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

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A23W0040

COLLISION WITH TERRAIN

Government of Canada, Royal Canadian Mounted Police
Pilatus Aircraft Ltd. PC-12/47E, C-GMPX
Whitehorse/Erik Nielsen International Airport, Yukon
17 April 2023

Canada

ABOUT THIS INVESTIGATION REPORT

This report is the result of an investigation into a class 3 occurrence. For more information, see the Policy on Occurrence Classification at www.tsb.gc.ca

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Citation

Transportation Safety Board of Canada, *Air Transportation Safety Investigation Report* A23W0040 (released 03 June 2025).

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Air transportation safety investigation report A23W0040

Cat. No. TU3-10/23-0040E-PDF
ISBN 978-0-660-76538-9

This report is available on the website of the Transportation Safety Board of Canada at www.tsb.gc.ca

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Summary

At 1134 Mountain Standard Time on 17 April 2023, the Government of Canada, Royal Canadian Mounted Police Pilatus Aircraft Ltd. PC-12/47E (registration C-GMPX, serial number 1017) departed Whitehorse/Erik Nielsen International Airport (CYXY), Yukon, on an instrument flight rules flight to Yellowknife Airport (CYZF), Northwest Territories. The pilot was the sole occupant. Shortly after the aircraft lifted off from Runway 32L, its stall warning system activated, triggering an aural "STALL" warning and the activation of the stick shaker. The pilot informed the tower controller of the intention to return for landing. At 1138, while the pilot was visually manoeuvring to land on Runway 32L, the aircraft impacted the terrain approximately 520 feet west-southwest of the centre of the displaced threshold, in a right-wing-low attitude. The aircraft subsequently hit a pile of millings with its left wing, rolled onto its left side, and slid approximately 130 feet before coming to rest on an airport service road. The pilot, who was seriously injured, exited the aircraft through the emergency exit with assistance from aircraft rescue and firefighting personnel, who arrived within minutes of the accident. An emergency locator transmitter signal was received by the search and rescue satellite system. The aircraft was destroyed; there was no post-impact fire.

1.0 FACTUAL INFORMATION

1.1 History of the flight

At 0815[1] on 17 April 2023, the Government of Canada, Royal Canadian Mounted Police (RCMP) Air Services Branch Pilatus Aircraft Ltd. (Pilatus) PC-12/47E departed Yellowknife Airport (CYZF), Northwest Territories, on an instrument flight rules (IFR) flight to Whitehorse/Erik Nielsen International Airport (CYXY), Yukon.

On board were the pilot and 3 RCMP members, who were being transported to CYXY. The flight was uneventful, and the occurrence aircraft landed at CYXY at 1044. At that time, the temperature at CYXY was just below freezing, the winds were from the north and light (5 knots), vertical visibility was 1600 feet above ground level (AGL), and horizontal visibility was 2 statute miles (SM) in light snow.

The pilot parked the aircraft at the RCMP hangar and the passengers de-planed. Shortly after the aircraft was parked, the refueller began uplifting the requested fuel (160 L per side). While the fuelling was underway, the pilot, with the assistance of the RCMP CYXY base pilot, swept the wings of the aircraft to remove the snow.

After the fuelling was complete, the pilot started the aircraft and prepared for the return IFR flight to CYZF alone on board. The pilot received the automatic terminal information service (ATIS), which reported a temperature of −1 °C, a dew point of −2 °C, winds from the northwest at 4 knots, a vertical visibility of 1100 feet AGL, and a horizontal visibility of 1½ SM.

At 1134, the aircraft was cleared for takeoff from Runway 32L and commenced its take-off roll directly ahead of the displaced threshold,[2] which was adjacent to the intersection of Taxiway Echo and Runway 32L.

The aircraft became airborne at a point down the runway approximately 3400 feet from the displaced threshold. Shortly after liftoff, the continuous aural “STALL” warning, along with the stick shaker (commonly referred to as “the shaker”), activated. At that point, approximately 4700 feet of runway remained. Concerned that the aircraft’s stick pusher (commonly referred to as “the pusher”) would engage while at a very low height above ground, the pilot depressed the PUSHER INTR (pusher interrupt) switch and held it depressed for the remainder of the occurrence flight.[3] With approximately 3775 feet of

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[1] All times in Mountain Standard Time (Coordinated Universal Time minus 7 hours).

[2] A displaced threshold is “a threshold not located at the extremity of a runway.” (Source: International Civil Aviation Organization, *Annex 14 to the Convention on International Civil Aviation*, *Aerodromes*, Volume I—Aerodrome Design and Operations, Ninth Edition (July 2022), section 1.1: Definitions, p. 1-4.) Although the displaced threshold area (the portion of the runway behind the displaced threshold) is unavailable for use in landings, this area can still be used for takeoffs and taxiing in both directions and for landings from the opposite direction.

[3] The PUSHER INTR switch is discussed in section 1.6.3.1 *General*.

runway remaining, the pilot briefly reduced power to flight idle and contemplated rejecting the takeoff and landing straight ahead.

At this time, the aircraft's speed was 120 knots calibrated airspeed (KCAS) and its height was 40 feet AGL. Approximately 2 seconds after the power reduction, the pilot re-applied power and continued the takeoff, having assessed that there was insufficient runway remaining to land straight ahead. The pilot then retracted the flaps[4] and landing gear.

The pilot was aware that the aural stall warning could be silenced by pulling specific circuit breakers but was unsure of which circuit breakers to pull. Therefore, the pilot opted to focus on flying and disregard the aural stall warning rather than attempt to locate the circuit breakers that could be pulled to suppress it. The aural stall warning and the shaker persisted for the remainder of the flight.

The pilot, having elected to remain below the clouds, then attempted to inform air traffic control (ATC) of the intention to perform an immediate return to the runway; however, because of radio congestion on the frequency, the transmission was not received.

The pilot commenced a 180° left turn to return and land on Runway 14R. The pilot then informed ATC of the intention to land but did not specify on which runway. The tower controller, who was unable to see the aircraft because of the low visibility at the time, cleared it for a right downwind approach to Runway 32L.

At this point, the pilot remembered that the published visual circuit direction was to the right for Runway 32; however, the aircraft was already established in the left-hand turn, so the pilot elected to continue the turn. The pilot, whose attention was focused on turning back for Runway 14R, did not reply to the tower controller's last communication.

While attempting to line up for Runway 14R, the aircraft passed roughly halfway between the runway and the control tower, at a height of approximately 450 feet AGL (Figure 1).

Approximately 4000 feet after the threshold of Runway 14R, the aircraft lined up over the runway, at approximately 350 feet AGL. At that point, the pilot determined that the aircraft was too high to safely land in that direction. At the same time, the pilot was also becoming increasingly concerned by the continuous aural stall warning and started to believe that there may be something seriously wrong with the aircraft.

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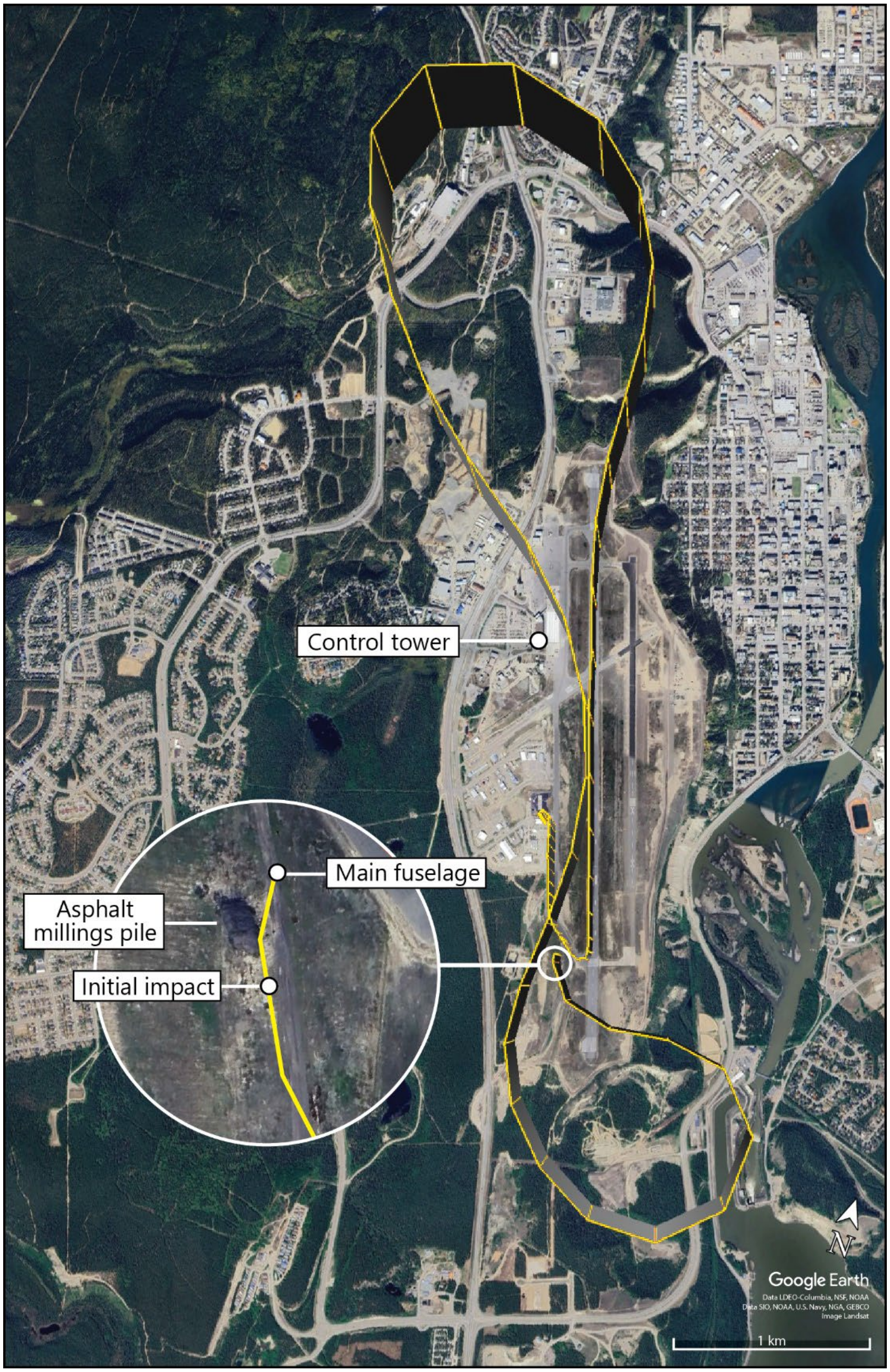
4 Each wing's trailing edge has a single-piece Fowler-type flap that is electrically actuated. The flaps may be set to 1 of the 4 pre-set positions: 0°, 15°, 30°, or 40°. At takeoff, the flaps were set to 15°, as directed in the Pilatus PC-12/47E pilot operating handbook (POH). (Source: Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 [14 October 2022], section 4.8.1: Before Departure, p. 4-17.)

Figure 1. Map showing the occurrence aircraft's flight track, with a close-up of the impact location and the final location of the main fuselage in inset (Source of main image and inset image: Google Earth, with TSB annotations)



After a brief period directly over the runway, the pilot then altered course approximately 20° to the right in anticipation of a 180° left turn onto final for Runway 32L. As the aircraft passed abeam and 1300 feet to the west of the displaced threshold of 32L, the pilot extended the landing gear. Two seconds later, with the aircraft at 170 feet AGL and engine torque at 0.9 psi, the "Pull up" terrain alert activated. Engine torque then increased, and the aircraft briefly levelled off.

As this was happening, the aircraft reached its lowest speed, approximately 93 KCAS, while at a height of approximately 200 feet AGL. The pilot then began a left turn, with bank angles ranging from 5° to 20°, to position the aircraft on final for Runway 32L. During the turn and on an easterly heading, the aircraft flew through the extended centreline for Runway 32L, approximately 0.4 nautical miles (NM) from the threshold.

After crossing the extended centreline, the pilot increased the bank angle of the left turn in an attempt to bring the aircraft back towards the extended centreline and intercept the final approach for Runway 32L.

The aircraft, now being flown visually on a westerly heading, crossed Runway 32L at an angle of approximately 75°, about 600 feet beyond the threshold and 800 feet before the displaced threshold. As the aircraft crossed the centreline, its height was approximately 100 feet AGL and its airspeed was 96 KCAS. The aircraft then entered a descending right turn, with bank angles reaching values in excess of 45°.

At 1138:16, the right wing of the aircraft struck the ground approximately 520 feet west-southwest of the middle of the displaced threshold of Runway 32L. Moments later, the left wing struck a frozen millings pile,[5] causing the left wing to separate from the aircraft. The aircraft rolled over onto its left side and slid approximately 130 feet before coming to rest on an airport service road approximately 210 feet north of the initial contact point and 480 feet west of the middle of the displaced threshold.

The occurrence pilot was seriously injured but able to exit the aircraft via the overwing emergency exit[6] with the help of aircraft rescue and firefighting personnel, who arrived at the location minutes after the accident.

1.2 Injuries to persons

The pilot was wearing the installed 4-point safety belt, which consisted of a lap strap and shoulder harness but suffered a head injury during the impact sequence. The pilot was admitted to hospital for an assessment of injuries and was subsequently released the following day.

Table 1. Injuries to persons

Degree of injury	Crew	Passengers	Persons not on board the aircraft	Total by injury

5 Millings, also referred to as aggregate, are recycled, crushed pieces of stone or concrete that can be repurposed and used in new construction projects. In this occurrence, the pile consisted of asphalt millings.

6 The overwing emergency exit "is located over the right wing and is 2 ft 2 in (0.68 m) high by 1 ft 6 in (0.49 m) wide. This exit contains a window and can be quickly opened from either inside or outside when required." (Source: Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 [14 October 2022], section 7-8: Doors, Windows, and Exits, p. 7-8-2.)

Fatal	0	–	–	0
Serious	1	–	–	1
Minor	0	–	–	0
Total injured	1	–	–	1

1.3 Damage to aircraft

The aircraft was destroyed due to the impact with terrain, the subsequent contact with a millings pile, and the rollover.

1.4 Other damage

The accident occurred west of Runway 32L, away from any built-up areas.

The crash resulted in an uncontrolled fuel spill of approximately 1000 L. The clean-up effort was coordinated by the Government of Yukon's Department of Highways and Public Works, Transportation Aviation Branch.

1.5 Personnel information

Table 2. Personnel information

Pilot licence	Airline transport pilot licence
Medical expiry date	01 June 2023
Total flying hours	8700
Flight hours on type	3000
Flight hours in the 24 hours before the occurrence	2.6
Flight hours in the 7 days before the occurrence	10.1
Flight hours in the 30 days before the occurrence	18.7
Flight hours in the 90 days before the occurrence	72.9
Flight hours on type in the 90 days before the occurrence	72.9
Hours on duty before the occurrence	4.5
Hours off duty before the work period	48

The occurrence pilot held a Canadian airline transport pilot licence – aeroplane endorsed for single- and multi-engine landplanes, with a Group 1 instrument rating. The pilot also held a Category 1 medical certificate that was valid until 01 June 2023.

The pilot joined the RCMP in November 2015 as the Base Manager and Pilatus PC-12 pilot at the RCMP's CYZF base. The pilot had last completed annual recurrent training, consisting of ground school, simulator training, and a pilot competency check, in March 2023.

The occurrence pilot had flown to CYXY 9 times since joining the RCMP. All 9 flights were carried out under IFR and consisted of instrument arrivals and departures. The occurrence pilot had never operated under visual flight rules (VFR) at CYXY.

