Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A06P0010

ENGINE POWER LOSS – FORCED LANDING

SONICBLUE AIRWAYS
CESSNA 208B (CARAVAN) C-GRXZ
PORT ALBERNI, BRITISH COLUMBIA, 11 nm SSE
21 JANUARY 2006

Canada

Aviation Investigation Report

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Synopsis

The Cessna 208B aircraft (registration C-GRXZ, serial number 208B0469) was en route at 9000 feet above sea level, from Tofino, British Columbia, to Vancouver International Airport, British Columbia, when the engine failed. The pilot began a glide in the direction of the Port Alberni Regional Airport before attempting an emergency landing on a logging road. The aircraft struck trees during a steep right-hand turn and crashed. The accident occurred at about 1420 Pacific standard time, approximately 11 nm south-southeast of the Port Alberni Regional Airport. Five passengers survived with serious injuries; the pilot and the other two passengers were fatally injured.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The pilot took off from Tofino, British Columbia, at 1353 Pacific standard time[1] on an instrument flight plan. The flight was over a designated mountainous region, in visual meteorological conditions (VMC),[2] above broken layers of cloud. Following the engine failure, the pilot began a right turn, declared an emergency to the Vancouver Area Control Centre, British Columbia, and requested a range and bearing to the nearest airport. At this time, the aircraft's rate of turn increased, and the aircraft rolled out on a heading direct to the Port Alberni Regional Airport, British Columbia, about 17 nautical miles (nm) to the northwest. The pilot was currently in VMC, but he would have to enter cloud during the descent. The pilot then requested navigational information to help keep the aircraft clear of the mountains.

Communication with the aircraft was lost as it descended through 7000 feet above sea level (asl). Radar data show that, at about 6000 feet asl, the pilot entered a tight left-hand, 360° turn, during which the rate of descent increased to about 2500 feet per minute. The aircraft came out of the turn at 4500 feet asl on a heading toward the Port Alberni Regional Airport. Aircraft in the area heard the pilot transmit a Mayday call indicating that he was attempting a forced landing on a logging road. The aircraft struck trees during a steep right-hand turn and crashed. Although fuel leaked into the cabin after the crash, there was no fire.

1.2 Engine Examination

The engine (PT6A-114A, serial number PCE19352) was removed from the wreckage and transported to an approved teardown facility. It was determined that all 58 blades in the compressor turbine (CT) section were broken. The CT blades had fractured at different heights relative to their blade tips. One particular blade was fractured near the airfoil root platform, and the topography of the fracture surface showed signs of fatigue cracking. The compressor had seized because of bearing damage following the CT blade failure.

1.3 Metallurgical Examination

Relevant parts of the engine were examined at the TSB Engineering Laboratory. Conclusions based on that examination are as follows:

- One CT blade failed as a result of the overstress extension of a fatigue-generated crack. The fracture initiated at a metallurgical anomaly in the parent blade material.

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1 All times are Pacific standard time (Coordinated Universal Time minus eight hours).

2 See Glossary at Appendix B for all abbreviations and acronyms.

- The fatigue crack progressed from the initiation site near the trailing edge, toward the leading edge in a high cycle mode, eventually resulting in blade failure due to overstress rupture when the remaining area could no longer support the applied loads.

- The remaining CT blades and the power turbine blades failed as a result of impact damage from the debris generated when the first CT blade failed.

- The number two bearing assembly failed as a result of the imbalance created when the CT blades broke.

1.4 Engine History

The engine was manufactured in 1995 by Pratt & Whitney Canada (P&WC) and is assigned a basic time between overhaul (TBO) of 3600 hours.

The engine had been overhauled twice since new. The first overhaul was done in the United States and was completed at 3528 hours. A hot section inspection was done on 22 October 2003, at 7677 hours, and all 58 CT blades were replaced with new blades. A TBO extension to 6000 hours was requested at that time and was granted in accordance with P&WC Service Bulletin (SB) 1703.

The second (most recent) engine overhaul was completed on 07 November 2005, at 9528 hours. During that overhaul, the CT blades that had been installed new in October 2003 were inspected and re-installed in accordance with approved P&WC overhaul procedures. At the time of the accident, the engine had accumulated about 140 hours of flight time since the most recent overhaul. The failed blade had been in operation for about 1991 hours since new.

