporation S2R (2), Pacific Aerospace Corporation 08-600 (2), and one each of the Reims Aviation F406, SOCATA-Group Aerospatiale TBM and Piper Aircraft Corp PA-42.

There were 37 occurrence events involving an abnormal engine indication. All were incidents except for one serious incident (also coded as an engine failure or malfunction) and one accident (also coded as a loss of control and collision with terrain), both of these occurrence were investigated by the ATSB, (AO-2013-154 and AO-2016-170). The 31 engine failure or malfunction occurrences involved a number of different aircraft with the PT6A engines, including the Beech 200/300 (13), Cessna 208 (6), Air Tractor 502/802 (4), Pilatus PC-12 (3), PAC 08-600 (2), Ayres S2R (2), and one Beech 1900.

Pratt & Whitney Canada PW 100/150

Nearly three-quarters of the 273 occurrence events involving Pratt & Whitney PW 100/150 series engines were installed in a derivative of the Bombardier DHC-8 (204 occurrence events). Other aircraft included the Fokker F27 (38), Embraer EMB-120 (16), ATR-72 (14) and one occurrence reported from a Dornier DO328.

Like most of the other engine types, the most frequently reported occurrence type involving the PW 100/150 was 'abnormal engine indications' with 140 reported. There were 54 propeller/rotor malfunctions, 38 engine failures or malfunctions, 9 occurrences relating to the APU and 32 classified as other. None of these involved accidents or serious incidents.

Honeywell International Inc. TPE331

There were 82 occurrence events involving aircraft fitted with Honeywell TPE331 engines. A breakdown of the occurrences showed that 46 were classified as abnormal engine indications, 29 as 'engine failures' or 'malfunctions', four as a propeller/rotor malfunction and 32 as 'other'. None of these involved accidents or serious incidents and none were investigated by the ATSB. Five aircraft types were represented in this set; the Fairchild SA226/SA227 (44), Cessna 441 (17), British Aerospace 3200/4100 (8), Dornier DO228 (2) and Rockwell 690 (1).

Case Study: Engine shutdown involving British Aerospace Jetstream 32, VH-OTQ, 60 km WNW of Newcastle (Williamtown) Airport, New South Wales, 14 December 2016

ATSB Investigation AO-2016-171

At about 0730 Eastern Daylight-saving Time on the 14 December 2016, a Pelican Airlines British Aerospace Jetstream 32 aircraft, registered VH-OTQ, departed Newcastle Airport for Dubbo, New South Wales. Two flight crew and six passengers were on board the regular public transport flight.

Just after the aircraft reached the cruising altitude of FL 160, the captain, who was the pilot monitoring, noticed the right engine exhaust gas temperature (EGT) gauge was indicating just outside the top of the green arc. The captain reduced the power to the right engine, but there was no corresponding reduction in the EGT.

The flight crew conducted the quick reference handbook (QRH) emergency checklist for the lack of response to power lever movement, the power lever was checked after about 5 minutes and was found to still be unresponsive.

The crew advised the controller of their situation and requested a new clearance to return to Newcastle. The crew also advised the controller that as a precaution they might conduct an in-flight engine shut down. The controller gave them a clearance to descend and track direct to Newcastle. The controller initiated an alert phase and the airport emergency services were requested to be on standby.

The flight crew conducted the QRH engine in-flight shutdown checklist and shutdown the right engine prior to commencing their descent to Newcastle.

On descent, passing through about 8,000 ft the captain became the flying pilot and the first officer the monitoring pilot. The crew conducted a visual approach and landed without further incident. The two crew and six passengers were not injured and the aircraft was not damaged.

Aircraft maintenance personnel inspected the right engine after the flight and found that the engine’s fuel control unit was at fault. An examination of the fuel control unit at a component overhaul facility found that the input drive shaft was not free to move. The fuel control unit was inspected and a bearing was found to have failed. The phenolic bearing cage that separates the bearings was found broken with many small fragments found to be interfering with the operation of the fuel control unit in that area.

The failed bearing assembly

Source: Aircraft operator

Rates of occurrences by operator

Over 50 operators were represented by the occurrence aircraft in this report. Many of these were involved in very low numbers of occurrences over the study period. For example, 22 of the operators were involved in only one occurrence in the five-year period. There were 19 operators involved in four or more occurrences in the five years. These 19 operators represented nearly 90 per cent of all occurrences in this study. 'Hours flown' data was obtained for these 19 operators, either directly from the operator, or from the Bureau of Infrastructure, Transport and Regional Economics (BITRE) (with the permission of the operator). The data was obtained with the understanding that operators would be de-identified in this public report.

At the time this information was collected, BITRE only had access to hours flown data up to 2015. As such, all rate analysis in this report is constrained to the four years between 2012 and 2015. Figure 6 shows the number of power plant occurrences for these 19 operators (de-identified) for the years between 2012 and 2015. With 132 occurrences reported in the four-year period, occurrences reported from operator 'A' represented 42 per cent of this group, and eight times the average number of the group (16.5). The counts in Figure 6 were normalised by flight hours and are shown in Figure 7 as the rate of power plant occurrences per 10,000 hours.

Figure 6: Number of power plant occurrences by operator, where hours flown data are known, 2012 and 2015.