Based on a review of the pilot's work and rest schedule, there was no indication that the pilot's performance was degraded by fatigue.

1.6 Aircraft information

1.6.1 General

The Pilatus PC-12/47E is a pressurized, single-engine turboprop aircraft that has a low-wing, T-tail design[7] and retractable landing gear. The occurrence aircraft was manufactured in 2008 and acquired the same year by the RCMP. At the time of the accident, the aircraft was configured with 4 passenger seats in the cabin.

Table 3. Aircraft information

Manufacturer	Pilatus Aircraft Ltd.
Type, model, and registration	PC-12/47E, C-GMPX
Year of manufacture	2008
Serial number	1017
Certificate of airworthiness / flight permit issue date	11 December 2008
Total airframe time	11 908.3 hours
Engine type (number of engines)	Pratt & Whitney Canada PT6A-67P (1)
Propeller type (number of propellers)	Hartzell HC-E4A-3D (1)
Maximum allowable take-off weight	10 450 lb (4740 kg)
Recommended fuel type(s)	Jet A, Jet A1, Jet B, JP-4
Fuel type used	Jet A

At the time of the occurrence, there were no recorded defects outstanding, and the aircraft's weight and centre of gravity were within the prescribed limits.

1.6.2 Avionics

The aircraft was equipped with a Honeywell Primus Apex Integrated Avionics System, a glass cockpit[8] system integrated into the flight deck. The system consists of 2 primary flight displays (PFDs) and 2 multifunction displays. The PFDs include the optional SmartView Synthetic Vision, which features advanced displays, such as 3-dimensional terrain, approach guidance, terrain alerting, and visual runway indicators. The multifunction displays provide Interactive Navigation graphical flight planning, digital charts and maps, radio tuning, and aircraft synoptic displays (i.e., active system diagrams).

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7 The horizontal stabilizer is mounted on top of the vertical stabilizer. This design is commonly referred to as a T-tail.

8 A glass cockpit refers to an aircraft cockpit that features electronic instrument displays rather than mechanical gauges.

The flight management system supports both precision and non-precision approaches, the Wide Area Augmentation System (WAAS),[9] and a full complement of area navigation (RNAV) approaches.

1.6.3 Stall warning / stick pusher system

1.6.3.1 General

The Pilatus PC-12/47E is equipped with a stall warning system (aural warning and shaker) and a stick pusher system. This design was implemented because the PC-12 could not originally meet all of the legacy requirements for stall certification presented in Part 23 of the United States (U.S.) *Federal Aviation Regulations*.

In particular, in a power-on stall, the aircraft exhibited no pre-stall warning, no pitch down, and a wing drop greater than 15°. As a result, the stall warning and pusher systems were implemented to prevent the aircraft from reaching an aerodynamic stall.[10] The former warns pilots of an imminent stall so that they can correct a high angle of attack (AOA), and the latter intervenes to prevent a stall by pushing forward on the elevator control system, thereby reducing the AOA.

The PC-12/47E pilot operating handbook (POH) describes the stall warning and pusher systems as follows:

> The airplane is equipped with a stick shaker-pusher system to improve aircraft handling in the low speed flight regime by preventing the airplane from inadvertently entering a stall condition. The stick shaker-pusher system contains two Angle-of-Attack (AOA) sensors,[11] two computers, a single stick shaker and a single stick pusher. The two computers are connected in such a way that either computer can, independently, provide stall warning (stick shaker and stall warning [a continuous aural "STALL" warning broadcast across the intercom system and a visual "STALL" warning on the PFD]) but both computers are required to actuate the stick pusher.
>
> […]
>
> The stick pusher, shaker, the Flight Alerting System (FAS)[12] visual "Stall" and aural "Stall" warnings are disabled on the ground […]. The stick pusher is inhibited for

9 The Wide Area Augmentation System is an air navigation aid that was developed by the U.S. Federal Aviation Administration (FAA) to enhance GPS (global positioning system).

10 Pilatus Owners and Pilots Association, PC-12 Stall Protection System, https://pilatusowners.org/wp-content/uploads/2014/06/04fall.pdf (last accessed on 04 March 2025).

11 The Pilatus POH uses both "sensor" and "transmitter" to refer to the entire AOA system unit, not simply the vane or resolver. In this report, the term "AOA transmitter" is used.

12 The Flight Alerting System (FAS) will present messages "… on the pilot's PFD to warn of a condition that requires immediate action from the pilot. FAS messages are directly related to the operation of the aircraft. All the FAS messages are accompanied by a voice callout and can only be cancelled by correcting the aircraft condition." (Source: Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 [14 October 2022], section 3.1.2: Flight Alerting System, p. 3-2.)

5 seconds after lift-off. The shaker and stall warning are operative immediately after lift-off.[13],[14]

The stick pusher computers receive input from the AOA vanes, engine torque, flap position, ice protection system settings, and self-test function. From these inputs, the stick pusher computers calculate a defined AOA for the activation of the stall warning system (shaker and aural and visual warnings) and the activation and deactivation of the pusher. Information from the computers is sent to the Modular Avionics Unit and is used to display the Low Speed Awareness Indication adjacent to the Air Speed Tape.

The activation of the shaker will disengage the autopilot, if engaged, in order to give full authority to the pusher system; however, the activation of the shaker does not affect how the aircraft responds to flight control inputs. As a result, the aircraft can still be flown, without much difficulty, while the shaker is activated.

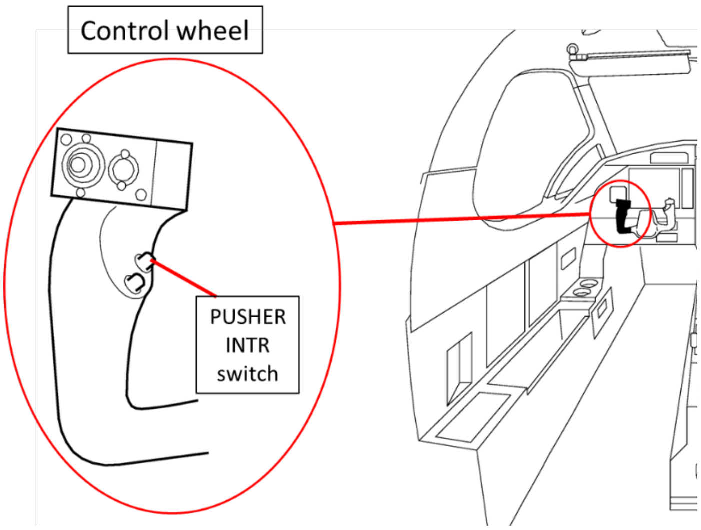
Each outboard control wheel horn is equipped with a PUSHER INTR switch (Figure 2), which, as long as it is pressed, enables the pilot to quickly disable the pusher and allows for free movement of the elevators from the cockpit using the control column.

Depressing the PUSHER INTR switch does not turn off other stall warning system functions. Therefore, if 1 of the AOA transmitters senses a stall, the aural stall warning and the shaker will activate whether or not the PUSHER INTR switch is depressed.

13 Ibid., section 7-21: Stall Warning / Stick Pusher System, p. 7-21-1.

14 At liftoff, the weight-on-wheels switch senses that the aircraft is airborne.

Figure 2. Left control wheel in the cockpit, with a close-up in inset showing the PUSHER INTR switch (Source: Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 [14 October 2022], section 7-21: Stall Warning / Stick Pusher System, Figure 7-21-1: Stall Warning/Stick Pusher System [Sheet 3 of 3], p 7-21-7, with TSB annotations)



The pusher system must be tested before takeoff on each flight[15] using the system's self-test function. This is done by pressing and holding the STICK PUSHER pushbutton, located on the SYSTEM TEST section of the overhead panel. The system will perform a self-test that tests the stick pusher computer and also verifies operation of the pusher servo, the interrupt function, the shaker, and the crew alerting system annunciations. The self-test does not check the validity of the input from the AOA transmitters.

1.6.3.2 Angle of attack system operation

The AOA system uses moveable, electrically heated vanes on probes, located on each wing, that extend forward from the leading edge (Figure 3). According to the POH, during the pre-flight inspection, pilots must check both AOA probes to ensure "free movement."[16]

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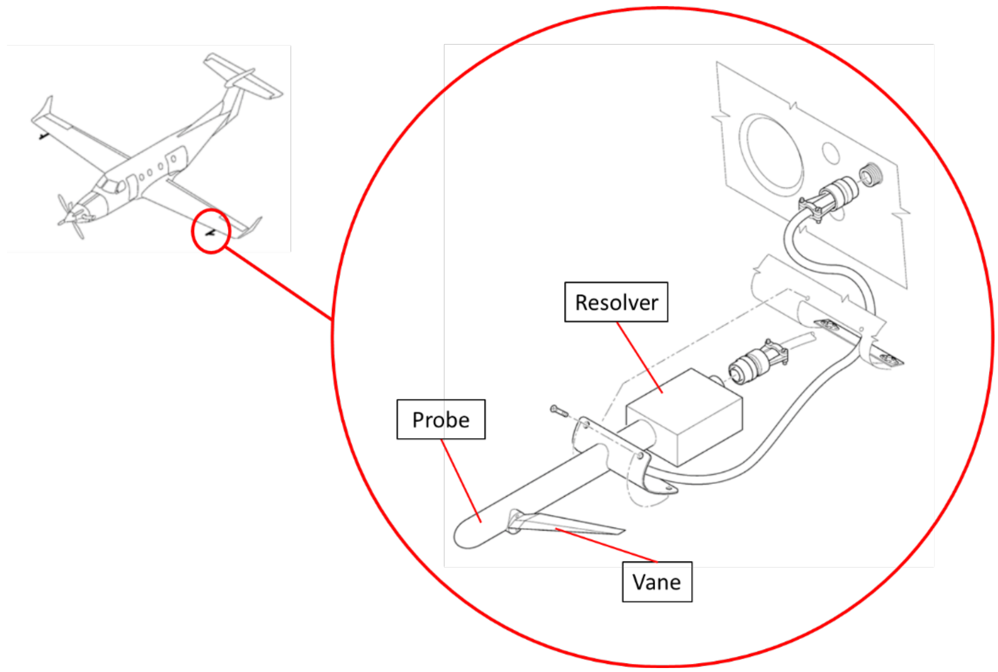
15 Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 7-21: Stall Warning / Stick Pusher System, p. 7-21-2.

16 Ibid., section 4.3: Preflight Inspection, pp. 4-5 and 4-7.

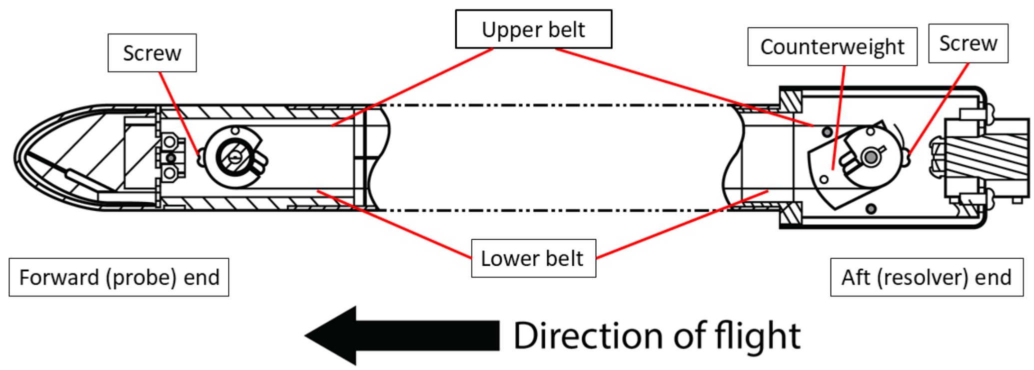
Figure 3. Angle of attack system, with close-up of vane and probe in inset (Source: Pilatus Aircraft Ltd., Doc. No. 02300, *PC-12/47E Aircraft Maintenance Manual*, Issue 01, Revision 30, Figure 1: AOA Transmitter – Removal/Installation, p. 5, with TSB annotations)



As the AOA vane moves based on relative airflow, its movement is transmitted ultimately to the stick pusher computer via a small stainless steel belt (approximately 4 mm wide by 432 mm long by 0.05 mm thick) on a pulley-type system (Figure 4). The belt forms a loop and wraps around a pulley at the probe (forward) end of the pulley system, where the belt is secured by a screw. The 2 ends of the belt wrap around a 2nd pulley at the resolver (aft) end of the pulley system, overlap each other, and are also secured with a screw.

In this configuration, the belt therefore has a hole on each of its ends (for the screw that secures these 2 belt ends at the aft end of the pulley system) and a 3rd hole approximately midway along its length (where the other screw secures the belt at the forward end of the system). On one end of the belt, the hole is round, and on the other, it is oval. For ease of understanding, the terms “upper belt” and “lower belt” are used to describe, respectively, the portion of the belt above the 2 pulleys and the portion of the belt below them.

Figure 4. Schematic diagram of the general assembly of the angle of attack system (Source: TSB)

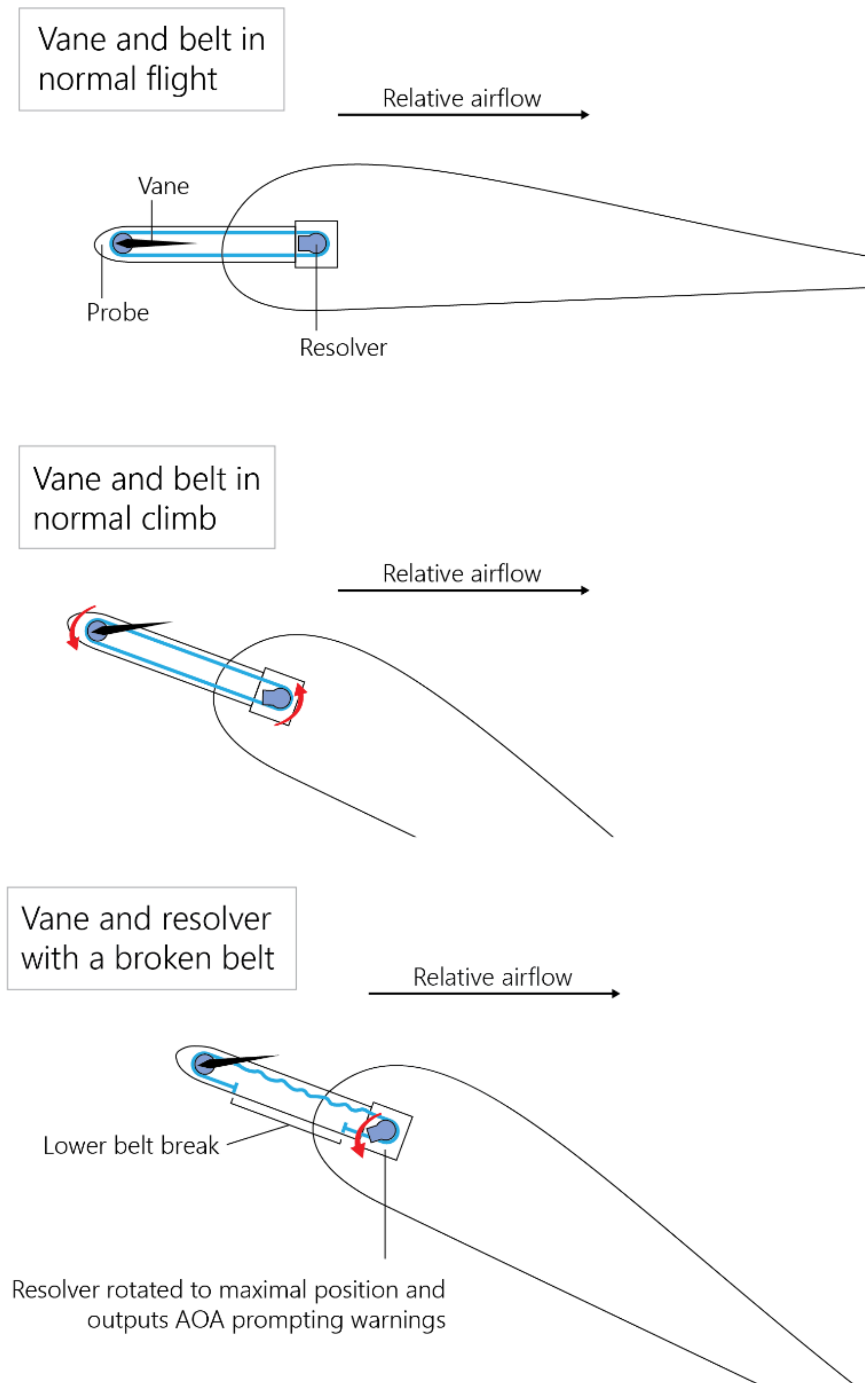


The vanes are mounted on precision bearings that rotate to align the vane with the relative airflow. This rotation is transferred from the forward pulley to the aft pulley, which generates a signal that is interpreted by the stick pusher computer as an AOA. As the AOA increases, the rotation of the forward pulley applies a tensile force to the upper belt. Conversely, when the AOA is reduced, a tensile load is transmitted to the lower belt. The aft pulley is equipped with a counterweight assembly that assists in dampening system responses caused by small oscillations and perturbations in the airflow.