1.5 Engine Condition and Trend Monitoring

The installation of an engine parameter recording system and use of an engine condition trend monitoring (ECTM) software is a condition of SB 1703 and must be fulfilled before allowing an extension to the TBO. Guidelines and standards for ECTM are contained in the P&WC ECTM user's guide and reference manual, and in service information letter (SIL) Gen-055. Those standards indicate that engine parameters should be recorded daily and processed in the ECTM software at least every three days. This is to ensure the quality of the recorded parameters during the downloading, and to ensure that the instrumentation that records the parameters remains functional. Sonicblue Airways was providing recorded engine parameters for processing and analysis, but on a weekly basis.

A review of the recorded engine data from the accident aircraft, as well as previous archived data, showed that there had been no exceedence of engine parameters and no change in the trend values over the period since the most recent overhaul. Recorded data for the last portion of the accident flight showed that the compressor speed (Ng) indicated 0 rpm, consistent with a seized compressor section, and the propeller rpm ranged between 5 and 19 rpm, consistent with a feathered propeller.

1.6 *Commercial Single-Engine Instrument Flight Rules Operations*

Canadian Aviation Regulations (CARs) allow air operators to fly single-engine aircraft under instrument flight rules (IFR) providing they are authorized to do so in their air operator certificate, and providing they comply with the applicable Commercial Air Service Standards (CASS). Section 723.22 of the CASS restricts single-engine instrument flight rules (SEIFR) operations to specific aircraft types, stipulates a proven mean time between failure (MTBF) for the engines that are used, establishes certain additional aircraft equipment requirements, and requires additional training for the involved pilots. Both the pilot and the aircraft met the CAR standards for SEIFR.

1.7 *Engine Reliability*

SEIFR authorization is based, in part, on the improved reliability of turbine engines as compared to their piston-engine counterparts. An essential element for SEIFR approval is that failure rates of the involved engine must remain low. CARs require the MTBF to be less than 0.01 failures per 1000 hours of flight time.

P&WC uses industry standard methods for calculating the MTBF of its engines. A basic In Flight Shut Down (IFSD) is an IFSD that is caused by a malfunction directly related to the engine or an engine component. These events are used in MTBF calculations and include unsubstantiated events where investigations are still in progress to identify the primary part that caused the event.

A non-basic IFSD is an IFSD caused by a component failure not directly related to the engine. These events are not included in the MTBF calculations and, for example, would include fuel pump failure, loss of oil pressure, bird ingestion, propeller failure, operator or maintenance error such as improper fuel load, failure to correctly complete compressor washes, engine overspeeds, engine over-temperatures, or improper engine adjustments.

In 2005, the basic IFSD rate for the PT6A-114A engine was about 0.0025 failures per 1000 hours. However, over the same time period, the total IFSD rate for the year, considering all causes, was approximately 0.01 failures per 1000 hours.

Other Canadian-approved flight operations such as extended range twin-engine operations (ETOPS) are also authorized, in part, because of the increased reliability of modern turbine engines. ETOPS are governed by Transport Canada’s (TC) TP 6327 entitled *Safety Criteria for Approval of Extended Range Twin Engine Operations (ETOPS)*. Appendix A of that publication recognizes that:

> No single parameter by itself, without other data/information, can adequately qualify reliability. There are a number of variables, maintenance and operating statistics and general information about the operational experience of a particular power unit, which characterize propulsion system reliability.

1.8 *Mountainous Regions*

TC first permitted SEIFR operations in Canada in 1993. At that time, the associated standard prohibited such operations in designated mountainous regions. Experience since 1993 has validated the premise behind SEIFR, which was that the reliability of modern turbine engines has made engine failure a low-probability event. Additionally, recent SEIFR rules published by the United States Federal Aviation Administration and the Australian Civil Aviation Safety Authority (CASA) do not contain prohibitions for flight over mountainous terrain. TC removed the restriction to SEIFR operations in designated mountainous regions in December 2000 in response to a report from industry proposing a need for changes to the regulations and standards governing SEIFR.