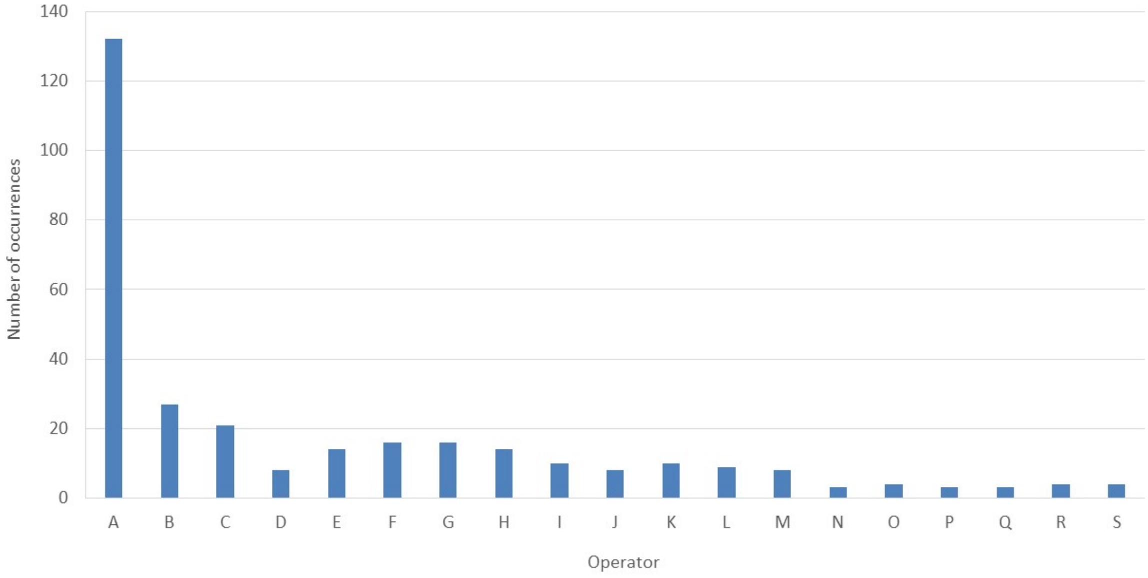
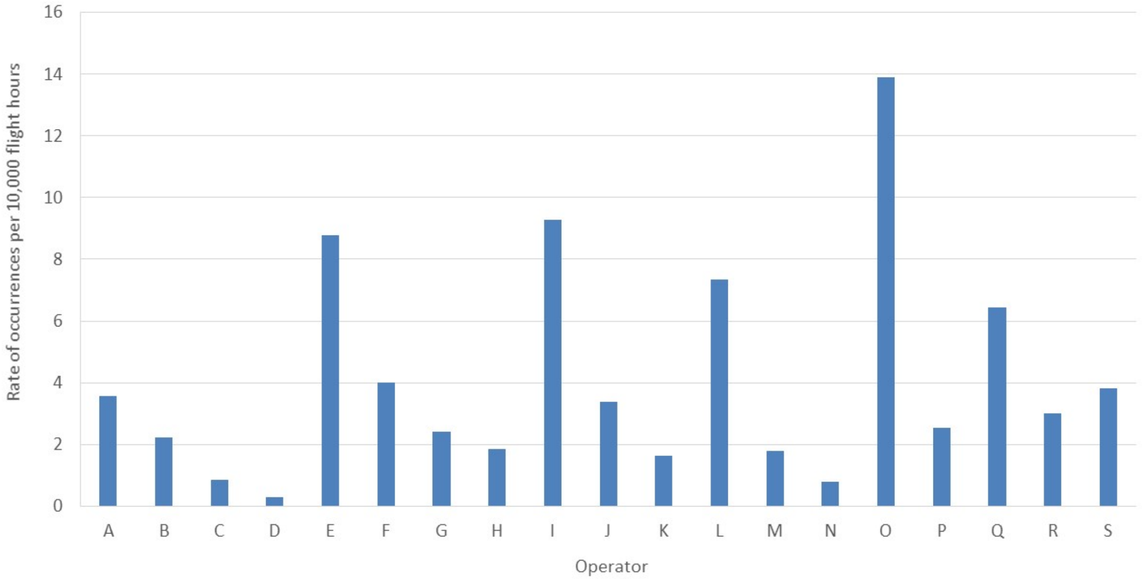


Figure 7: Rate of power plant occurrences by operator, normalised per 10,000 flight hours, where hours flown data are known, 2012 - 2015