If the lower belt were to be severed or detached from either pulley, the rotation of the vane would not be transmitted to the resolver, and the tensile aligning forces on the belt would be lost. The free rotation angle of the counterweight (as a result of gravitational forces) is greater than its nominal rotational angle range when the belt is intact. Therefore, if there were a broken or detached lower belt in any flight attitude, gravitational forces would cause the counterweight to rotate and drop to a position at the bottom of the resolver.

This extreme rotation would result in the resolver generating an AOA signal in the stall regime. Figure 5 depicts this motion. Within the Pilatus PC-12 fault monitoring system, there is no monitoring for belt continuity, nor is there a record in the data recorders or in any other aircraft system that would indicate which AOA transmitter may be reporting a stall to the AOA computers.

Figure 5. Typical angle of attack vane and belt movement in relative airflow during normal flight and normal climb, as well as during a belt breakage (Source: TSB)



If either AOA vane senses an AOA that, based on the computer's calculation, is approaching a stall condition (5 to 10 knots before the activation of the pusher), it will trigger the aircraft's continuous aural "STALL" warning and activate the shaker.[17] According to Pilatus, the volume of the aural stall warning is pre-adjusted to ⅓ of the maximum volume, and the volume cannot be adjusted at the audio panel because the warning is always present on 2 unswitched outputs which are provided to the headsets (it will not be heard over the speakers).[18]

A "STALL" indication will also appear on the PFDs. The aural stall warning and the shaker will continue to be active until the stick pusher computer senses that the AOA has decreased below the calculated threshold value. If the second AOA transmitter also senses an excessive AOA, the pusher will activate to "induce a controlled lowering of the nose before the onset of the physical aerodynamic stall."[19]

Pilatus indicated that during the certification process, the "uncommanded stall warning" failure mode was classified as "minor" since it involved a "misleading indication but no significant reduction in the safety margin."[20]

1.6.3.3 Emergency procedures

1.6.3.3.1 General

The POH provides guidance to pilots for dealing with abnormalities that may arise and highlights the well-established principle for managing priorities: aviate, navigate, communicate. In an abnormal situation, or if there is any indication of a malfunction, Pilatus recommends that pilots follow the "PPAA" work process:

P	Power	Check engine power setting versus actual power
P	Performance	Check speed, flight path and aircraft configuration
A	Analysis	Analyze the situation within the time available using all means of other indications to verify initial cue (e.g. cross reference CAS [crew alerting system] message with other system parameters or indications, check circuit breaker panel for CAS related CB [circuit breaker] status)
A	Action	Immediate and subsequent actions guided by airmanship and given checklist procedures[21]

Some of the emergency procedures in the POH include a list of indications to help the pilot identify the situation and the appropriate procedure to follow. For example, the "FUEL PUMP FAILURE" emergency procedure lists the following indications:

3.16.7 FUEL PUMP FAILURE

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17 Ibid., section 7-21: Stall Warning / Stick Pusher System, p. 7-21-3.

18 Pilatus Aircraft Ltd., TSB Query Response Document (A23W0040), v03 (26 February 2024), p. 3 of 15.

19 Pilatus Aircraft Ltd., email from Pilatus Aircraft Ltd. to TSB investigator (19 April 2023).

20 Pilatus Aircraft Ltd., TSB Query Response Document (A23W0040), v03 (26 February 2024), p. 10 of 15.

21 Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 3.1: General, p. 3-1.

Indication:

- Fuel pump(s) on for more than 10s with fuel balanced and no Fuel Pressure Low caution, or
- Both fuel pumps on for more than 10s with 2 or more segments difference between left and right and no Fuel Pressure Low caution, or
- Fuel pumps not running with green PUMP advisory on, or
- Fuel pressure low and Fuel pumps not running.[22]

1.6.3.3.2 Inadvertent pusher/shaker operation

Section 3.13 of the POH contains an emergency procedure titled "Inadvertent Pusher/Shaker Operation." It is broken down further into 2 sections. The 1st is section 3.13.1 Pusher and the 2nd, section 3.13.2 Shaker. This latter section contains the procedure to deal with an inadvertent shaker, which states the following:

Indication: Non-commanded shaker operation.

1.	**AOA**	**Decrease**
2.	**IAS [indicated airspeed]**	**Increase**

If shaker continues to operate:

3.	**STALL WARN 1 circuit breaker (Essential Bus LK3)**	**Pull**
4.	**STALL WARN 2 circuit breaker (Main Bus RH3)**	**Pull**

WARNING

THE AIRCRAFT IS NOT STALL PROTECTED.[23]

The STALL WARN 1 circuit breaker is located on the front-left circuit breaker panel, approximately adjacent to the left pilot's seat (figures 6 and 7). The STALL WARN 2 circuit breaker is located on the opposite side of the cockpit, on the front-right circuit breaker panel, outboard of the right pilot's seat (figures 6 and 8). The STALL WARN circuit breakers are not collared.[24] According to Pilatus, circuit breakers are grouped by their associated electrical bus and, to ensure physical bus separation, placed on individual circuit breaker panels.[25]

The occurrence pilot was not aware that the inadvertent shaker operation checklist would apply in this emergency nor were there attempts to refer to the quick reference handbook – emergency procedures.

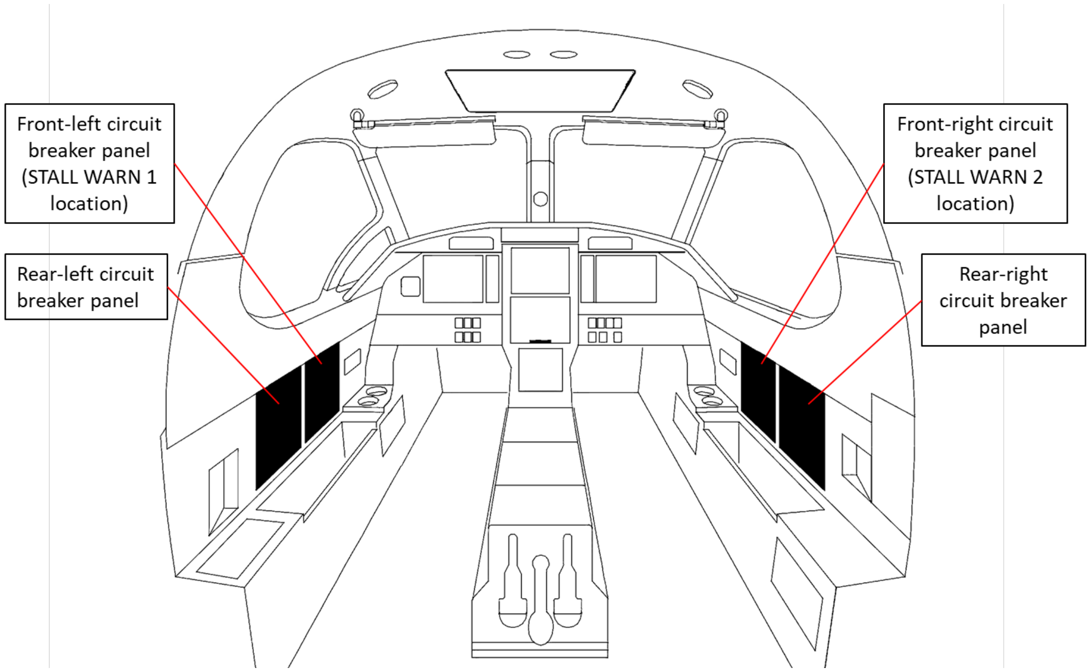
22 Ibid., section 3.16.7: Fuel Pump Failure, p. 3-65.

23 Ibid., section 3.13.2: Shaker, p. 3-42.

24 Circuit breaker collars, which are often different colours, assist with visual identification of circuit breakers.

25 Pilatus Aircraft Ltd., email from Pilatus Aircraft Ltd. to TSB investigator (28 March 2024).

Figure 6. Cockpit layout showing location of circuit breaker panels and STALL WARN circuit breakers (Source: Pilatus Aircraft Ltd., Report No. 02277, Pilot's Operating Handbook and EASA Approved Airplane Flight Manual, Revision 23 [14 October 2022], section 7-13: Electrical, p. 7-13-10, with TSB annotations)



The 2 emergency procedures outlined in section 3.13 of the POH, unlike the emergency procedure for a fuel pump failure, make no reference to any other indications, such as an aural stall warning or a visual stall indication on the PFD. In addition, the procedures offer no possible source of, or explanation for, the emergency.

1.6.4 Monitor warning system

The PC-12 is equipped with a monitor warning system (MWS) that provides warnings, cautions, and aural alerts to the crew in the event of certain faults, functions, or conditions.[26] Some situations, such as a stall condition, require immediate action from the pilot. For that reason, these systems use voice callouts that can be cancelled only by correcting the aircraft's condition.

When the aircraft is airborne, there is an aural warning hierarchy that establishes which aural warning has priority over others. In general, certain aural alerts are suppressed by other aural alerts with higher priority, until those higher-priority alerts are cleared. Once the higher-priority aural alert has been cleared, the next highest priority aural alert is enabled.

The aural "STALL" warning is the highest priority and will suppress all other MWS aural alerts. According to the POH, when the system detects a stall, the aural "STALL" warning is

26 Flight Safety International, *Pilatus PC-12 NG Pilot Training Guide*, Pilot Initial, Revision 0.2 (April 2022), p. 5-4.

continuous and not mutable by pressing the master warning attention light.[27] The manufacturer also notes that when the aural stall warning is triggered, it will command the shaker simultaneously. Therefore, the aural "STALL" warning is generated in conjunction with a shaker command.[28]

According to the POH, the AURAL WARN INHIBIT switch (located on the rear-left sidewall panel, generally adjacent to and behind the pilot's seat) can be set to INHIBIT to silence "failed repetitive aural" warnings controlled by the MWS.[29] Although not specified in the POH, this includes silencing the aural stall warning. According to Pilatus, it would be uncommon for PC-12 pilots to have a reason to use the AURAL WARN INHIBIT switch.[30]

In normal operations, the switch should be set to ON, and this is confirmed during the cockpit preparation stage of the normal checklist during the pre-flight inspection.[31] The POH does not identify specific scenarios in which the AURAL WARN INHIBIT switch could be useful to the pilot while the aircraft is airborne.

The aircraft will also provide terrain alerts (the terrain awareness and warning system [TAWS] and the enhanced ground proximity warning system [EGPWS]) and traffic alerts (the traffic advisory system [TAS] and the traffic collision avoidance system [TCAS]). In the hierarchy of aural warnings, terrain alerts will have priority over traffic alerts. Terrain and traffic alerts are fed directly into the audio panel and will thus be audible simultaneously with aural alerts from the Monitor Warning Function (with one overlying the other).[32] The AURAL WARN INHIBIT switch will not silence any terrain or traffic alerts because they are generated by their respective units and fed directly into the audio system.

1.7 Meteorological information

At 1138, an aerodrome special meteorological report (SPECI) for CYXY was issued, indicating the following:

- Winds from 360° true at 3 knots
- Visibility of 1½ SM in light snow
- Vertical visibility of 800 feet AGL
- Temperature −1 °C and dew point −1 °C

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[27] Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 7-31: Primus Apex – Monitor Warning System (MWS), p. 7-31-3.

[28] Pilatus Aircraft Ltd., TSB Query Response Document (A23W0040), v03 (26 February 2024), p. 3 of 15.

[29] Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 7-31: Primus Apex – Monitor Warning System (MWS), p. 7-31-4.

[30] Pilatus Aircraft Ltd., TSB Query Response Document (A23W0040), v03 (26 February 2024), p. 2 of 15.

[31] Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 4.3.8: Cockpit, p. 4-8.

[32] Ibid., section 7-31: Primus Apex – Monitor Warning System (MWS), p. 7-31-4.

- Altimeter setting 29.58 inches of mercury
- The remarks indicated that snow was responsible for all 8 oktas[33] of sky coverage

The aerodrome forecast for CYXY, issued at 1105 and valid from 1100 to 2300, called for the following:

- Winds from 340° true at 5 knots
- Visibility greater than 6 SM in light snow
- A layer of scattered clouds based at 1500 feet AGL and an overcast ceiling based at 3000 feet AGL
- Temporarily, between 1100 and 1500, visibility of 1½ SM in light snow, with a vertical visibility of 1000 feet AGL

At the time of the occurrence, the actual weather was consistent with the weather conditions reported in the aerodrome special meteorological report issued at 1138.

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

CYXY is located west of Whitehorse, at an elevation of 2317 feet above sea level and on a level plateau roughly parallel to, and approximately 225 feet above, the Yukon River. To the east of the airport, the terrain initially drops and then begins to rise on the east side of the Yukon River. Immediately west of the airport, the terrain begins to rise.

The airport, which is located in mountainous terrain and surrounded by a Class D control zone with a 5-nautical-mile radius extending from the surface up to 5300 feet above sea level, is served by a NAV CANADA control tower from 0700 to 2100 daily. CYXY has 3 asphalt runways (Runway 14R/32L, Runway 14L/32R, and Runway 02/20). Precision instrument approaches are available for runways 14R and 32L.

Runway 32L, which is 150 feet wide, has a length of 9500 feet, including a displaced threshold area of 1402 feet. The full length of 9500 feet is available for takeoff if a pilot backtracks to the threshold of Runway 32L. For landings or for takeoffs that begin at the displaced threshold (beside the intersection of the runway and Taxiway Echo), a runway length of 8098 feet is available. On the day of the occurrence, both landings and takeoffs were occurring on Runway 32L.

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33 An okta is a unit of measurement expressing the extent of cloud cover, with 1 okta equal to one eighth of the sky.

Per *Canadian Aviation Regulations* (CARs) subsection 602.96(3),[34] when an aircraft is operating in the vicinity of an aerodrome, all turns shall normally be made to the left within the aerodrome traffic circuit, unless right turns are specified in the *Canada Flight Supplement*. The *Canada Flight Supplement* specifies right-hand circuits for runways 32L and 32R at CYXY.