1.9 *Navigation Equipment*

In the event that an emergency landing is required, Section 723.22 of the CASS requires that an aircraft used in SEIFR operations have an electronic means of rapidly determining the location of the nearest airport and navigating to it. For an operator to be assured that such equipment is able to perform accurately, it must not only be functioning (serviceable), but the data it is using to calculate the exact whereabouts of the "nearest suitable airfield" must be accurate. This requirement can only be met through the use of the most current databases available. The accident aircraft was equipped with an approved King KLN 89B global positioning system (GPS) navigation system, but the system had an expired aviation database that was more than seven years out of date.

A button on the King KLN 89B GPS allows the pilot to display the range and bearing to the nearest airports; with the exception of the age of the database, this equipment meets the requirements of Section 723.22 of the CASS. Although not currently required by regulation, more modern GPS equipment is available that provides moving map displays, obstacle information, as well as the positions of towns, cities, roads, or other geographical features that could potentially be used to identify emergency landing sites if there are no airports within gliding range.

1.10 *Terrain Awareness Equipment*

The air traffic control system in Canada does not have detailed low-level terrain information; therefore, a controller has no ability to provide obstacle clearance information to a pilot. However, modern aircraft systems that display this type of information are available. These include enhanced ground proximity warning systems (EGPWS), and terrain awareness and warning systems (TAWS). At the time of the accident, Canada had no requirement for terrain avoidance equipment to be installed on aircraft engaged in SEIFR operations.

Unlike the Canadian regulations, Section 135.154 of the United States *Federal Aviation Regulations* does not allow the operation of "a turbine-powered airplane configured with six to nine passenger seats, excluding any pilot seat, unless that airplane is equipped with an approved terrain awareness and warning system that meets as a minimum the requirements for Class B equipment in Technical Standard Order (TSO)–C151."

1.11 Aircraft Glide Performance

A graph in the Cessna 208B pilot operating manual shows that an aircraft equipped with a cargo pod should be able to glide about 2 nm for every 1000 feet of altitude loss in glide configuration. In this accident, the aircraft was 9000 feet asl when the engine power was lost. The nearest airport was at Port Alberni, about 17 nm to the northwest, at an elevation of 247 feet asl. Calculations indicate that, based on the published glide ratio, and given the weather conditions at the time of the accident, it would have been theoretically possible for the aircraft to glide to the Port Alberni Regional Airport and have sufficient altitude while descending to overfly all of the en route terrain obstacles on the direct track line.

This scenario presupposes that the glide path be immediately established after the engine failure, awareness that there were no en route terrain obstacles, and a preparedness to enter instrument meteorological conditions (IMC).

1.12 Route/Altitude Selection

The accident flight was being conducted on published low-level airways between Tofino and Vancouver. Low-level airways are not designed to take into account the proximity of various en route airports. There is no specific requirement for operators who are authorized to conduct SEIFR flights to evaluate or alter their routes to minimize the risk exposure of passengers in the event of an engine failure while en route.

1.13 Weather

The Environment Canada graphical area forecast (GFA) showed that, throughout the area of the flight, there would be patchy ceilings between 800 feet above ground level (agl) and 1500 feet agl with broken layers above, between 2000 feet and 8000 feet. Ceiling heights were not reported for the Port Alberni Regional Airport.

1.14 Pilot Information

In the early 1990s, TC evaluated ways to mitigate risks associated with proposed SEIFR operations.[3] Part of that evaluation recognized a requirement for enhanced pilot training in preparation for SEIFR operations and concluded that pilots were to receive initial and recurrent training on engine failure in IMC.

The CARs require additional pilot training in preparation for SEIFR operations. The requirements are listed in Subsection 723.98(24) of the CASS, and include ground and simulator training for loss of engine power, as well as proper checklist use.

3 Transport Canada position paper (RDIMS 10197)

Simulator and emergency training for Cessna 208B pilots working for Sonicblue Airways was accomplished through an approved course at Flight Safety International in Wichita, Kansas, United States. Flight Safety International's standard simulator training does not include either ground briefing or practice of forced landing procedures in mountainous regions under instrument flight conditions. Flight Safety International can develop and provide specialized training to meet a customer's training requirements.