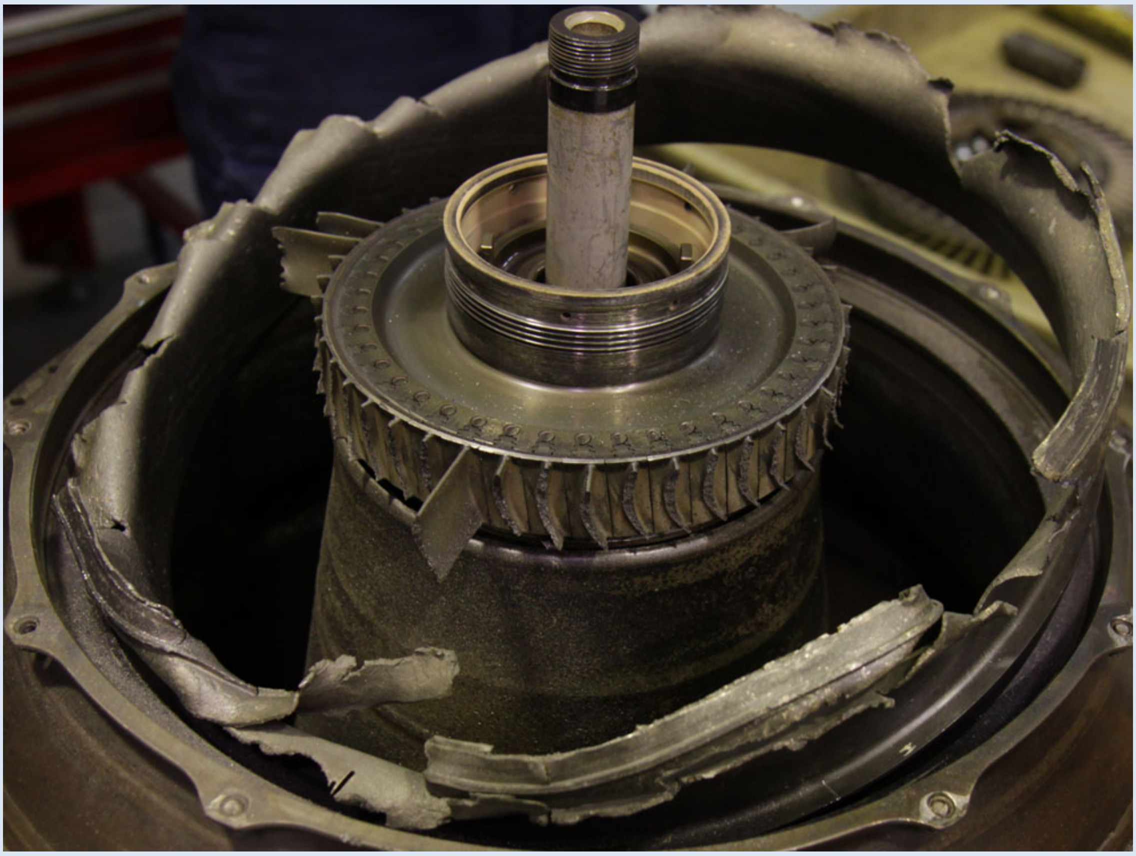
Although operator ‘A’ had the highest number of reported occurrences, once the hours flown are taken into account, the rate of occurrences for operator ‘A’ (3.55 per 10,000 hours) was less than the average for the group of 4.1 per 10,000 hours. Conversely, there were a number of other operators that had fewer reported occurrences combined with relatively low flight hours, which resulted in much higher rates. Operator ‘O’ for example, had the highest rate of occurrences with 13.9 per 10,000 hours. This was significantly (more than two standard deviations) higher than the average of the group. Additionally, operators ‘I’ and ‘E’ had elevated rates (more than one standard deviation) when compared to the average of the group.

Although operator ‘O’ had by far the highest rate of occurrences in this group, there were only four occurrences in the four years between 2012 and 2015. Also, all four occurrences were classified as incidents (rather than accidents or serious incidents) and classified as low-risk rating occurrences (see page 22 for details on risk ratings). Additionally, the aircraft used by operator ‘O’ that were involved in these occurrences were used in freight operations rather than passenger or charter operations.

Case Study: Engine failure involving a Beech Aircraft Corporation Model 200, Super King Air, VH-ZMP, 277 km NNW of Marshall Islands International Airport (Majuro Atoll), 12 September 2013

ATSB investigation AO-2013-154

On 12 September 2013, a twin-engine Beech Aircraft Corporation, Model 200 Super King Air was conducting a passenger charter flight from Utirik Atoll to Marshall Islands International Airport (Majuro Atoll). About 40 minutes into the flight, while in cruise to the destination, the pilot observed abnormal oil pressure indications for the left engine and approximately 2 minutes later the engine failed. The crew secured the engine and elected to continue with the original flight plan. The aircraft landed at Majuro Atoll without further incident. The failure of the left engine, a Pratt & Whitney Canada PT6A-41, resulted from fatigue cracking and breakdown of the first-stage sun and planet gears in the propeller reduction gearbox. The specific factors contributing to the initiation of the gear breakdown could not be positively identified.