A pile of millings was located approximately 500 feet from the centreline of Runway 32L. *Aerodrome Standards and Recommended Practices* (TP 312), published by Transport Canada (TC), requires obstacles on a precision runway to be more than 400 feet (122 m) from the centreline of the runway.[35]

1.11 Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation. The aircraft was equipped with equipment that provided valuable information about the occurrence flight (Table 4).

Table 4. Equipment that provided information for the investigation

Equipment	Information obtained
SKYTRAC Systems Limited (SKYTRAC) ISAT-100 (GPS-based flight-following system)	Positional information
Honeywell Primus Apex Integrated Avionics System (integrated flight deck)	Aircraft flight path, engine parameters, control inputs; acceleration information, and aircraft alert and warning logs
Honeywell Mark VI EGPWS	Flight path and warning information

EGPWS data revealed that the EGPWS activated several times due to excessive descent rate, closure with terrain, altitude loss, and bank angle. For example, during the initial turnback, the aircraft's angle of bank reached a maximum of 66° left bank, activating the "Bank Angle, Bank Angle"[36] aural warning. Moments later, a high rate of descent triggered the "Don't Sink, Don't Sink"[37] warning, followed by the "Caution Terrain, Caution Terrain"[38] warning.

During the final seconds of the occurrence flight, the following EGPWS warnings activated at least once:

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34 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 602.96(3).

35 Transport Canada, TP 312E, *Aerodrome Standards and Recommended Practices*, 5th Edition, Amendment 1 (effective 15 January 2020), section 4.2: Precision Obstacle Free Zone (POFZ), Figure 4-7: Precision Obstacle Free Zone, p. 78 of 319.

36 When the autopilot is not engaged, this alert signals roll angles exceeding ±15° to ±50° between 10 and 210 feet AGL and ±50° above 210 feet AGL.

37 This warning indicates a significant altitude loss after takeoff or a low-altitude go-around with landing gear or flaps not in the landing configuration.

38 This warning signals an excessive descent rate (the caution envelope is based on radio altitude and aircraft descent rate).

- "Don't Sink, Don't Sink"
- "Terrain, Terrain"[39]
- "Pull Up, Pull Up"[40]
- "Bank Angle, Bank Angle"

These EGPWS warnings went unnoticed by the pilot.

1.12 Wreckage and impact information

1.12.1 General

The investigation determined that the aircraft had initially touched down in a right-wing-low attitude, in shallow mud on the otherwise frozen ground, while the pilot was attempting to position the aircraft for landing on Runway 32L. The aircraft then most likely bounced and regained a near wings-level attitude, and shortly afterwards, the left wing impacted the pile of asphalt millings. This impact caused the left wing to separate from the fuselage (Figure 9). The aircraft then rolled onto its left side and slid in that attitude approximately 130 feet across the ground, which was primarily a hard-packed dirt service road.

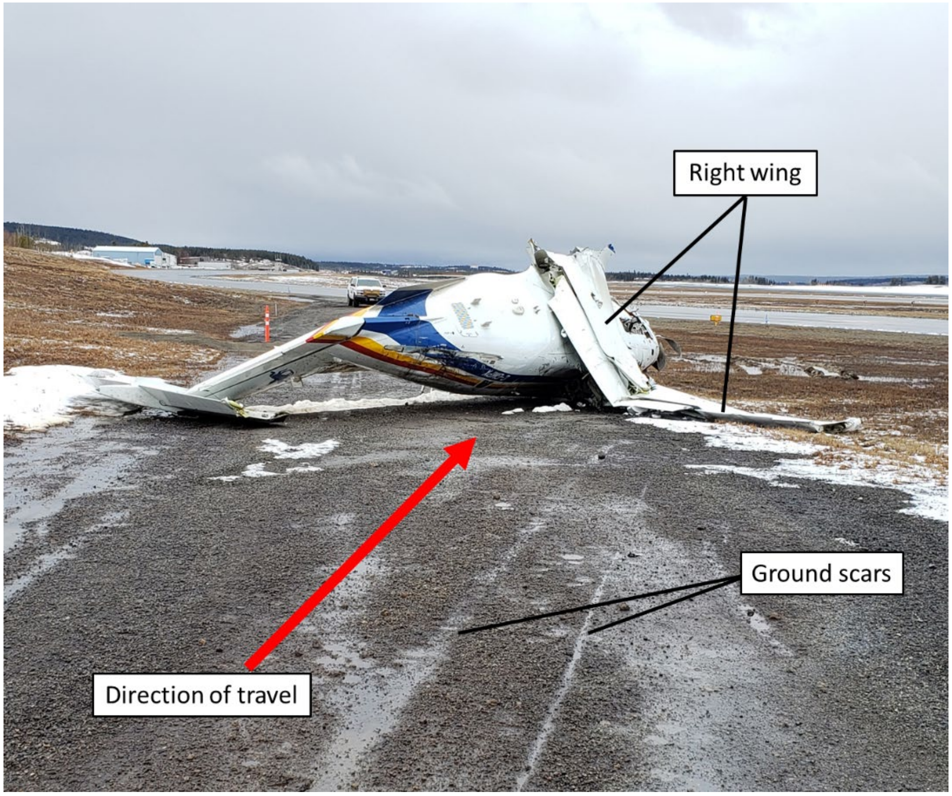
39 This signals excessive closure to terrain (with a caution envelope that is based on radio altitude and how rapidly radio altitude is decreasing, which is referred to as the closure rate).

40 This alert also signals excessive closure to terrain (with a warning envelope based on radio altitude and closure rate).

Figure 7. Wreckage path of occurrence aircraft, minutes after the accident (Source: Royal Canadian Mounted Police)

The aircraft's right wing broke at the root and also approximately halfway between the root and the wing tip. The right wing was found lying across the underside of the fuselage and along the ground beside it (Figure 10). During the on-site examination of the wreckage, it was determined that the flaps were in the up position (i.e., at 0°) at the time of impact.

Figure 8. Close-up of main wreckage, taken days after the occurrence (Source: Royal Canadian Mounted Police)



The main fuselage remained mostly intact. The blades on the propeller were twisted and bent in a manner consistent with power being applied at the time of impact.

The landing gear was extended at the time of impact. Upward vertical forces had caused the right main landing gear assembly to puncture the top surface of the right wing. The nose wheel had been forced, by horizontal impact forces, back into the nose wheel well.

1.12.2 Examination of angle of attack transmitters

Given that the stall warning system activated shortly after takeoff, the investigation sought to better understand the potential role that the AOA transmitters may have played in this occurrence. As a result, the 2 AOA transmitters (Table 5) were removed from the wreckage and sent initially to the TSB Engineering Laboratory in Ottawa, Ontario, for examination, and then to the manufacturer, Collins Aerospace (Collins), for a more detailed examination.

Table 5. Details of occurrence angle of attack transmitters, sent for examination

Component	Part number	Serial number	Installation year	Belts replaced	Date belt entered service	Flight hours on belt since replacement
Left AOA transmitter	Collins Aerospace 0012AC11	1373	2011	2013 and 2016	December 2016	4090.5

Right AOA transmitter	Collins Aerospace 0012AC12	1985	2017	2019	December 2020*	1235.6

*The belt on the right AOA transmitter was replaced in 2019; however, it did not return to service until December 2020.

When the AOA transmitters were removed from the wreckage, it was noted that both the stainless steel belt from the left AOA transmitter and that from the right AOA transmitter had each broken widthwise in 2 locations: near the centre hole and near the overlapped belt-end holes. The details of the damage found on the belts are summarized in Table 6.

Table 6. Damage observed during macroscopic examination of the angle of attack transmitter belts

Component	Damage location	Observation
Left AOA transmitter belt	Near centre hole (at probe end)	• Fatigue cracking was observed over 85% of this fracture surface. • Overload fractures were also observed on the fracture surface, where the fracture surface ended at each side edge of the belt. An estimated 15% (approximate) of the fracture surface was due to overload. • Fatigue crack initiation may have originated at regions of micro-pitting.
	Near oval end hole (at resolver end)	• The entire fracture surface exhibited signs of overload.
Right AOA transmitter belt	Near centre hole (at probe end)	• Significant heat damage was observed, as well as clear indications of electrical arcing and subsequent burn-through.
	Near oval end hole (at resolver end)	• The entire fracture surface exhibited signs of overload.

1.12.2.1 Belt design

The belts used in the occurrence aircraft's AOA transmitters had been manufactured using a wet-etch process. The wet-etch process uses chemical etchants (often acidic) to create precise components from a sheet material. This process, which is chemical and not mechanical in nature, leaves a smooth finished edge and does not alter the inherent strength and fatigue properties of the material. The process can, however, result in surface pitting if the process control is inadequate.

Because of the belt failures, post-occurrence testing involved manually rotating the counterweights to their maximal and minimal positions and recording the corresponding electrical outputs.

According to Collins, when the AOA transmitter (part number 0012AC11/0012AC12) was developed to support the PC-12, a design life of 15 000 operational hours was provided within the specification. A reliability prediction completed by Collins estimated an in-service mean time to failure for the AOA transmitter of 2500 flight hours. According to

Pilatus, the historical achieved mean time to failure for the AOA transmitter on the PC-12 is approximately 5500 flight hours.[41]

The sensor belt component is listed by Collins as an "on condition" replacement item. As designed, the AOA transmitter does not have any on-aircraft maintenance requirements once installed, and it is only removed if there is a failure, at which point it is returned to Collins. At the time of the occurrence, the left AOA transmitter belt had accumulated 4090 flight hours, while the right AOA transmitter belt had accumulated 1235 hours.

A new AOA transmitter design (part number 0012AC13/0012AC14) was completed in September 2022 and became available in May 2023. Pilatus currently has no plans to issue a service bulletin or service letter related to this new AOA transmitter. According to Pilatus, the design change was primarily to address low reliability of the component caused by the predominant failure modes of heater failures and sticking vanes. Design changes to address these failures modes were initially incorporated into the AOA transmitter version for the PC-21, but also implemented in the PC-12 version due to commonality.[42]

One of the design changes included moving away from the wet-etch manufacturing process. This was done to reduce pitting on the belt after prolonged exposure to the atmosphere. It is anticipated that this design change will increase the life of the belt and decrease the failure rate. The failure modes will not change.

According to Collins, the new AOA transmitters will be upgraded during repairs resulting from normal attrition of the belts.

1.12.2.2 Belt examination

The post-occurrence examination of the AOA transmitters, which was conducted in part by Collins, revealed that, at the time of the failure, the lower belt of the left AOA transmitter had fatigue crack growth present through approximately 85% of the cross-section. The remaining 15% of the cross-sectional area near the edges of the belt would likely not have been able to withstand more than 1.5 pounds (0.7 kg) of force. As a result, the investigation concluded that it is highly likely that a fatigue failure occurred on the left AOA transmitter belt. The fatigue likely originated at one of the areas of surface pitting left by the wet-etch process and propagated over time, weakening the left AOA transmitter belt.

At some point before the aircraft reached rotation speed (V_R) and rotated for takeoff, the belt experienced a failure, causing the resolver counterweight to rotate, uncommanded, to the maximal position. This rotation of the resolver counterweight caused the activation of the shaker and the aural stall warning. In that state, the AOA resolver counterweight would not return to a normal position, even if the aircraft exited the climb and entered level flight. This caused the shaker and the aural stall warning to persist.

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41 Pilatus Aircraft Ltd., TSB Query Response Document (A23W0040), v03 (26 February 2024), p. 10 of 15.

42 Ibid., p. 11 of 15.

During the aircraft's subsequent collision with terrain, it is highly probable that the remaining (upper) portion of the belt in the left AOA transmitter failed due to overstress caused by the impact. It was noted that the belt in the right AOA transmitter had failed in overstress, which is consistent with damage resulting from the collision with terrain.

Likewise, for arcing to have occurred, the belt needed to be in a failed condition, with power on. This could only have happened after impact, as the belt exhibited no signs of fatigue, and had failed purely in overstress.

The investigation considered the possibility of inadvertent damage to the AOA transmitters during the mechanical de-icing that occurred before takeoff on the occurrence flight. To prevent possible over-rotation of the AOA vanes, which would overstress the belt, during such processes as de-icing, the vanes have physical stops cast into them. The damage noted in the AOA transmitters was consistent with a fatigue failure, making it unlikely that an external force was responsible for the breakage of the left lower belt.

1.13 Medical and pathological information

According to information gathered during the investigation, there was no indication that the pilot's performance was affected by medical factors.

1.14 Fire

There was no indication of fire either before or after the occurrence.

1.15 Survival aspects

1.15.1 General

During and after the aircraft's collision with terrain, the fuselage and cockpit remained largely intact. This contributed to the survivability of the accident, as did the emergency exit and the 4-point safety belt the pilot wore (as required by regulation[43]), the latter of which consisted of an adjustable lap belt and a dual-strap inertia reel-type shoulder harness. It is likely that the shoulder harness reduced the severity of the pilot's injuries.

1.15.2 Emergency locator transmitter

The occurrence aircraft was equipped with a Kannad 406 MHz emergency locator transmitter (ELT). The ELT activated upon impact and transmitted a distress signal that was detected by the Cospas-Sarsat search and rescue satellite system. Shortly after the occurrence, aircraft rescue and firefighting personnel turned off the ELT.

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43 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 605.27(3).

1.16 Tests and research

1.16.1 TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP068/2023 – NVM Recovery - Various
- LP115/2023 – Analysis of Angle of Attack System
- LP120/2023 – Fractographic Analysis of Angle of Attack Ribbons
- LP071/2023 – Aircraft Animation and Performance Analysis

1.16.2 Performance analysis

To assist the investigation, a performance analysis was conducted at the TSB Engineering Laboratory using data collected from various sources on board the aircraft and from NAV CANADA's automatic dependent surveillance – broadcast (ADS-B) system. The information collected allowed the investigation to reconstruct much of the occurrence flight.

1.16.2.1 Aerodynamic stall assessment

After altering course to the right and passing south of the airfield, the aircraft initiated a left turn in an attempt to align itself for landing on Runway 32L. The initial segment of the left turn (which occurred from 1137:15 to 1137:29) involved a gradual increase in the bank angle up to approximately 27°, with the airspeed dropping to 93 KCAS and the aircraft's height decreasing to as low as 190 feet AGL.

During this segment, the aircraft's computed stall margin reached as low as approximately 0.5 knots. In the next segment of the left turn (1137:29 to 1138:01), the bank angle increased and reached a maximum value of approximately 47°. However, the aircraft's height and stall margin were both higher than in the previous segment, reaching their lowest approximate values at 238 feet AGL and 14 knots, respectively.

The final segment of the turn and subsequent collision with terrain (1138:01 to 1138:15) are characterized by a rapid change in the aircraft's bank angle from approximately 35° left to approximately 46° right, commencing at a height of approximately 185 feet AGL, and a drop in the aircraft's airspeed below the stall speed (with the lowest stall margin at approximately -10 knots), resulting in an aerodynamic stall that was followed by the aircraft's collision with terrain.

Given that the POH's stall performance data[44] are based on flight idle power,[45] the investigation's calculated stall speeds are also based on flight idle power. Therefore, the aircraft's stall margins would have been greater with power on, as was the case in this occurrence. The performance analysis determined that it is likely that the aircraft stalled during the final turn and remained in a stalled condition until impact.