The pilot of the accident aircraft was qualified and met the currency, recency and training requirements of the CARs and of the company operations manual. He held a valid commercial pilot licence, a Category 1 medical, a valid pilot proficiency check (PPC), and a Group 1 instrument rating. He had 2480 hours of total flight experience, of which about 750 had been flown in the Cessna Caravan aircraft type. Training required by Subsection 723.98(24) of the CASS had been completed in February 2005 at Flight Safety International in Wichita, Kansas.

Autopsy and toxicology examinations following the accident found no irregularities that would have affected the accident sequence. The pilot's workload and schedule were appropriate from the perspective of both rest and duty time requirements.

1.15 Forced Landing Procedures

Forced landing patterns are taught as visual manoeuvres during training for private and commercial pilot licences. There are no additional requirements for pilots to train for the completion of a forced landing pattern in instrument conditions. In this accident, based on radar and voice data, the aircraft did break out into visual conditions in time to set up for an emergency landing.

1.16 Survivability

The Cessna 208B Caravan has many designed crashworthy features, including 14 g seats at all positions, shoulder belts for all occupants, and a reinforced keel along the fuselage bottom. Cessna has also designed the main landing gear to absorb the initial shock of a forced landing. In this occurrence, the seat frames buckled from the excess g loading, but all harnesses held.

The aircraft's two fuel shutoff valves, one in each wing root, were found with one in the fully open position, and one in a partially open position. Part of the forced landing check requires the pilot to close the fuel valves before touchdown. It is not known whether the pilot completed this checklist item.

During the impact sequence, both wing support structures were damaged. Any fore-aft movement of the wing could also have caused the fuel valve actuating cable to move from its selected position. Regardless, the design of these fuel valves is such that deceleration forces associated with a crash will tend to move the valves toward the OPEN (forward) position. In this occurrence, fuel did leak into the cabin area, causing some chemical injury to one passenger and increasing the risk of a post-crash fire.

2.0 Analysis

2.1 Engine Failure

The engine lost power when a CT blade failed as a result of the overstress extension of a fatigue-generated crack. The subsequent internal damage to the engine was immediate and catastrophic, causing the compressor section to seize because of vibration and bearing damage. Given the internal damage, the pilot would have been unable to restart the engine. This left the pilot with only one option—to attempt an emergency landing without engine power.

2.2 Pilot Reaction to the Engine Failure

It could not be determined why the pilot initially turned right, away from Port Alberni, while declaring the emergency. However, during that manoeuvre, the aircraft's rate of turn increased and the aircraft then rolled out on a heading direct to the Port Alberni Regional Airport. This suggests that the pilot had selected the onboard GPS to display the nearest airports, and then tightened the turn to line up with the Port Alberni Regional Airport.

The pilot then requested information to help him avoid high terrain, suggesting that he believed that there could be high terrain on his direct path to the Port Alberni Regional Airport. There is no capability for air traffic controllers to provide such navigational guidance. Additionally, there is currently no requirement for aircraft used in SEIFR operations to be equipped with TAWS. As a result, the pilot would have had no capability to locate or identify obstacles if he entered IMC.

The 360° descending turn conducted by the pilot may suggest that the pilot had seen a break in the cloud, and descended through it to maintain visual conditions. That manoeuvre allowed the pilot to avoid flight into cloud below safe IFR altitudes and in an area where he suspected there was high terrain.

A post-accident evaluation determined that there were no terrain risks between the aircraft and the airport when the engine failed. The pilot did not know this because the ground was obscured by cloud. Had the aircraft been equipped with a serviceable TAWS, it would have informed the pilot that there were no terrain risks between the point of the engine failure and his intended emergency landing field. With this information, he may have continued with his original plan to fly directly to the Port Alberni Regional Airport rather than descending into a mountainous region to maintain visual reference with the ground.

The last radio transmissions from the pilot indicated that he was clear of cloud in visual conditions, and that he had time to identify a potential landing area. He transmitted a Mayday call, and indicated that he was setting up for an emergency landing on a logging road. Because this procedure was being flown in visual conditions, the pilot would have been able to rely on his previous training to accomplish the emergency landing.

2.3 Mean Time Between Failure Calculations

The CARs require that engines used for commercial SEIFR operations maintain low MTBF rates. However, the MTBF of the engine may not be the most appropriate indicator of the margin of safety because these calculations do not take into account IFSDs not directly attributable to the engine itself. Regardless of the cause, any system failure that results in a loss of propulsive power leading to an emergency landing represents an elevated risk. Therefore, it would be more appropriate to monitor all SEIFR IFSD events, as is done under rules governing ETOPS operations.