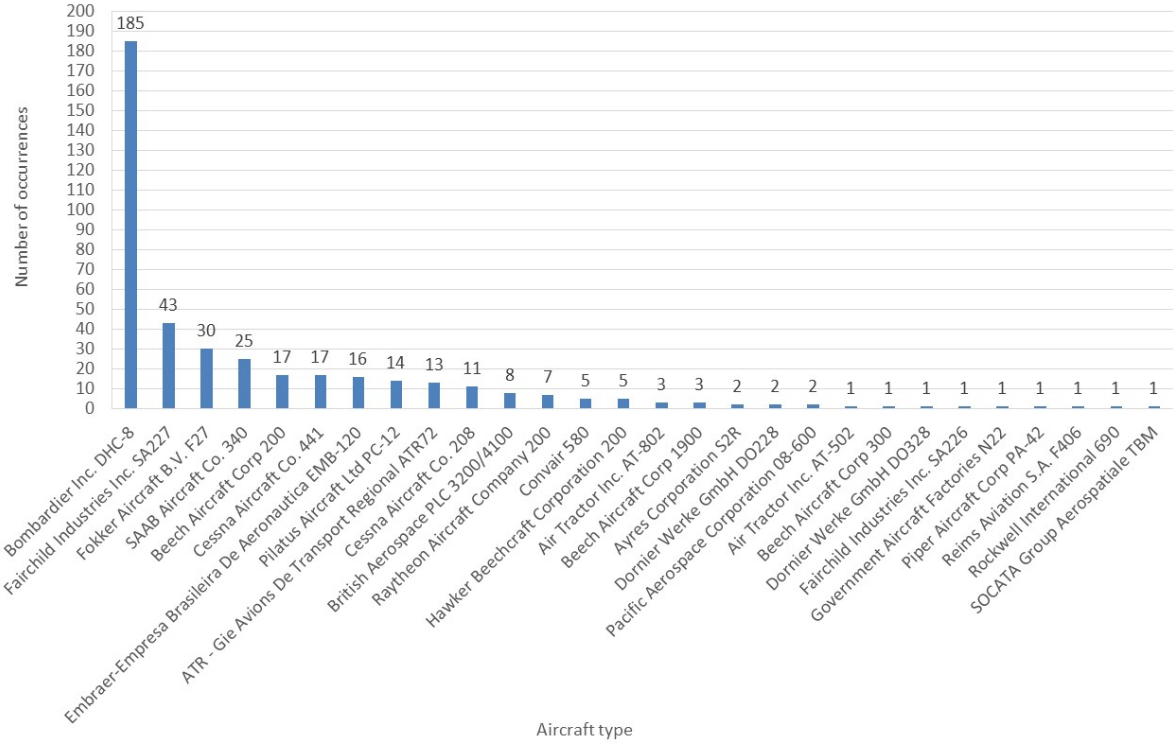
Remnants of the second stage power turbine disk Source: Aircraft operator

Rates of occurrences by aircraft model

The number of power plant occurrences for every aircraft type involved in power plant occurrences between 2012 and 2016 is shown in Figure 8. Nearly half (44.4%) of all occurrences in this study involved Bombardier DHC-8 (Dash-8) aircraft (185 occurrences, all series), The next most common aircraft, the Fairchild SA226/227 (Metro), had less than a quarter of the Dash-8 occurrences (43) reported in the same time period. These were followed by the Fokker F27 (Friendship) with 30 occurrences, SAAB 340 (25), Beechcraft 200 (King Air) (17), Cessna 441 (Conquest II) (17), Embraer EMB 120 (Brasilia) (16), Pilatus PC-12 (14), ATR-72 (13), and

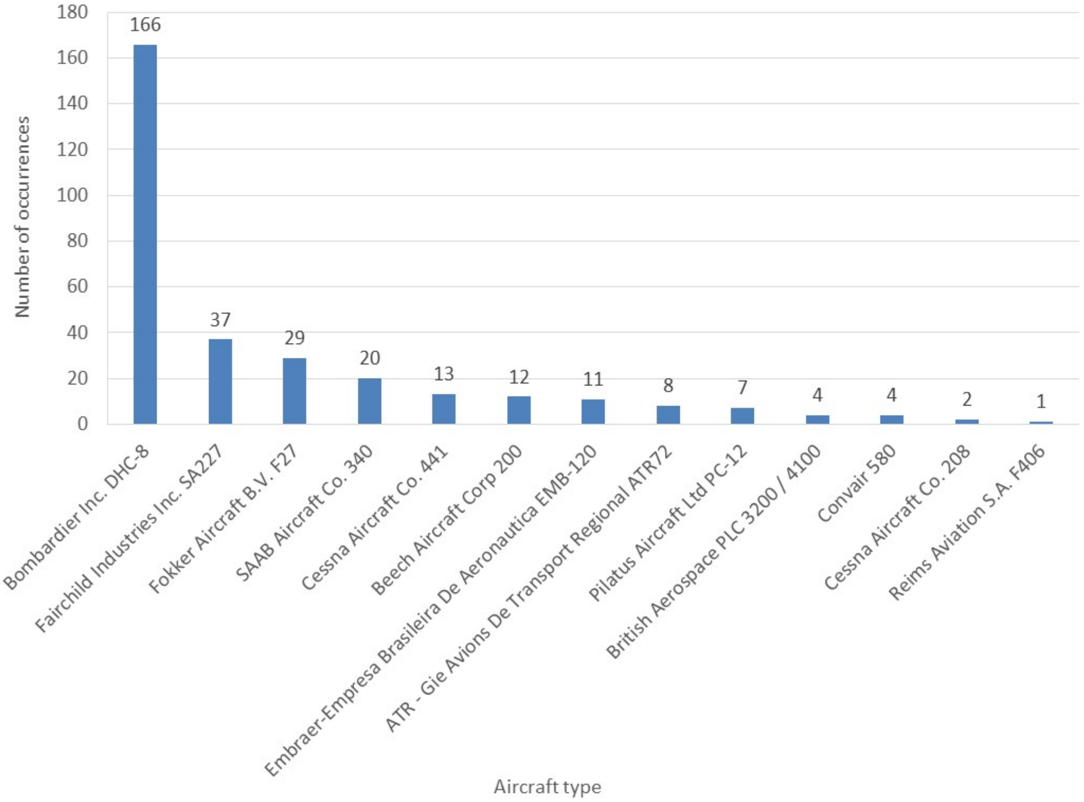
Cessna 208 (Caravan) (11). Following these aircraft were another 18 aircraft, all with less than ten occurrences each in the five-year period.