1.17 Organizational and management information

1.17.1 General

The RCMP Air Services Branch (the Branch) was established in 1937. According to the RCMP's website,

> The RCMP's Air Services provides direct operational support in technical and specialized areas of airborne law enforcement […] [and is] able to mobilize personnel and equipment necessary to meet the diverse demands of the RCMP and provide support to the RCMP in both heavily populated and remote areas of Canada.[46]

The Branch's headquarters is located in Ottawa. At the time of the occurrence, the RCMP's fleet consisted of 21 airplanes and 9 helicopters, located at 19 bases (11 of which are Pilatus PC-12 bases) across 11 RCMP Divisions.

At the time of the occurrence, the RCMP had a total of 16 PC-12 aircraft and 42 PC-12 pilots, based at the following locations:

- Boundary Bay, British Columbia;
- Prince George, British Columbia;
- Edmonton, Alberta;
- Yellowknife, Northwest Territories;
- Thompson, Manitoba;
- Winnipeg, Manitoba;
- London, Ontario;
- Ottawa, Ontario;
- Montreal, Quebec;
- Moncton, New Brunswick; and
- Iqaluit, Nunavut.

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44 Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 5-3: Performance Data for MSN 1576 - 1942 with a 5-bladed Propeller, Figure 5-3-2: Stall Speeds KIAS - Flight Idle Power (metric units), p. 5-3-2.

45 The Pilatus POH defines flight idle power as "[t]he power required to run an engine, in flight, at the lowest speed that will ensure satisfactory engine and systems operation and airplane handling characteristics." (Source: Ibid., section 1: General, p. 1-14.)

46 Royal Canadian Mounted Police, Air Services Branch, https://www.rcmp-grc.gc.ca/to-ot/asb-sa-eng.htm (last accessed on 11 March 2025).

The Branch operates under a private operator registration document issued by TC.[47] Although not required by regulation, the RCMP has chosen to adopt specific standards from CARs subparts 702 (Aerial Work) and 703 (Air Taxi Operations) for "aerial work and transportation activities routinely undertaken by RCMP."[48]

In the 5 years leading up to the occurrence, the RCMP had averaged approximately 10 000 flight hours annually on the PC-12. According to the RCMP, of all the PC-12 flights the RCMP conducts, the majority involve transporting personnel and/or supplies, and 90 to 95% are conducted under IFR.

1.17.2 Standard operating procedures

1.17.2.1 General

Standard operating procedures (SOPs) assist pilot decision making by providing pilots with predetermined successful solutions, based on corporate knowledge and industry best practices, for specific situations that they may encounter. SOPs can help reduce pilot workload, given that less mental effort is required to work through the decision-making process because that process has already been done for the pilot. Once a procedure has been developed, pilots must be given opportunities to practise it and be encouraged to use it so that the procedure becomes routine.

In multi-crew commercial flight operations, SOPs are required by regulation and widely accepted as a tool to enhance safety.[49] Currently, there is no requirement for SOPs in any single-pilot flight operation; however, the RCMP has voluntarily developed SOPs to assist its pilots in both single- and dual-pilot operations.

1.17.2.2 Crew resource management

The RCMP's SOPs include a section on crew resource management (CRM) in which it is explained that, although the RCMP operates the PC-12 as a single-pilot aircraft most of the time, "[…] CRM still plays a major role in [its] operation."[50] This section also states that efforts should be made to operate the aircraft with 2 pilots for flights into congested airspace or on particularly long-duty days,[51] noting that "[t]he addition of a second pilot

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47 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 604.04(1).

48 Royal Canadian Mounted Police, *RCMP Air Services Fixed Wing Operations Manual*, Revision 4.0 (18 February 2022), Foreword from RCMP Air Services Director General, p. 1-i.

49 Federal Aviation Administration (FAA), Advisory Circular (AC) 120-71B: Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers (2017).

50 Royal Canadian Mounted Police, *Air Services Standard Operating Procedures for the PC 12/47-E*, Amendment No. 5 (03 February 2015), section 1.4: Crew Resource Management, subsection 1.4.1: General, p. 1-2.

51 Ibid.

should both enhance the situational awareness of the crew and increase the efficiency of the cockpit."[52]

According to another section of the SOPs, which covers pre-flight duties and, more specifically, setting up the radio and PFD in the event of an in-flight emergency after takeoff, pilots should have the PFD set up for an approach back to an airfield (an "emergency return").[53] When the aircraft is operated with 2 pilots, the pilot flying (PF) must give the pilot not flying a take-off briefing that covers the following items:

- Power setting, type of takeoff and initial climb
- Malfunctions before/after VR [rotation] (reject/recovery)
- Departure Procedure
- Any non-standard procedures planned[54]

In a 2-pilot operation, the items listed above are to be covered during the departure and emergency briefing in the "Before Departure" portion of both the *RCMP PC12/47E Normal Procedures Checklist*[55] and the POH.[56] An effective planning tool, the takeoff briefing allows the flight crew to minimize the number and difficulty of decisions they will need to make in the air. As identified in previous research, "planning during low-workload periods improves the quality of decisions made during high-workload situations."[57] When the aircraft is operated by a single pilot, there is no requirement for the pilot to review, or "self-brief," the departure and emergency briefing step.

The following sample take-off briefing, for dual-pilot operations, is provided in the SOPs:

> "This will be a standard 9900LB takeoff runway 25, using max takeoff power. If we have any emergencies prior to VR [rotation] we will reject; after VR we will handle in flight and plan a recovery to runway 25 if able. NAV#1 is set for the return; I'll switch once through 1000'. We are on the OTTAWA NINE DEPARTURE: runway heading to 3000' expect vectors."[58]

The sample briefing, which is to be spoken by the PF, does not specify how the recovery may vary depending on whether it is carried out visually or by reference to flight instruments. For example, it does not include a statement such as, "If we are in a position to maintain VMC [visual meteorological conditions], the plan will be to…" or "Today, we will

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52 Ibid., section 1.4: Crew Resource Management, subsection 1.4.3: Single-Pilot and Multi-Crew Operations, p. 1-3.

53 Ibid., section 2.2: Pre-Flight Duties, subsection 2.2.3 Radio/PFD set up for Departure, p. 2-3.

54 Ibid., section 2.3: In-Flight Duties, subsection 2.3.1: Takeoff Brief, p. 2-9.

55 RCMP Air Services, RCMP PC12/47E Normal Procedures Checklist, Amendment #11 (02 June 2022).

56 Pilatus Aircraft Ltd., Report No. 02277, *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual*, Revision 23 (14 October 2022), section 4.8.1: Before Departure, p. 4-17.

57 A. Mizzi and P. McCarthy, "Flight Crew Briefings with Resilience Engineering Capacities - The STC Model" (09 January 2023), p. 1.

58 Royal Canadian Mounted Police, *Air Services Standard Operating Procedures for the PC 12/47-E*, Amendment No. 5 (03 February 2015), section 2.3.1: Takeoff Brief, Table 2-10: Takeoff Brief, p. 2-9.

have to deal with any emergencies while in IMC [instrument meteorological conditions]… and the plan will be to…”

The SOPs note that

> [t]he briefing may have as much or as little detail as the PIC [pilot-in-command] deems appropriate under the circumstances. For example, in the event of a particularly long or short runway the PIC may want to consider revising the emergency recovery as required for the situation.[59]

No additional guidance is provided to expand on how the emergency recovery may be affected by runway length. Likewise, the SOPs do not discuss the assessment of runway length required versus runway length available as a way to assist with pilot decision making in situations involving an aborted takeoff and/or airborne reject.

1.17.3 Operational control

The *RCMP Air Services Fixed Wing Operations Manual* defines operational control as “the exercise of authority over, or the initiation, continuation, diversion or termination of a flight.”[60] According to this manual RCMP pilots operate under a self-dispatch operational control system. This means that operational control is delegated to the PIC of a flight by the operations manager. As a result, flights are self-dispatched and released by the PIC in accordance with the Flight Authorization Procedures[61] found in the manual. The manual also states that the operations manager “retains responsibility for the day-to-day conduct of flight operations.”[62]

1.17.4 Training program

1.17.4.1 General

The Branch’s training program meets the requirements of the CARs. The following subsections discuss some aspects of the RCMP’s training that are relevant to the occurrence.

1.17.4.2 Ground training

Some of the training that is directly relevant to the occurrence is listed in Table 7.[63] The frequency of completion for each training subject is also provided.

Table 7. Ground training subjects for Royal Canadian Mounted Police pilots

Subject	Interval
CRM	2 years

59 Ibid., section 2.3.1: Takeoff Brief, p. 2-9.

60 Royal Canadian Mounted Police, *RCMP Air Services Fixed Wing Operations Manual*, Revision 4.0 (18 February 2022), section 4.1.1: Definition, p. 4-1.

61 Ibid., subsection 4.2.2(3): Flight Authorization Procedures, pp. 4-2 to 4-4.

62 Ibid., section 4.1.2: Responsibility and Authority, p. 4-1.

63 Ibid., section 6.6: Training Program, p. 6-16.

Single-pilot resource management	2 years
Threat and error management	2 years
Human factors	3 years
Low-visibility operations	2 years

According to the *RCMP Air Services Fixed Wing Operations Manual*, RCMP pilots use threat and error management to "[…] identify, then attempt to eliminate or reduce threats," allowing them to "[…] turn unpredictable threats into predictable threats."[64]

1.17.4.3 Simulator training

The initial and recurrent PC-12 training (ground school and simulator) for RCMP pilots is conducted using a U.S.-based third-party training provider. Over the course of the investigation, 11 RCMP PC-12 pilots from across Canada were interviewed to better understand the training they had received. The following is a summary of some of the feedback obtained from the pilots interviewed:

- In the simulator, U.S. airports are used for most of the training exercises because of the limitations of the visual database for Canadian airports.
- During recurrent simulator training, RCMP PC-12 pilots practise rejected takeoffs from various heights above the ground (e.g., 20 to 100 feet AGL) after rotation.
- Visual emergency turnback manoeuvres often involve a left turn because the pilot has better visibility in that direction due to seat position, and terrain is not typically a concern at the airports used in the simulator.
- Almost all pilots interviewed reported that, before the occurrence, they had never experienced an emergency scenario during training that replicated the occurrence scenario (i.e., involving the inadvertent operation of the shaker and the activation of the aural stall warning). When the investigation reviewed the occurrence pilot's training record for the last simulator session, there was no indication of such a training scenario. Typically, the only stall-related malfunction given to RCMP pilots during training exercises was an inadvertent pusher event.

During simulator training provided to 2 RCMP PC-12 pilots shortly after the occurrence, they were presented with a scenario similar to that of the occurrence flight, incorporating an aural stall warning and inadvertent shaker activation on rotation. In this scenario, 2 different strategies were employed, 1 by each of the pilots:

1. One pilot elected to fly a VFR circuit without actioning the checklist. After landing, the pilot commented that he had not realized how much of an annoyance the aural stall warning could be if it was allowed to continue uninterrupted.
2. The other pilot levelled off and completed the checklist, including pulling the STALL WARN 1 and STALL WARN 2 circuit breakers. It was noted by the observer that the pilot, who was well within the range of human anthropometrics that the aircraft was

[64] Ibid., section 6.8.15: Threat and Error Management (Self Study), p. 6-28.

designed to accommodate, struggled to pull the STALL WARN 2 circuit breaker located on the front-right circuit breaker panel. In addition, the pilot commented that because of the distance to reach, there was an increased risk of pulling the wrong circuit breaker on the front-right circuit breaker panel.

The following observations were made during subsequent recurrent training with other RCMP PC-12 pilots:

- Some pilots experienced considerable difficulty pulling the STALL WARN 2 circuit breaker because it was hard for them to reach across the cockpit.
- Pilots who either were unable to pull the STALL WARN 1 and STALL WARN 2 circuit breakers or elected not to pull them because they were so close to landing reported that the continuous aural stall warning was distracting and made it challenging to focus on flying the aircraft. One pilot echoed previous feedback regarding how annoying the aural stall warning was and that it would definitely cause a pilot's stress level to increase.

1.17.5 PC-12 flight operations

According to the Branch, 90 to 95% of its PC-12 flights are conducted with a single pilot. Typically, a 2nd pilot is present on RCMP PC-12 flights that exceed 8 hours in duration, in accordance with the CARs. When there are 2 pilots on such a flight, the 2nd pilot normally acts as a safety pilot rather than as a traditional first officer with specific flight-related duties. As the SOPs state, "[c]are has been taken […] to ensure that the addition of the PNF [pilot not flying] does not disrupt the normal working environment of the PF."[65]

According to Branch personnel, switching to multi-crew operations was considered several years ago; however, owing to budgetary considerations and the fact that the PC-12 is certified for single-pilot operations, the Branch elected to continue primarily operating single-pilot. Over the course of the investigation, over half of the RCMP PC-12 pilots interviewed indicated that they felt 2-pilot PC-12 operations would enhance safety; some of those pilots also highlighted that most PC-12 operators in Canada operate the aircraft with a multi-crew cockpit.

Another Canadian PC-12 operator also indicated that operational efficiency and flight safety were greatly enhanced by operating the aircraft with 2 pilots and that it would not consider operating the aircraft with a single pilot. This is consistent with research efforts comparing multi-crew operations to single-pilot operations. According to the Air Line Pilots Association, International (ALPA),

65 Royal Canadian Mounted Police, *Air Services Standard Operating Procedures for the PC 12/47-E*, Amendment No. 5 (03 February 2015), section 1.4.3: Single-Pilot and Multi-Crew Operations, p. 1-3.

> [t]wo pilots on the flight deck ensure redundancy; they monitor the health of each other and the aircraft, maintain situational awareness of aircraft systems and the external environment, and provide a critical layer of security.[66]

Likewise, the European Cockpit Association states, in one of its position papers, that

> [w]hile humans may introduce some failure-scenarios, they at the same time eliminate system-failure scenarios and act as a critical onboard backup for failed systems, bridge technology-gaps and adapt in real-time and in the real environment to non-anticipated situations.[67]

A 2017 joint study conducted by the U.S. National Aeronautics and Space Administration (NASA) and the U.S. Federal Aviation Administration (FAA) sought to quantify the pilot's contribution to flight safety during normal operations and in response to system failures. The study found "[…] significant increases in workload for single pilot operations, compared to two-crew, with subjective assessments of safety and performance being significantly degraded […]"[68] The study also found that multi-crew operations resulted in more consistent and accurate use of checklists, as well as improved flight path performance.[69] It concluded that even though the single-pilot test subjects overcame the non-normal conditions presented, those pilots "rated the workload, safety, and acceptability as being unacceptable in an emergency situation."[70] In addition, it was noted that there were "notable flight performance decrements" during single-pilot operations, compared to multi-crew operations, that "suggest unacceptable, reduced safety margins."[71]

1.17.6 Safety management

According to CARs section 604.202, private air operators are required to have a safety management system (SMS) that meets the requirements of CARs section 604.203. At the time of the occurrence, the RCMP's SMS was similar to that defined by the CARs; however, the RCMP's SMS had not been approved or assessed by TC, nor was this required by regulation.

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66 Air Line Pilots Association, International (ALPA), ALPA White Paper, *A Gamble with Safety: Reduced-Crew Operations* (June 2024), Section 1: Aviation Safety, p. 9, at https://www.alpa.org/-/media/ALPA/Files/pdfs/news-events/white-papers/white-paper-reduced-crew-operations.pdf (last accessed on 12 March 2025).

67 European Cockpit Association, *Position Paper: The Human and the concepts of Extended Minimum Crew Operations (eMCO) and Single Pilot Operations (SiPO)* (19 July 2021), Augmenting and not replacing human capacity, p. 4, at https://www.eurocockpit.eu/sites/default/files/2021-07/eMCO_SiPO_PP_21_0719_F_0.pdf (last accessed on 12 March 2025).