2.4 Equipment

SEIFR operations are at increased risk of collision with terrain in mountainous regions where there are generally fewer airfields, unique terrain features, and fewer available sites for off-field emergency landings.

The GPS in the aircraft had an expired aviation database. The provision and use of out-of-date information, particularly during an emergency, can lead to an increased risk to flight safety.

Many aviation-approved GPS databases do not normally include roads or water bodies or other terrain features that could be useful in identifying potential emergency landing areas in the event that an emergency airfield is not within gliding range. Although equipment is available to display terrain warning information, Canada has no requirement for such equipment to be installed on aircraft engaged in SEIFR operations.

When the CAR restriction disallowing SEIFR operations in designated mountainous regions was removed without including a requirement for TAWS equipment, the level of safety to SEIFR operations was significantly reduced. Inclusion of a requirement for TAWS equipment in SEIFR operations would not only increase the margin of safety, but also move to harmonize Canadian regulations with the United States regulatory environment.

2.5 Routes and Altitudes

Published IFR routes are not structured to ensure that available airports remain within the normal power-out gliding range of single-engine aircraft. Unless airline operators are required to evaluate and structure the routes they use for SEIFR operations, the time that this type of flight is exposed to the potential of an emergency off-field landing will remain high.

2.6 Training

Although the current regulatory standard (Subsection 723.98(24) of the CASS) does require additional pilot training in preparation for SEIFR operations, there is no specific requirement for the simulator and emergency training to include either ground briefing or practice of engine failure/forced landing procedures under instrument flight conditions or in designated mountainous regions.

Had the pilot been able to glide the aircraft to the Port Alberni Regional Airport, the forced landing pattern would have had to be accomplished with a ceiling as low as 800 feet agl. This type of procedure is not currently practised in simulator or in-flight training.

Initial and recurrent training in an approved simulator to cover engine failure procedures in IMC, as well as forced landing procedures under instrument conditions, would better prepare a pilot to respond to such an emergency.

The following TSB Engineering Laboratory report was completed:

LP 010/2006 – Compressor Turbine Blade Examination

This report is available from the Transportation Safety Board of Canada upon request.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The engine lost power when a compressor turbine blade failed as a result of the overstress extension of a fatigue-generated crack. The fracture initiated at a metallurgical anomaly in the parent blade material and progressed, eventually resulting in blade failure due to overstress rupture.

2. The combination of aircraft position at the time of the engine failure, the lack of equipment enabling the pilot to locate and identify high terrain, and the resultant manoeuvring required to avoid entering instrument flight conditions likely prevented the pilot from attempting to glide to the nearest airfield.

3.2 Findings as to Risk

1. Single-engine instrument flight rules (SEIFR) operations in designated mountainous regions have unique obstacle risks in the event of an engine failure. Canadian equipment requirements for such operations do not currently include independent terrain mapping, such as terrain awareness and warning systems (TAWS).

2. Airline operators are not currently required to conduct any additional route evaluation or structuring to ensure that the risk of an off-field landing is minimized during SEIFR operations.

3. Pilots involved in commercial SEIFR operations do not receive training in how to conduct a forced landing under instrument flight conditions; such training would likely improve a pilot's ability to respond to an engine failure when operating in instrument meteorological conditions (IMC).

4. Mean time between failure (MTBF) calculations do not take into account In Flight Shut Downs (IFSDs) not directly attributable to the engine itself; it may be more appropriate to monitor all IFSD events.

5. The design of the Cessna 208B Caravan fuel shutoff valves increases the risk that the valves will open on impact, allowing fuel spillage and increasing the potential for fire.

3.3 Other Finding

1. Sonicblue Airways was not providing downloaded engine parameter data for engine condition trend monitoring (ECTM) evaluation at appropriate intervals.