Figure 8: Number of power plant occurrences by aircraft type, 2012-2016. The occurrence count is given by the data markers.



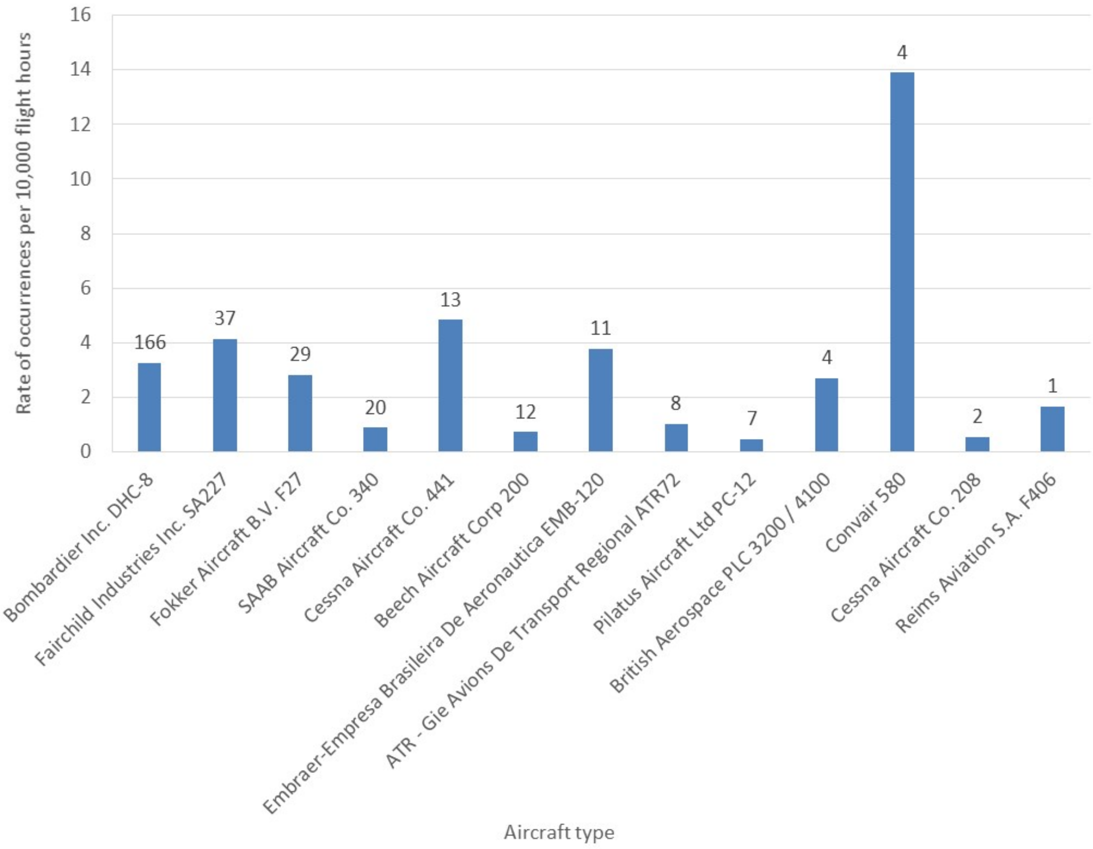
The (non-normalised) count data displayed in Figure 8 does not take into account the numbers of each type of aircraft in the data set, or the hours flown by them. To make more meaningful comparisons, count data can be normalised by an exposure measure. This report used hours flown as the exposure measure to obtain rates of power plant occurrences per 10,000 hours flown. As previously described, this count data was obtained for 19 operators for the four years between 2012 and 2015. Accordingly, only occurrences that happened in those four years are used for the rate analysis. This leaves the aircraft shown in Figure 9 for further analysis.

Figure 9: Number of power plant occurrences in turboprop aircraft by aircraft, where hours flown are known, 2012-2015. The occurrence count is given by the data markers.



Data from Figure 9 was divided by the total hours flown for each aircraft model in the four-year period between 2012 and 2015. This is displayed as the rate of power plant occurrences per 10,000 hours flown in Figure 10. The order of the aircraft in Figure 9 has been retained in Figure 10 to highlight contrast between the counts and rate data. Note that the data in Figure 10 is normalised by airframe flight hours, not engine hours, and thus does not take into account the specific engine hours or the number of engines per aircraft. In Figure 10 the Pilatus PC-12 and Cessna 208 are the only single engine aircraft, all the other aircraft have two engines.