68 R.E. Bailey, L.J. Kramer, K.D. Kennedy, C.L. Stephens, and T.J. Etherington, "An assessment of reduced crew and single pilot operations in commercial transport aircraft operations," Proceedings of the 2017 IEEE [Institute of Electrical and Electronics Engineers]/AIAA [American Institute of Aeronautics and Astronautics] 36th Digital Avionics Systems Conference (DASC), St. Petersburg, FL (17–21 September 2017), p. 1.

69 Ibid., pp. 5-6.

70 Ibid., p. 13.

71 Ibid., p. 13.

The Branch uses an internal accident/incident reporting software system (called ADREP) as the official system for reporting, tracking, and auditing purposes. From 2016 to 2022, there was an average of 96 reports submitted per year. The investigation examined the ADREP database to see whether any issues similar to those encountered during the occurrence flight had been previously reported. The following data were noted:

- Stall warnings and inadvertent shaker activation: There were no reports of RCMP PC-12 pilots experiencing an erroneous stall warning or inadvertent shaker during flight.
- Single-pilot operations: In 2019, there was a report of an engine over-torque that had occurred while the pilot was conducting low-level visual manoeuvring during a search and rescue operation. The report noted that because of pilot workload, the engine torque gauge was overlooked. The report went on to state that it is easy to avoid an over-torque during normal operations; however, search and rescue missions are much different and most fixed-wing operations conducted for similar missions utilize 2 pilots. The report also stated that the RCMP was going to conduct a full hazard risk analysis; however, this analysis was never performed.

1.18 Additional information

1.18.1 Human performance considerations

1.18.1.1 Startle and surprise

Given the increased reliability of modern aircraft, pilots may develop a "mindset of normalcy, with little expectation of actual emergencies. This conditioned expectation of normalcy can create a heightened stress response when some unexpected, novel, or emergency event does occur."[72] This observation leads to the following discussion of 2 increasingly popular terms in aviation, namely, "startle" and "surprise."

The terms "startle" and "surprise" are often used interchangeably in aviation; however, they are distinct terms. Startle typically occurs as a result of a "sudden exposure to *intense stimulation* [emphasis in original]" and causes an "involuntary physiological reflex" (e.g., fight or flight reaction) and a "conditioned, behavioral startle response," which consists of both an emotional and a cognitive response.[73] The startle response can be the result of auditory, visual, or tactile stimuli and is typically of short duration (i.e., from less than 1 second for a mild response to between 1 and 1.5 seconds for a high-intensity response).[74]

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72 W.L. Martin, P.S. Murray, and P.R. Bates, "The effects of stress on pilot reactions to unexpected, novel, and emergency events" in *Proceedings of the 9th International Symposium of the Australian Aviation Psychology Association*, Sydney, Australia, 19–22 April 2010 (Australian Aviation Psychology Association, 2010), p. 263.

73 J. Rivera, A.B. Talone, C.T. Boesser, F. Jentsch, and M. Yeh, "Startle and Surprise on the Flight Deck: Similarities, Differences, and Prevalence" in *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*, Chicago, IL, 27–31 October 2014 (Human Factors and Ergonomics Society, 2014), p. 1047.

74 Ibid.

An example of a potential startle scenario is a very loud, unexpected noise that causes a pilot to have a physical reaction (e.g., a rapid involuntary muscle movement) in the cockpit.

On the other hand, surprise is an emotional and cognitive response to something unexpected, resulting from a mismatch between what individuals are expecting versus what they perceive.[75,76,77] In other words, surprise occurs when a person encounters an unanticipated situation that does not match the person's understanding of the way things are supposed to be. Such situations may be related to unexpected changes in aircraft state (e.g., system alerts), environmental conditions (e.g., low visibility), or unexpected instructions or actions from others (e.g., ATC).[78]

So long as the uncertainty and confusion around a surprise situation persist, a person's level of stress is unlikely to decrease and may in fact increase, particularly if additional stressors arise. For example, if something else unexpected or unintended occurs, the person's stress levels can rise even further, exacerbating an already challenging situation.[79]

Surprise has been identified as a factor in a number of loss-of-control accidents.[80] One such example is the accident of Air France flight 447, which departed Rio de Janeiro/Galeão–Antonio Carlos Jobim International Airport in Rio de Janeiro, Brazil, on 31 May 2009 en route to Charles de Gaulle Airport in Paris, France.[81] In that occurrence, ice crystals obstructed the aircraft's speed probes, the aircraft entered an aerodynamic stall, and the flight crew, who struggled to understand the situation, were unable to recover before impact.

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75 A. Landman, E.L. Groen, M.M.R. van Paassen, A.W. Bronkhorst, and M. Mulder, "Dealing With Unexpected Events on the Flight Deck: A Conceptual Model of Startle and Surprise," *Human Factors*, Vol. 59, No. 8 (December 2017), p. 1162.

76 NLR – Netherlands Aerospace Centre (for the European Aviation Safety Agency [EASA]), report number NLR-CR-2018-242, *Startle Effect Management* (29 November 2018), p. 15.

77 J. Rivera, A.B. Talone, C.T. Boesser, F. Jentsch, and M. Yeh, "Startle and Surprise on the Flight Deck: Similarities, Differences, and Prevalence" in *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*, Chicago, IL, 27–31 October 2014 (Human Factors and Ergonomics Society, 2014), p. 1048.

78 J.A. Kochan, E.G. Breiter, and F. Jentsch, "Surprise and Unexpectedness in Flying: Database Reviews and Analyses," in *Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting*, New Orleans, LA, 20-24 September 2004 (Human Factors and Ergonomics Society, 2004), Table 1: Categories and Examples Associated with Unexpected or Surprising Events, p. 337.

79 J. Rivera, A.B. Talone, C.T. Boesser, F. Jentsch, and M. Yeh, "Startle and Surprise on the Flight Deck: Similarities, Differences, and Prevalence" in *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*, Chicago, IL, 27–31 October 2014 (Human Factors and Ergonomics Society, 2014), pp. 1048-1049.

80 Ibid., p. 1048.

81 Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), report f-cp090601, *Final Report on the accident on 1st June 2009 to the Airbus A330-203 registered F-GZCP operated by Air France flight AF 447 Rio de Janeiro – Paris*, at https://bea.aero/fileadmin/documents/docspa/2009/f-cp090601.en/pdf/f-cp090601.en.pdf (last accessed on 13 March 2025).

The report identified surprise as one of the main factors that contributed to the loss of control. The flight crew could not make sense of the conflicting indications they received, leading to surprise in an already stressful situation.

1.18.1.2 Impact of stress on pilot performance

How a pilot reacts to a stressful situation is dependent on many different factors. In some instances, a pilot is able to react quickly and manage unexpected stressful events. In other instances, a surprise situation can create a significant amount of acute stress for a pilot. In these situations, the pilot may experience a broad range of physiological symptoms, which may include an elevated heart rate, elevated blood pressure, or increased perspiration.[82] In addition, and perhaps more importantly, if the unexpected situation that causes surprise is perceived as being important or threatening, or both, the situation can produce a moderate to severe stress reaction in the pilot that could negatively affect the pilot's performance.[83]

This happens when the acute stress produces an emotional state of increased arousal that impairs cognitive or motor performance in a particular task.[84,85] In particular, stress "impairs top-down cognitive functions and increases stimulus-driven attentional control. […] [P]eople are less able to manage their attention effectively, as they are more distracted from their task by the salience of the stimuli (alarm, threatening aspect)."[86] In some cases, surprise can cause anxiety, rendering a pilot unable to comprehend or analyze information and adversely impacting the pilot's decision making. The pilot can forget operating standards, "freeze", or experience a loss of situational awareness.[87,88]

Generally speaking, stressors fall into 2 categories: external (e.g., noise, vibration, heat) and internal (e.g., anxiety, fatigue, frustration). External stressors act to impair a person's ability

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82 C.D. Wickens, W.S. Helton, J.G. Hollands, and S. Banbury, *Engineering Psychology and Human Performance*, 5th edition (Routledge, 2022), pp. 492-493.

83 W.L. Martin, P.S. Murray, and P.R. Bates, "The effects of stress on pilot reactions to unexpected, novel, and emergency events" in *Proceedings of the 9th International Symposium of the Australian Aviation Psychology Association*, Sydney, Australia, 19–22 April 2010 (Australian Aviation Psychology Association, 2010), p. 263.

84 C.D. Wickens, W.S. Helton, J.G. Hollands, and S. Banbury, *Engineering Psychology and Human Performance*, 5th edition (Routledge, 2022), p. 492.

85 A. Landman, E.L. Groen, M.M.R. van Paassen, A.W. Bronkhorst, and M. Mulder, "Dealing With Unexpected Events on the Flight Deck: A Conceptual Model of Startle and Surprise," in *Human Factors*, Vol. 59, No. 8 (December 2017), p. 1165.

86 M. Diarra, M. Marchitto, M.C. Bressolle, T. Baccino, and V. Drai-Zerbib "A narrative review of the interconnection between pilot acute stress, startle, and surprise effects in the aviation context: Contribution of physiological measurements," *Frontiers in Neuroergonomics*, Vol. 4, (23 February 2023), p. 11.

87 J. Rivera, A.B. Talone, C.T. Boesser, F. Jentsch, and M. Yeh, "Startle and Surprise on the Flight Deck: Similarities, Differences, and Prevalence" in *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*, Chicago, IL, 27–31 October 2014 (Human Factors and Ergonomics Society, 2014), p. 1048.

88 J. Tichon, T. Mavin, G. Wallis, T. Visser, and S. Riek, "Using Pupillometry and Electromyography to Track Positive and Negative Affect During Flight Simulation," in *Aviation Psychology and Applied Human Factors*, Vol. 4, Issue 1 (March 2014), p. 23.

to perceive the environment. Internal stressors are more likely to impair the ability to effectively process information and make sound decisions.[89] The effects of stress on pilot performance cannot be understated. Research has identified that nearly half of all fatal aviation accidents can be attributed to "stress-related failures of decision making."[90] It has also shown increased levels of stress "to have negative effects on flying skills involving psychomotor, working memory, and attentional components." [91]

1.18.1.2.1 Attentional narrowing and distraction

In the context of this occurrence, it is important to understand the influence that external stressors, such as an aural warning, can have on pilot performance. Aural warnings can be quite effective in directing a pilot's attention to something that might have gone unnoticed. However, a loud, persistent aural warning can also become a nuisance to a pilot, causing additional stress.[92] If this situation persists, acute stress can continue to build and potentially lead to attentional narrowing and distraction.[93,94]

Attentional narrowing results when

> the individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others of a subjectively equal or higher detectability, or of a more immediate priority.[95]

This behaviour can be desirable in certain situations, but attentional narrowing comes at the cost of potentially missing other pieces of important information. When workload and stress increase, an individual tends to focus attention on the stimuli perceived to be the most important at that moment.[96] For instance, a pilot who is attempting to manoeuvre for landing in reduced visibility is at greater risk of attentional narrowing. As the visibility deteriorates, and as stress levels increase, the pilot can become overly focused on looking

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89 C.D. Wickens, W.S. Helton, J.G. Hollands, and S. Banbury, *Engineering Psychology and Human Performance*, 5th edition (Routledge, 2022), pp. 492-493.

90 C.K. McClernon, M.E. McCauley, P. O Connor, and J.S. Warm, "Stress training enhances novice pilot performance in a stressful operational flight," in *Human Factors*, Vol. 53, Issue 3 (June 2011), pp. 207-218, Introduction.

91 Ibid.

92 C.D. Wickens, W.S. Helton, J.G. Hollands, and S. Banbury, *Engineering Psychology and Human Performance*, 5th edition (Routledge, 2022), p. 98.

93 C.K. McClernon, M.E. McCauley, P. O Connor, and J.S. Warm, "Stress training enhances novice pilot performance in a stressful operational flight," in *Human Factors*, Vol. 53, Issue 3 (June 2011), pp. 207-218.

94 M. Diarra, M. Marchitto, M.C. Bressolle, T. Baccino, and V. Drai-Zerbib "A narrative review of the interconnection between pilot acute stress, startle, and surprise effects in the aviation context: Contribution of physiological measurements," in *Frontiers in Neuroergonomics*, Vol. 4, (23 February 2023), p. 11.

95 R.W. Gibb, R. Gray, and L. Scharff, *Aviation Visual Perception: Research, Misperception, and Mishaps* (Routledge, 2010), p. 27.

96 J. Prinet and N. Sarter, "Attentional Narrowing: a First Step Towards Controlled Studies of a Threat to Aviation Safety," in *Proceedings of the 18th International Symposium on Aviation Psychology* (2015), p. 189, at corescholar.libraries.wright.edu/isap_2015/75 (last accessed on 13 March 2025).

outside the cockpit window to identify ground references, to the exclusion of flight instruments that may provide critical information about the aircraft's flight profile.[97,98]

The other way that stress can impact attention is through distraction. For example, the presence of an external stressor, such as a loud aural warning that cannot be muted, can become a major source of distraction because the pilot is required to continually attempt to process and filter out the signal to maintain performance.

Disregarding the stressor this way can be challenging, and it can easily result in the pilot experiencing increased levels of stress. As with attentional narrowing, a distraction, such as an aural warning, can cause other critical cues to go undetected. For that reason, it is important for the pilot to effectively deal with external distractions, if at all possible.

As discussed in these subsections, stress can degrade performance. If steps are not taken to reduce or eliminate the stressors, a vicious cycle can develop wherein stress causes a degradation of performance, which in turn creates more stress, and so on. Likewise, if something else perceived as being potentially stressful occurs, the situation can deteriorate, and stress can degrade pilot performance either momentarily or for an extended period of time.[99]

In these situations, it is vital that the pilot finds a way to break the cycle between stress and performance. The next section will identify some ways in which a pilot can deal with stressful, surprise situations.

1.18.1.3 Reducing the impact of stress on pilot performance

To reduce the potential adverse effects of stress on pilot performance, a number of strategies can be implemented, both inside and outside the cockpit. When a pilot is faced with a startle or surprise event, the stress of that situation will likely cause the pilot to experience a range of emotional and cognitive responses, which may be "autonomic, conditioned, or situationally reactive."[100] If these responses are not managed effectively, they can have a significant impact on pilot performance. For that reason, the pilot must develop strategies to deal with stressful situations to ensure that safety margins are maintained.

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97 M.R. Endsley, "Chapter 19: Situation Awareness," in G. Salvendy, *Handbook of Human Factors and Ergonomics*, 4th Edition (John Wiley & Sons, 2012), p. 559.

98 Australian Transport Safety Bureau, Investigation Report AO-2018-039: Loss of control in flight involving Leonardo Helicopters AW139 helicopter, VH-YHF, near Adelaide River mouth, 38 km ENE of Darwin, Northern Territory, on 13 May 2018 (published 16 April 2020), at https://www.atsb.gov.au/publications/investigation_reports/2018/aair/ao-2018-039 (last accessed on 14 March 2025).

99 W.L. Martin, P.S. Murray, and P.R. Bates, "The effects of stress on pilot reactions to unexpected, novel, and emergency events" in *Proceedings of the 9th International Symposium of the Australian Aviation Psychology Association*, Sydney, Australia, 19–22 April 2010 (Australian Aviation Psychology Association, 2010), p. 265.

100 Ibid., p. 263.

Research indicates that the most important element in controlling stress levels associated with startle and surprise events is previous experience in dealing with novel and emergency situations.[101] This can have a moderating effect on arousal levels and can therefore lessen the likelihood of performance degradation resulting from a surprise-type event.[102] Repeated exposure to unexpected situations in a training environment or during actual operations can help a pilot prepare for these situations.