4.0 Safety Action

4.1 Action Taken

4.1.1 Terrain Awareness and Warning System Equipment Requirement

A requirement for the installation and use of terrain awareness and warning systems (TAWS) has been supported by Transport Canada (TC). This installation and use of TAWS equipment will enhance a pilot's ability to identify and avoid terrain risks in the event of a loss of propulsion under instrument meteorological conditions (IMC). Information about the TAWS equipment requirements that are being approved for Canada can be found in TC's Commercial and Business Aviation Advisory Circular 0236 dated 29 July 2005, which is available on the TC website.

4.1.2 Enhanced Pilot Training Requirement

On 06 June 2007, the TSB sent a Safety Advisory to TC suggesting that TC consider incorporating additional pilot training requirements into Subsection 723.98(24) of the Commercial Air Service Standards (CASS) to ensure that single-engine instrument flight rules (SEIFR) pilots receive practical training on engine failure procedures in IMC. The training would include the pilot's initial response to the failure, the descent in instrument conditions, the avoidance of terrain hazards during the descent, and the practice of forced landings under various degraded surface weather conditions.

TC responded to this Safety Advisory on 25 July 2007. The response outlined a number of difficulties involved in establishing a specific standard that could cover a myriad of circumstances that a pilot may meet in the event of an engine failure under SEIFR operations.

TC's position is that air operators should be proactive in reviewing their SEIFR operations, specific to their individual training program, to ensure that this possible training gap or related hazard is addressed within the company operations manual.

TC's Civil Aviation Standards Branch will prepare an issue paper with the recommendation that air operators review their company training programs to ensure that SEIFR pilots receive practical training on engine failure procedures in IMC specific to the air operator operations and geographic location.

4.2 Action Required

4.2.1 Propulsion System Reliability

SEIFR authorization is based in part on the improved reliability of turbine engines as compared to piston engines. An essential element for SEIFR approval is that mean time between failure (MTBF) of the engine must remain high. *Canadian Aviation Regulations* (CARs) require the MTBF of the engine to be better than 0.01 per 1000 hours (that is, less than 1 failure per 100 000 hours of flight time).

Other Canadian-approved flight operations such as extended range twin-engine operations (ETOPS) are authorized in part because of the increased reliability of modern turbine engines. ETOPS are governed by TP 6327, *Safety Criteria for Approval of Extended Range Twin Engine Operations (ETOPS)*. Appendix A of that publication recognizes that:

> No single parameter by itself, without other data/information, can adequately qualify reliability. There are a number of variables, maintenance and operating statistics and general information about the operational experience of a particular power unit, which characterize propulsion system reliability.

To ensure the reliability of propulsion systems used for ETOPS, TP 6327 requires a record of all engine shutdown events both ground and in flight for all causes (excluding normal training events) including flameout. It also requires a list of all occurrences where achieved thrust was below the intended level, for whatever reason.

Although many of the rules governing ETOPs cannot be applied directly to single-engine operations, the underlying concept used to monitor propulsion system reliability could be applied to SEIFR to ensure a similar level of safety for crews and passengers.

While the engine type that was involved in this accident met the established reliability standard, it is important to note that, had the total number of In Flight Shut Down (IFSD) events (that is, loss of propulsion for all causes) been considered, the failure rate for the entire propulsion system would not have met the CARs standard in 7 of the last 10 years.

Any system failure that results in a loss of power and an emergency landing represents an elevated risk to the travelling public. Because the outcome of an engine failure in SEIFR operations can be catastrophic, the propulsion system reliability assessment should take into account all relevant variables and should not be limited to MTBF values alone.