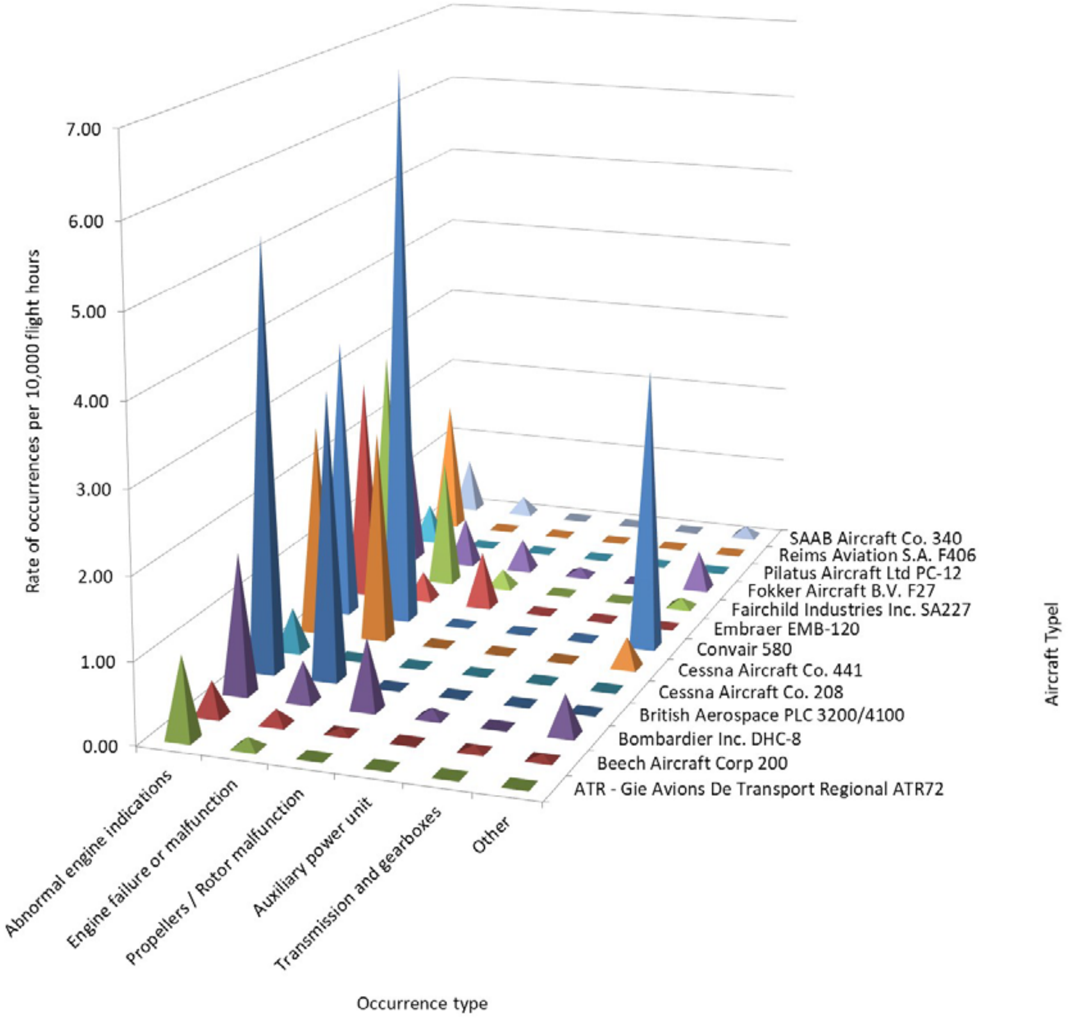
Figure 10: Rate of power plant occurrences by aircraft model per 10,000 hours flown, for aircraft where hours flown are known, 2012-1015. The occurrence count is given by the data markers.



With a rate of 13.9 power plant-related occurrences per 10,000 hours flown, the Convair 580[6] had the highest rate. This was significantly (more than three standard deviations) higher than the average of the group and nearly three times the rate of the next aircraft, the Cessna 441 (4.8 per 10,000 flight hours). The Fairchild SA226/227 had the next highest rate with 4.1 occurrences per 10,000 hours, followed by the Embraer 120 (3.8 per 10,000). Notably, the DHC-8, which had the highest number of occurrences in Figure 9, had only the fifth highest rate (3.3 per 10,000 hours) once the number of hours flown were taken into account. The remaining eight aircraft models had comparatively lower rates ranging between 0.47 and 2.82 occurrences per 10,000 hours flown (by airframe). When comparing rates of occurrences like those in Figure 10, it is important to consider that different aircraft models are operated by different airline operators, and that higher rates of occurrences could simply be a result of a better reporting culture in particular operations.

Figure 10 shows the rate of all power plant occurrences while in Figure 11 the rate of occurrences are displayed individually for each of the six occurrence types in the power plant group.

Figure 11: Rate of power plant occurrences by aircraft model by occurrence type per 10,000 hours flown, for aircraft where hours flown are known, 2012-1015.



Abnormal engine indications accounted for the highest rate of occurrence events for most aircraft models. In fact, the only aircraft model where abnormal engine indications were not the most prevalent type of occurrence rate was the Convair 580, which had a greatest rate of reported engine failure or malfunction (with the abnormal engine indications being the next highest rate).

Although the rates for the Convair 580 are quite high, the actual number of occurrences involving the Convair 580 are very low, just four in four years. The occurrence involving abnormal engine indications related to abnormal oil pressure readings and led to a return landing, due to the rear turbine scavenge pump malfunction. The two occurrences involving engine failures or malfunctions related to a faulty thrust reverser during the landing and a fire warning and inflight shut down due to a cracked exhaust flange. One occurrence, coded as a ‘technical failure – other’, involved a fire warning and smoke in the cabin during the taxi as a result of a separated exhaust pipe.

The British Aerospace PLC 3200/4100 had the highest rate of abnormal engine indications with 5.3 per 10,000 hours flown. These were due to only three occurrences, one due to a faulty torque limiting system, one due to a faulty anti-ice valve connector, and one due to a faulty tachometer generator.