The aviation industry's primary method for preparing pilots to manage surprising and unexpected situations is scenario-based training.[103,104] Specific training targeting surprise and stress management is not widespread within aviation; however, it is gaining popularity, and the topics are more frequently being discussed during CRM training.[105] The scenarios chosen need to evoke a sense of surprise in the crew members so that they each learn how to recognize their individual responses to a surprising situation and then apply the appropriate techniques to maintain effective performance.

For that reason, it is vital that air operators provide training that allows pilots to “train like they fight”. If pilots are given the opportunity to experience these “novel” events in a safe and secure training environment, in which they are under supervision until they are able to demonstrate competence, there is a much greater likelihood that they will be able to apply that positive experience if faced with a similar event in real life.[106] This practice will ultimately lead to reduced stress levels, better information processing, and overall, better outcomes and margins of safety.[107] On the other hand, if the training does not adequately test pilots’ ability to manage their stress in response to startle and surprise events, they will be much less likely to be able to manage such situations in the air.

Since it is impossible to experience every possible situation before encountering it during a flight, a pilot must also rely on other strategies to manage the stress associated with unexpected events. One of the best ways to reduce the risk of degraded performance

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101 Ibid., pp. 265-266.

102 Ibid., p. 266.

103 NLR – Netherlands Aerospace Centre (for the European Aviation Safety Agency [EASA]), Report Number NLR-CR-2018-242, *Startle Effect Management* (29 November 2018), Executive Summary and p. 140, at https://www.easa.europa.eu/en/downloads/67174/en (last accessed on 17 March 2025).

104 U.S. Federal Aviation Administration (FAA), FAA-H-8083-3C, *Airplane Flying Handbook* (2021), Chapter 5: Maintaining Aircraft Control: Upset Prevention and Recovery Training, p. 5-3, at https://www.faa.gov/sites/faa.gov/files/regulations_policies/handbooks_manuals/aviation/airplane_handbook/06_afh_ch5.pdf (last accessed on 17 March 2025).

105 NLR – Netherlands Aerospace Centre (for the European Aviation Safety Agency [EASA]), Report Number NLR-CR-2018-242, *Startle Effect Management* (29 November 2018), pp. 49 and 52, at https://www.easa.europa.eu/en/downloads/67174/en (last accessed on 17 March 2025).

106 W.L. Martin, P.S. Murray, and P.R. Bates, “The effects of stress on pilot reactions to unexpected, novel, and emergency events” in *Proceedings of the 9th International Symposium of the Australian Aviation Psychology Association*, Sydney, Australia, 19–22 April 2010 (Australian Aviation Psychology Association, 2010), p. 266.

107 Ibid.

resulting from startle and surprise is to anticipate potential stimuli and mentally rehearse the actions to take during critical phases of flight.

For example, in one non-aviation study, participants who learned to anticipate the moment of an unexpected stimulus (a blank pistol shot) were not surprised by it when it occurred, and the intensity of the startle effect was reduced.[108] In an aviation context, the same strategy can be applied in situations where surprise and startle represent a significant risk. For example, mentally preparing, or rehearsing, for a problem on takeoff can effectively eliminate the element of surprise.

Likewise, if a pilot pre-plans for such things as the routing to follow for an emergency recovery, whether the pilot is operating in visual meteorological conditions or in instrument meteorological conditions, the pilot’s cognitive load during flight will be significantly reduced, given that this aspect of the decision-making process will have been completed while the aircraft is still on the ground, without the stress of time pressure associated with in-flight decision making. This pre-planning will reduce processing demands as well as stress levels, helping to ensure adequate performance levels.

Another strategy that should be considered is recruiting more resources to manage the situation.[109] This can be as simple as an individual focusing more intently on the issue, by “trying harder;” however, this strategy has its risks since it involves doing more in less time (i.e., speed-accuracy trade off).[110]

Another option is that the individual receives help from others, inside the aircraft or externally, to diagnose and manage the issue or to offload tasks to enable the individual to devote greater focus to the primary issue. If additional resources cannot be utilized, another possible option is to try and remove the stressor entirely.[111] For example, if an aural warning continues to sound during a high-stress situation, shutting off the alarm would eliminate that stressor and reduce the risk of attentional narrowing or distraction resulting from a nuisance alarm. In this case, removing the stressor (i.e., muting the alert) would free up attentional resources that may be needed for higher-priority tasks, such as flying the aircraft.

1.18.2 Summary of information gathered from other RCMP pilots

During the investigation, information was collected from RCMP PC-12 pilots. This was carried out to better understand the level of system knowledge possessed by RCMP PC-12

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108 J. Rivera, A.B. Talone, C.T. Boesser, F. Jentsch, and M. Yeh, “Startle and Surprise on the Flight Deck: Similarities, Differences, and Prevalence” in *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*, Chicago, IL, 27–31 October 2014 (Human Factors and Ergonomics Society, 2014), p. 1048.

109 C.D. Wickens, W.S. Helton, J.G. Hollands, and S. Banbury, *Engineering Psychology and Human Performance*, 5th edition (Routledge, 2022), pp. 499-500.

110 Ibid.

111 Ibid.

pilots in general, as well as to obtain insight on some of the challenges that might be encountered during a scenario similar to that of the occurrence flight, involving a continuous aural stall warning and an inadvertent shaker activation. The observations gathered are summarized in Table 8.

Table 8. Observations from Royal Canadian Mounted Police pilots, organized by topic

Topic	Summary of observations
Stall warning system (general)	• Pilots possessed varying degrees of system knowledge regarding the cockpit indications that would result if only 1 AOA transmitter sensed a stall condition versus if both AOA transmitters sensed a stall condition. In particular, some pilots were unsure of the cockpit indications that would result if an AOA transmitter erroneously reported that the AOA had exceeded the stall threshold. • Some pilots thought the system became active as soon as power was applied and that it could be activated on the ground if a gust of wind deflected the AOA vane all the way down.
STALL WARN 1 and STALL WARN 2 circuit breakers	• Most pilots were aware that there was 1 applicable circuit breaker on each side of the cockpit. However, some pilots were unsure of the locations and names of both circuit breakers and incorrectly identified them. • Most pilots reported that, when flying single pilot, it would be difficult, even nearly impossible, to locate and pull the STALL WARN 1 and STALL WARN 2 circuit breakers while attempting to fly visually in weather conditions similar to those present during the occurrence flight. This task would be even harder to accomplish while depressing the PUSHER INTR switch. • One pilot reported that before the start of a post-occurrence simulator training session, he had located the circuit breakers to facilitate locating them during the session. Then, during that session, due to parallax,[112] the pilot inadvertently pulled a circuit breaker other than the STALL WARN 1 circuit breaker.
PUSHER INTR switch	• Some pilots were unsure if depressing this switch would silence the aural stall warning or stop the shaker.
AURAL WARN INHIBIT switch	• There was a general misunderstanding of and unfamiliarity with the AURAL WARN INHIBIT switch. Pilots reported having very little interaction with this switch during routine operations; however, some post-maintenance activities require them to use it because maintenance personnel sometimes select the switch to INHIBIT while working on the aircraft (on jacks) to prevent nuisance warnings. • Virtually none of the pilots interviewed had considered, before the occurrence, the possibility of using this switch as a means of silencing nuisance alarms, such as the aural stall warning. Some pilots were unsure whether the AURAL WARN INHIBIT switch silences the aural stall warning since the POH states that the aural stall warning was "not mutable." • The pilots interviewed had no memory of receiving formal training on the functionality of this switch.

112 Parallax refers to the effect by which the position of an object appears to be displaced when it is viewed along 2 different lines of sight.

	• Several pilots suggested that there should be a way to silence nuisance warnings that is easily accessible to the pilot (i.e., in the field of view).
AOA transmitter pre-flight inspection	• Some pilots physically moved the vanes on the probes, but others only visually inspected them. Some of the pilots physically move the vanes on the 1st flight and then visually inspect them on subsequent flights. Some pilots reported a reluctance to physically move the vanes out of concern for possibly damaging them.
Stall warning test	• Some pilots were unsure whether the test would identify a problem (e.g., a broken belt) with the AOA transmitter input.
Departure/emergency briefs	• Most of the PC-12 pilots reported that they did not carry out any type of departure "self-brief" to plan for contingencies, such as a malfunction on takeoff. Several pilots highlighted the benefits of completing a departure briefing and reported that they had shifted away from doing it while operating single-pilot. One pilot noted that single-pilot operations can make pilots lazy when it comes to procedures like briefings, given that there is no other pilot to brief.
Simulator training	• Most pilots reported that the simulator training lacked operational realism. • Pilots generally reported that they believed simulator training would be enhanced if it were conducted by an RCMP training pilot.
False aural stall warning	• None of the pilots interviewed remembered having experienced, before the occurrence, a false aural stall warning scenario during simulator training or during actual operations. Likewise, they were unaware of any such occurrences involving the PC-12.
Turnbacks	• Pilots reported that they had been trained to perform turnbacks in either direction; however, it was instinctual to go left because of the better visuals available to the pilot, who is normally in the left pilot seat.
Single-pilot versus dual-pilot operations	• Most pilots stated that the PC-12 can be safely flown, under most circumstances, with a single pilot; however, almost all of the pilots interviewed reported that if all flights were conducted dual-pilot, those operations would be safer because a pilot can become very busy during a single-pilot operation. • A few pilots stated that they believed this occurrence could have been avoided if 2 pilots had been on board the aircraft.

1.18.3 Previous occurrences

To better understand the risk of an erroneous stall warning, the investigation reviewed previously reported occurrences and communicated with PC-12 operators from Canada and around the world, as well as the aircraft and AOA system manufacturers. The investigation also examined the NASA aviation safety reporting system database and the FAA service difficulty reporting system database. The TC service difficulty reports database was reviewed with no results.[113]

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[113] As of September 2022.

1.18.3.1 Previous TSB investigation

On 09 May 2022,[114] a Pilatus PC-12/47E aircraft was conducting an IFR flight from Winnipeg/St. Andrews (CYAV), Manitoba, to Gods Lake Narrows (CYGO), Manitoba. On board were 2 pilots. Shortly after takeoff, the aircraft's shaker activated, and the stall warning alert sounded. The flight crew elected to remain within VFR flight conditions and stay below the clouds, based at approximately 1000 feet AGL. The flight crew declared an emergency and returned for landing. Owing to the activation of the shaker and aural stall warning, the flight crew experienced considerable difficulty communicating during the event. Given the aircraft’s proximity to the runway and the difficulties encountered communicating with the other pilot, the PIC (who was in the left seat) decided to abandon attempts to locate and pull the STALL WARN 2 circuit breaker on the right side of the cockpit and chose to continue with a VFR circuit to landing.

A subsequent inspection by the air operator’s maintenance personnel revealed a faulty AOA transmitter. The AOA transmitter was replaced, and the aircraft was returned to service.

1.18.3.2 Experiences of other PC-12 air operators

Between 2019 and 2023, one dual-pilot PC-12 air operator encountered 4 instances of false stall warnings on takeoff. In each of those instances, as soon as the aircraft became airborne, both the shaker and the continuous aural stall warning activated. In only 1 of those instances did the flight crew carry out the emergency procedure for inadvertent shaker operation and pull the STALL WARN circuit breakers. In the other 3 instances, the flight crew elected to complete the VFR circuit to the landing with the shaker and aural stall warning still activated.

Another PC-12 air operator reported 2 similar occurrences on takeoff. In one of those instances, the pilot rejected the takeoff and landed straight ahead. The issue was related to a faulty AOA vane. The pilot in that occurrence reported that during the pre-flight inspection, there was no indication of a problem with the AOA vanes. The same air operator reported that its maintenance personnel had detected AOA vanes that were either seized or did not move freely. As a result, the air operator produced an internal safety bulletin to ensure that pilots thoroughly check the AOA vanes for correct movement during pre-flight inspections.

1.18.3.3 Manufacturers

1.18.3.3.1 Collins Aerospace

The manufacturer of the AOA transmitters was aware of a 2013 occurrence in which an AOA transmitter failure resulted in a formal investigation, which was conducted by the FAA. Collins was not a party to the investigation; however, it did discover that the vane-to-resolver belt had broken on the unit and had produced an inadvertent shaker activation and an aural stall warning.

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[114] TSB Class 5 occurrence A22C0034.

1.18.3.3.2 Pilatus Aircraft Ltd.

Pilatus records indicate 52 occurrences, in the 10.6 million flying hours of the entire aircraft fleet, involving an inadvertent shaker activation. Eleven of the 52 were reported as having occurred on takeoff. The remaining events either did not occur on takeoff or did not have a phase of flight indicated in the records when the event occurred.

1.18.3.4 National Aeronautics and Space Administration and Federal Aviation Administration

A review of the NASA aviation safety reporting system and the FAA service difficulty reporting system databases revealed several occurrences of false stall warnings on takeoff in the PC-12. These occurrences, including one illustrating the difficulties that even dual-pilot crews face when responding to the inadvertent activation of the shaker and following the appropriate procedure, are summarized in Appendix A.

2.0 ANALYSIS

The analysis will discuss the factors that played a role in the occurrence, as well as identify some issues that represent a risk to aviation safety. In particular, the analysis will focus on aircraft handling, the Pilatus Aircraft Ltd. (Pilatus) PC-12 aircraft's stall warning system, human performance considerations, the air operator's standard operating procedures (SOPs), and the training and procedures for responding to an inadvertent shaker emergency on the PC-12.

2.1 Aircraft handling

Shortly after takeoff from Runway 32L, the pilot initially attempted to carry out a turnback and land on Runway 14R; however, after the aircraft had reversed course, it was not in a position to land safely. Specifically, it was too high, at an approximate height of 350 feet above ground level (AGL), and too far down the runway. At that point, the pilot was flying visually alongside Runway 14R, in low ceilings and visibility below visual flight rules (VFR) limits, and had to quickly devise a new plan.

The pilot had to consider the risks of venturing away from the airport, in instrument meteorological conditions, and potentially losing visual references in unfamiliar mountainous terrain, as opposed to staying close to the airfield and keeping the runway in sight at all times. The pilot opted for the latter, having decided that it was safer to remain below the clouds. This plan subsequently required the pilot to manoeuvre at a low airspeed and low height above ground, in reduced visibility.

As the aircraft flew parallel to Runway 14R, the pilot recognized the need to create some distance from the runway to account for the aircraft's turning radius for a 180° turn onto final. To do this, the pilot made a small heading correction to offset to the right. During this manoeuvre, the pilot's attention was focused on the runway. This likely contributed to the pilot omitting to extend the flaps for landing and also led to an unintended reduction of airspeed to within 0.5 knots of the calculated stall speed.

As the aircraft passed abeam, and 1300 feet to the west of, the threshold for Runway 32L, the aircraft was flying at approximately 200 feet AGL and 100 knots calibrated airspeed. The pilot then initiated a 180° left turn, with bank angles generally ranging between 5° and 20°. This resulted in the aircraft crossing the extended centreline almost perpendicularly, on an easterly heading, at approximately 0.4 nautical miles (NM) from the threshold of Runway 32L. Recognizing that the aircraft had overshot the final approach course, the pilot increased the left bank angle to approximately 47° to reduce the aircraft's turn radius and to keep the runway in sight.