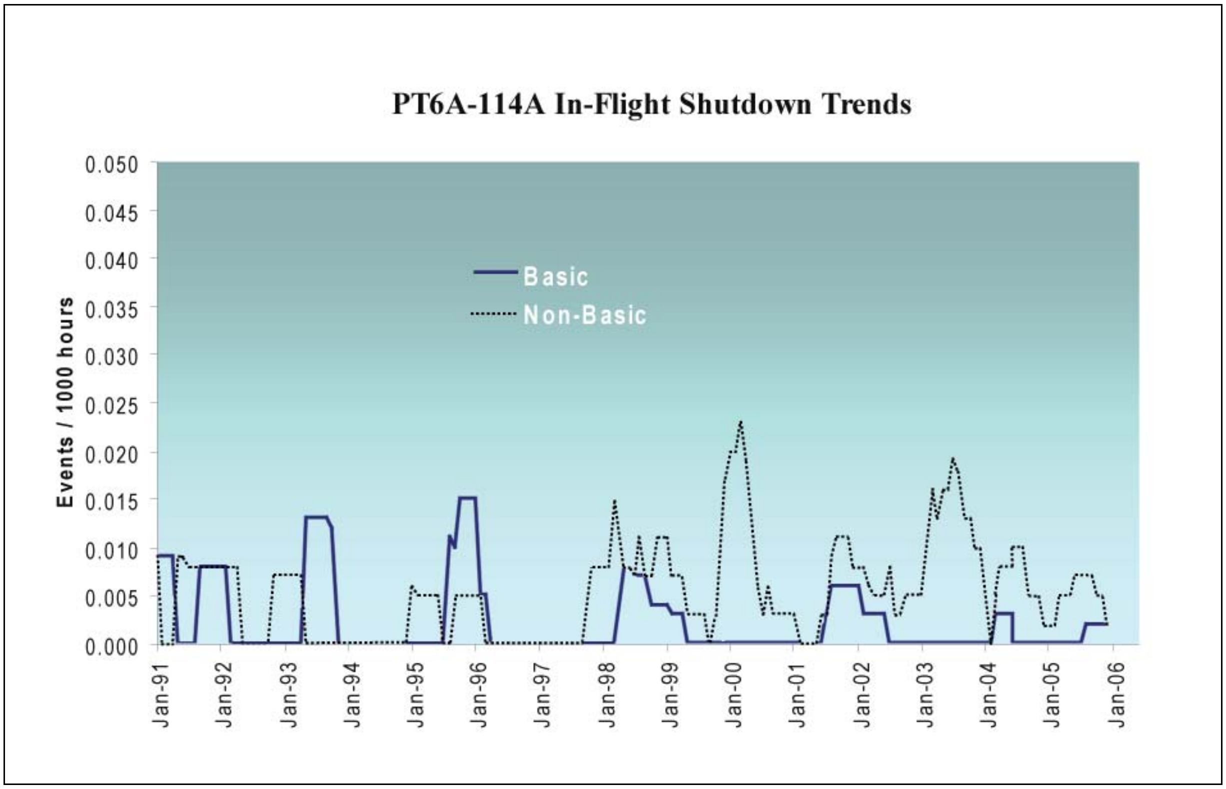
Therefore, the Board recommends that:

> The Department of Transport take into account all propulsion system failures when assessing the safety of single-engine commercial operations.

A07-08

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 09 August 2007.

Appendix A – Pratt & Whitney Canada In Flight Shut Down Data – Rolling Six-Month Average



A basic In Flight Shut Down (IFSD) is an IFSD caused by a malfunction directly related to the engine or an engine component (solid line). These events are used in mean time before failure (MTBF) calculations and include unsubstantiated events where investigations are still in progress to identify the primary part that caused the event.

A non-basic IFSD is an IFSD caused by a component failure not directly related to the engine (dotted line). These events are not included in the MTBF calculations.

Appendix B – Glossary

agl	above ground level
asl	above sea level
CARs	*Canadian Aviation Regulations*
CASA	Civil Aviation Safety Authority (Australia)
CASS	Commercial Air Service Standards
CT	compressor turbine
ECTM	engine condition trend monitoring
EGPWS	enhanced ground proximity warning system
ETOPS	extended range twin-engine operations
g	load factor
GFA	graphical area forecast
GPS	global positioning system
IFR	instrument flight rules
IFSD	In Flight Shut Down
IMC	instrument meteorological conditions
MTBF	mean time between failure
Ng	compressor speed
nm	nautical miles
PPC	pilot proficiency check
P&WC	Pratt & Whitney Canada
RDIMS	Records, Document and Information Management System
rpm	revolutions per minute
SB	Service Bulletin
SEIFR	single-engine instrument flight rules
SIL	service information letter
TAWS	terrain awareness and warning system
TBO	time between overhaul
TC	Transport Canada
TP 6327	*Safety Criteria for Approval of Extended Range Twin Engine Operations (ETOPS)*
TSB	Transportation Safety Board of Canada
TSO	Technical Standard Order
VMC	visual meteorological conditions
°	degrees