Higher risk technical failures

There are limitations in how well occurrence frequency-based analysis can be used to identify areas of significant safety concern. The frequency of occurrences of a certain type is not necessarily indicative of the risk that those types of occurrences pose. As a result, all occurrences reported to the ATSB are risk rated using the Event Risk Classification (ERC) framework. This risk rating can then be used to help identify occurrences that may require monitoring, follow-up or further investigation.

The ATSB assesses the probable level of safety risk associated with each reported safety occurrence, considering the circumstances of the occurrence at the time it happened.[8] The safety risk of occurrences is assessed using a modified version of the Aviation Risk Management Solutions ERC framework.[9] This framework assesses the safety risk on the most credible potential accident outcome that could have eventuated, and the effectiveness of the remaining defences that stood between the occurrence and that outcome. For example, for an engine failure or malfunction occurrence, the types of factors that may be used to determine the ERC rating could include the number of engines the aircraft had, the number of engines affected and the extent of the failure(s). The intention of this assessment is to determine if there was a credible risk of injury to passengers, crew, and the public or damage to the aircraft.

Most occurrences reported to the ATSB are unlikely to result in any type of accident because there are numerous defences in place including pilot skills and training, standard operating procedures, aircraft systems and design, air traffic management, airspace and aerodrome infrastructure, and components of an operator's safety management system.

Figure 12 shows how the low, medium, and high-risk occurrences are distributed across the six occurrence types. It can be seen clearly from this figure that the vast majority of all occurrence types are low-risk occurrences.

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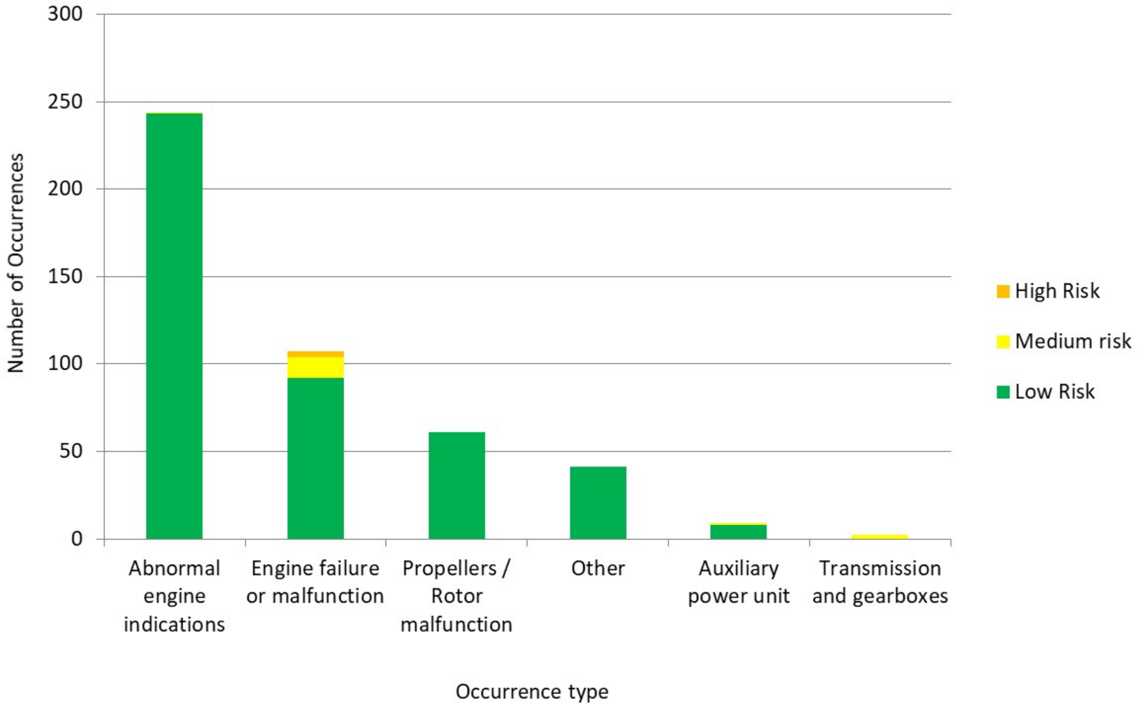
8 The Event Risk Classification (ERC) methodology is used by the ATSB to make assessments of the safety risk associated with occurrences. For more information on how the ATSB uses occurrence and investigation data to drive proactive safety improvements, see Godley, 2012.

9 The methodology is from the report *The ARMS Methodology for Operational Risk Assessment in Aviation Organisations* (version 4.1, March 2010). Aviation Risk Management Solutions (ARMS) is an industry working group set up 2007 in order to develop a new and better methodology for Operational Risk Assessments. It is a non-political, non-profit working group, with a mission to produce a good risk assessment methodology for the industry. The results are freely available to the whole industry and to anyone else interested in the concept.

Figure 12: The number of low, medium, and high-risk occurrence events for power plant-related occurrences between 2012 and 2016.



In the set of 417 occurrences described in this report, 400 (96%) were classified as being a low risk rating with a low or no accident outcome. Only fourteen were classified as medium-risk, twelve of these involved engine failures or malfunctions. There was also one abnormal engine indication and one auxiliary power unit occurrence. There were no occurrences in the study set that were classified with a very high-risk rating. The three occurrences classified as high risk occurrences all involved engine failures or malfunctions with forced/precautionary landings in Cessna 208 aircraft. These three occurrences are summarised below:

- ATSB investigation AO-2015-094: At about 0930 Western Standard Time, a Cessna 208B, registered VH-LNH, departed Kununurra, Western Australia, on a scenic flight to the Bungle Bungle Range. On board were the pilot and 12 passengers. Soon after take-off, oil began leaking from the engine area, forming an opaque film on the windscreen. The pilot also found that there was insufficient thrust to maintain level flight. Despite substantially limited forward visibility due to the film of oil on the windscreen, the pilot was able to return to Kununurra and land. Subsequent inspection of the aircraft showed that the propeller had feathered and seized. Aside from the apparent damage to the engine/propeller system, there was no damage to the aircraft, and no injuries. Inspection of the engine showed that an oil leak had developed from a join between the oil transfer elbow and oil transfer tube at the forward end of the engine.

Figure 13: Photographs of VH-LNH after the aircraft had landed, with oil visible on the engine cowl and forward fuselage.

- ATSB investigation AO-2016-155: On 16 November 2016, during climb 9 km north of Solomon Aerodrome, Western Australia, the engine failed on a Cessna 208 (VH-LNH).The crew conducted a forced landing on a road. There were no injuries and the aircraft was not damaged.
- ATSB occurrence 201503594: On 9 August 2015, while on descent during parachuting operations, the engine of the Cessna 208 (VH-LNI) failed and the crew performed a glide approach to runway 20. The engineering inspection revealed a small amount of water in the fuel drain, the engineers adjusted and re-calibrated the fuel control unit.

Summary

A review of power plant occurrences reported to the ATSB showed that there were 417 power plant-related occurrences involving turboprop engine aircraft between 2012 and 2016 (83 per year on average). The subset of occurrences involving the operators whose flight hours were known consisted of 314 occurrences in the four years between 2012 and 2015 (79 per year on average). With a combined total of just over 1.4 million flight hours for these aircraft in this timeframe, this equates to approximately 2.2 occurrences every 10,000 flight hours, or roughly one occurrence every 4,500 flight hours. As a comparison, previous ATSB research (AR-2013-002) found that the average occurrence rate for turbofan-powered aircraft was approximately one every 20,000 flight hours (2008–2012). Although it should be noted that not only did the turbo fan set include a higher number of flight hours (about 5.5 million), that set also comprised a different make-up of operation types.

The vast majority (96%) of these occurrences were classified as being low risk rating occurrences with a low or no accident outcome, however, there were four occurrences classified as medium risk and three as high risk. All three high risk rating occurrences involved engine failure or malfunctions with forced/precautionary landings in single–engine Cessna 208 aircraft. There were no occurrences classified as very high risk. The two occurrences in the set that resulted in any injury (both minor) were the result of engine failure or malfunctions and collision with terrain occurrences in aerial agricultural operations. The five occurrences classified as accidents all involved aerial work operations, four in aerial agriculture and one in emergency services operations.

With a rate of 13.9 power plant-related occurrences per 10,000 hours flown, the Convair 580[6] had the highest rate of occurrences, however, with only four occurrences between 2012 and 2015, the high rate was due to comparatively low flight hours for this aircraft. All four of these occurrences were classified as incidents (rather than accidents or serious incidents) and classified as low risk rating occurrences. Additionally, the sole operator of this aircraft type in Australia advised the ATSB that they retired the fleet in 2017 and replaced these aircraft with a newer turbofan alternative.

As always, the individual reporting practices of each operator could also potentially influence the final data. With this in mind, the ATSB encourages all operators to continue vigilantly reporting all technical problems and, where possible, to provide follow-up engineering inspection reports.

Sources and submissions

Sources of information

The sources of information during the investigation included:

- the ATSB aviation occurrence database at http://www.atsb.gov.au/avdata/
- ATSB investigation reports that are available from www.atsb.gov.au
- the Bureau of Infrastructure, Transport and Regional Economics.

References

Civil Aviation Safety Authority (CASA) (2012, November), *Civil Aviation Advisory Publication (CAAP) 51-1(2): Defect Reporting*. This publication is available from the CASA website, www.casa.gov.au

Godley, S. T. (2012, September), *Proactively monitoring emerging risks through the analysis of occurrence and investigation data: Techniques used by the Australian Investigator*. Paper presented at the 2012 annual meeting of the International Society of Air Safety Investigators (ISASI), Baltimore, MD.

Aviation Risk Management Solutions (ARMS), *Methodology for Operational Risk Assessment in Aviation Organisations* (version 4.1, March 2010) is available from the EASA website at www.easa.europa.eu/document-library/general-publications/arms-methodology-operational-risk-assessment-2007-2010.

Submissions

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

A draft of this report was provided to the National Transportation Safety Board of the United States, General Electric, Rolls-Royce, Honeywell, Pratt and Whitney Canada and the Australian operator of the Convair 580.

Submissions were received from Pratt and Whitney Canada and the Australian operator of the Convair 580. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

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

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

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

Purpose of safety investigations

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

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

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

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

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

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

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Aviation Research Investigation
Power plant failures in turboprop-powered aircraft, 2012 to 2016
AR-2017-017
Final – 15 June 2018