Approximately 0.5 NM east of the threshold, the aircraft reached the apex of the left turn and began flying, on a northwesterly and then a westerly heading, towards Runway 32L. However, because of the aircraft's proximity to the runway, this heading put the aircraft on a course that resulted in it crossing Runway 32L at an angle of approximately 75° and at a distance of approximately 600 feet beyond the threshold. When crossing Runway 32L, the aircraft was in a 40° right bank at a calibrated airspeed of 96 knots and a height of approximately 100 feet AGL. The pilot, who felt a strong motivation to land, increased the right bank to a maximum of 46° as the aircraft descended below 50 feet AGL. This increase in bank, at a low airspeed and with the flaps retracted, caused the aircraft's airspeed to drop below the calculated stall speed by approximately 10 knots, likely resulting in the aircraft entering an aerodynamic stall at a very low height above ground.

Finding as to causes and contributing factors

During the final moments of the flight, the aircraft's right turn in excess of 45° of bank, while it was operating at a low height above the ground and just above the calculated stall speed, likely resulted in the aircraft entering an aerodynamic stall, with insufficient height to recover before impacting the terrain.

2.2 False stall warning

The PC-12's stall warning system is inhibited until the weight-on-wheels switch indicates that the aircraft is airborne. The system is designed this way to prevent false stall warnings on the ground. However, this also means that in some situations, such as the one experienced during the occurrence flight in which the stainless steel belt in one of the angle of attack (AOA) transmitters was broken, a pilot will become aware that a problem exists only after the aircraft lifts off. Depending on a variety of variables, such as runway length available, weather conditions, and pilot workload, this can present a number of challenges for the pilot, especially in a single-pilot operation.

The PC-12's stall warning system relies on a 0.05 mm thick stainless steel belt on a pulley system within the AOA transmitter to transmit AOA changes to the stick pusher computer. The belt is secured by screws, through holes, to pulleys at the resolver and probe ends of the AOA transmitter. The belt is considered an "on condition" replacement item and was designed with an approximate mean time to failure of 2500 flight hours. The AOA transmitter, including its components (e.g., the belt), is not subject to any type of on-aircraft maintenance requirements. Once installed, it is removed from the aircraft only if it experiences some type of failure. If a failure occurs, the unit is sent to the manufacturer for overhaul and/or replacement, which normally involves installing a new belt in the AOA transmitter. As a result, there is no way for air operators to inspect the belt for fatigue cracking. An AOA transmitter can therefore remain in service well beyond the belt's mean time to failure. Once beyond the mean time to failure, it is reasonable to expect an increased likelihood of component failure due to a variety of reasons, including the undetected development of fatigue cracks.

A post-occurrence examination of the AOA transmitters revealed that the left AOA transmitter's stainless steel belt, which had accumulated 4090 flight hours, was broken in 2 places. It was determined that 1 of these fractures, which had exhibited signs of overload, was directly related to the impact sequence; however, the other fracture, at the probe end of the belt, was of significance to the investigation. The examination of the breakage at the probe end of the left AOA belt revealed fatigue cracking on over 85% of the fracture surface.

The remaining 15% of the fracture surface was due to overload. This fatigue cracking significantly weakened the belt until it was unable to withstand more than 1.5 pounds (0.7 kg) of force. It is highly likely that the fatigue crack began at a site of surface pitting left by the wet-etch manufacturing process and propagated over time, weakening the belt until, at some point before rotation during takeoff on the occurrence flight, the forces applied to the belt caused it to finally fail. With the lower belt broken, gravitational forces caused the counterweight on the aft pulley, at the resolver end, to rotate to a position that generated a stall warning as soon as the system became active when the aircraft took off.

In 2023, a new AOA transmitter design that did not rely on the wet-etch manufacturing process became available. According to Pilatus, the design change was originally initiated to address reliability issues associated with heater failures and sticking vanes on the PC-21 AOA transmitter, and the design was subsequently implemented on the PC-12 version due to commonality. According to Collins, the change in the manufacturing process reduces pitting on the belt after prolonged exposure to the atmosphere, thereby increasing the life of the belt and reducing the failure rate. Although multiple instances of false stall warnings have been documented, Pilatus had no intention, at the time of report writing, to issue a service bulletin or service letter related to this new transmitter design. Instead, its plan is for the AOA transmitters to be upgraded during repairs resulting from normal attrition of the belts.

As a result, some air operators may be unaware that a new design, less susceptible to failures such as the one encountered during the occurrence, is available. Likewise, given that there is no requirement for air operators of existing PC-12 aircraft to change over to the new design, it is highly likely that there will be additional instances of false stall warnings on takeoff as a result of an unexpected failure of the AOA belt.

Finding as to causes and contributing factors

The stainless steel belt in the left AOA transmitter experienced a fatigue crack likely attributed to the wet-etch design process. Owing to the fact that the belt is an on-condition component, the fatigue cracking went undetected until the belt failed at, or just before, takeoff on the occurrence flight, causing the AOA transmitter to transmit a false stall signal when the aircraft became airborne.

2.3 Human performance factors

Modern aircraft offer pilots a level of reliability that can, at times, lead them to develop a mindset of normalcy. For example, if an aircraft type rarely experiences problems on takeoff, pilots can become conditioned to believe that such a problem will never arise. Then, if an unexpected situation (e.g., an emergency) does occur, it can generate a heightened stress response due to the surprise effect. Unfortunately, as long as uncertainty and confusion about that situation persist, it is unlikely that the pilots' level of stress will decrease. In fact, stress can increase as they unsuccessfully attempt to understand what is happening. If additional stressors are subsequently introduced, these stressors can produce a moderate-to-severe stress reaction that negatively affects their performance. In particular, acute stress can lead to a variety of cognitive impairments, including attentional narrowing and distraction.

During the final moments of the occurrence flight, the aircraft likely entered an aerodynamic stall at a height above ground that precluded recovery. To fully understand the circumstances leading to this situation, it is necessary to look at the factors and cascading series of events that contributed to the outcome of this occurrence. These include:

- The surprise event (i.e., the activation of the aural stall warning at an unexpected time, which did not make sense to the pilot)
- Concern about pusher activation at a low height above ground, which the pilot had been conditioned to develop through training
- A perceived sense of urgency, due to the uncertainty of the situation, to land as soon as possible
- The decision to continue the takeoff due to a belief that inadequate runway length remained to safely land and stop the aircraft
- The pilot's automatic, inadvertent left turn towards higher terrain during the initial climb-out (possibly an instinctual action acquired from training)
- Aggressive flight control inputs near the apex of the turnback that resulted in the activation of the enhanced ground proximity warning system (EGPWS) "Bank Angle, Bank Angle" aural warning, as the aircraft reached a maximum of 66° left bank
- A high rate of descent during the last half of the turnback that triggered the EGPWS "Don't Sink, Don't Sink" warning, followed by the "Caution Terrain, Caution Terrain" warning
- Low cloud and reduced visibility, which increased pilot workload
- The pilot's lack of experience and familiarity with operating under VFR around CYXY
- The need for the pilot to quickly formulate a new plan following the unsuccessful turnback
- The continuous aural stall warning, which was distracting and stressful
- The pilot did not know how to silence the continuous aural stall warning, which likely exacerbated an already stressful situation
- The fact that this was a novel situation for the pilot and required a lot of cognitive resources
- The fact that the pilot was operating single-pilot, which increased the pilot's workload
- The aircraft's overshooting of the on-course for Runway 32L, adding to the pilot's workload and stress
- Aggressive manoeuvring that was used during the final seconds of the flight in an attempt to line up for Runway 32L

The sequence of events began with the initial surprise event: the continuous aural stall warning. The pilot had never experienced this type of situation previously and was unaware of similar occurrences. As a result, the activation of the aural stall warning at a point in the flight where it was both unexpected and inconsistent with what the pilot was seeing produced an immediate and intense stress response. The combination of events and factors listed above then imposed additional layers of stress on the pilot, who was alone in managing the situation and flying beneath a low cloud ceiling in reduced visibility and in unfamiliar mountainous terrain.

Given that the pilot was unable to silence the continuous aural stall warning, a major source of distraction and stress persisted. Additionally, the growing uncertainty about the situation caused the pilot's stress level to increase until the pilot's performance was degraded by attentional narrowing and distractions, reducing the ability to process cues from the environment. The following are some specific examples:

- The pilot had difficult correctly assessing the runway length available for a rejected takeoff.
- The attempted turnback resulted in the aircraft being too high and too far down Runway 14R to safely land on it.
- The continuous aural stall warning was distracting to the pilot and contributed to the pilot omitting to extend the flaps, in accordance with published procedures, for landing. This reduced the aircraft's stall margin by approximately 10 knots.
- Before commencing the left turn for Runway 32L, the pilot's attention was fixated on the runway. This likely resulted in a momentary breakdown in the pilot's instrument scan, owing to the fact that the aircraft's airspeed decreased to within 0.5 knots of the calculated stall speed. The aircraft's flight profile also triggered the "Don't Sink, Don't Sink" warning on the EGPWS.
- The position from which the aircraft initiated the left turn for Runway 32L, and its bank angles at that time, resulted in the aircraft overshooting the on-course by approximately 0.5 NM.
- During this left turn for Runway 32L, the aircraft's bank angles reached as high as 47° while it was less than 250 feet above the ground.
- After overshooting the on-course, the pilot put the aircraft on a course that resulted in the aircraft approaching and crossing Runway 32L at an approximate angle of 75°.
- As the aircraft crossed overhead of Runway 32L, approximately 600 feet beyond the threshold, the pilot applied aggressive control inputs that resulted in the aircraft's airspeed dropping below the calculated stall speed.

Several of the outcomes highlighted above are indicative of an individual who was experiencing a significant stress response because of a perceived sense of urgency to land as soon as possible. Therefore, while the pilot was making a final attempt to align with

Runway 32L, critical cues about the aircraft's flight profile went unnoticed, likely leading to the aircraft inadvertently entering an aerodynamic stall.

Finding as to causes and contributing factors

While attempting to align the aircraft for landing, the pilot experienced attentional narrowing due to an intense stress reaction in response to a surprise event. As a result, the pilot's attention was focused outside the aircraft, and the pilot unknowingly placed the aircraft in a flight regime that likely resulted in an aerodynamic stall at a very low height above ground.

2.4 Standard operating procedures for pre-takeoff self-briefings

The Royal Canadian Mounted Police (RCMP) Air Services Branch has SOPs that highlight the importance of crew resource management (CRM) in multi-crew and single-pilot operations. The SOPs also discuss the importance of identifying and then attempting to eliminate or reduce threats by turning unpredictable threats into predictable threats. A CRM strategy that can help accomplish this, one that is widely used in multi-crew operations, is a take-off briefing. Per the RCMP's PC-12 SOPs, take-off briefings must be completed when the aircraft is operated with 2 pilots. That briefing must include the following:

- a discussion of the power setting, the takeoff type, and the initial climb;
- a plan in the case of malfunctions before or after rotation (e.g., reject or recovery);
- the departure procedure; and
- any non-standard procedures planned.

On the other hand, there is no requirement for RCMP PC-12 pilots to conduct a take-off briefing in a single-pilot operation. As a result, the RCMP SOPs may have implicitly contributed to a perception among pilots that a structured take-off "self-brief" is not an important CRM strategy during single-pilot operations.

Given that RCMP PC-12 pilots usually operate single-pilot, they are rarely in situations requiring take-off briefings, so there is little opportunity for these pilots to make this CRM strategy a habit and reinforce its value. Although some of the pilots did acknowledge that these take-off briefings were beneficial, these pilots also noted that they were not usually performed because they were not required in single-pilot operations.

In accordance with the generally accepted practices within the RCMP, the occurrence pilot did not conduct a take-off briefing like the one required for multi-crew operations, nor was one required. The absence of a pre-departure briefing (i.e., mental rehearsal) before the surprise event (the false stall warning) shortly after takeoff likely contributed to a rapid increase in the pilot's stress level and workload since it made it necessary for the pilot to rapidly process the unexpected cues from the environment and then make time-critical decisions. Some of these decisions included whether to

- reject the takeoff or continue flying;
- climb into the clouds with an active stall warning indication or remain visual in reduced visibility; and

- turn left or turn right for the turnback, once the decision had been made to continue visually.

Moments after lifting off, the pilot briefly contemplated rejecting the takeoff but assessed that insufficient runway length remained. At that time, power had been reduced, the aircraft's speed was 120 knots, its height was 40 feet AGL, and more than 3700 feet of runway remained. It is likely that the absence of a mental rehearsal before takeoff, combined with the reduced forward visibility, played a role in the pilot's assessment that there was insufficient runway length remaining to reject the takeoff, even though it was more than double the estimated length required to reject the takeoff from that height and airspeed.

After deciding to continue the takeoff, the pilot made a time-critical decision to remain visual rather than enter the clouds with a continuous active stall warning. Since the pilot had not self-briefed emergency recovery actions before the flight, that decision had to be made under intense time pressure, likely to the exclusion of some risk considerations. For example, it is highly likely that this decision to remain visual was made without a full understanding of the risks associated with visually manoeuvring at a low height above the ground and in reduced visibility around an airport that the pilot had only ever used for instrument flight rules departures and arrivals.

It is possible that in the absence of a self-briefed pre-takeoff recovery plan, the pilot instinctually turned to the left during the initial climb, bringing the aircraft towards higher terrain that presented a hazard because of the low ceilings and reduced visibility. Once the aircraft was established in the left turn, the pilot remembered that the published visual circuit procedure instructed pilots to turn to the right, because of the higher terrain to the west (left) of the airfield. By accidentally turning to the left, the pilot added another layer of stress to an already stressful situation.

A structured take-off briefing can be used to support pilot decision making in multi-crew and single-pilot operations. In each of the 3 examples identified above, the pilot inadvertently made time-critical decisions that contributed to the pilot's overall stress level and reduced safety margins. Taking the time while on the ground to develop plans and brief contingency and emergency actions can greatly reduce the cognitive demands on a pilot who must deal with an emergency situation while airborne. For example, if a pilot, before a flight, considers the runway length required for a landing versus the runway length available for it, the pilot will be better able to identify whether there is sufficient distance for a rejected takeoff or whether it is necessary to continue flying. Similarly, by briefing emergency recovery actions, such as whether to continue into cloud or remain VFR, which way to turn, and what routing to follow, a pilot will free up cognitive resources given that some of those decisions will have been made in advance. This is particularly important in single-pilot operations, in which a pilot must manage all cognitive processing demands on their own.

Finding as to risk

If SOPs for single-pilot operations exclude elements traditionally associated with multi-crew operations, such as pre-takeoff briefings, there is increased risk that pilots engaged in single-pilot operations will be inadequately prepared for an emergency situation.

2.5 Training and procedures for inadvertent shaker emergencies

2.5.1 General

Based on the information presented in Pilatus's PC-12 pilot operating handbook (POH), the pilot experienced what is referred to as an "inadvertent shaker" emergency. In light of the outcome of this occurrence, the investigation examined the training received by pilots, as well as the procedures in the POH, to address this emergency. Besides shaking the control wheel, activation of the shaker does not affect how the aircraft responds to flight control inputs, and therefore, the aircraft can be flown while the shaker is activated.

However, the accompanying continuous aural stall warning can be particularly distracting to a pilot, as seen in this occurrence and others. Without training and clear procedures that enable pilots to respond appropriately to this emergency, the activation of the stall warning system can produce a significant stress response.

The rest of this section will focus on both the training received by RCMP PC-12 pilots to deal with an inadvertent shaker activation as well as the procedures in place to support pilot decision making when pilots are faced with this emergency.

2.5.2 Training

Both initial and recurrent training for RCMP PC-12 pilots are carried out using a third-party provider and third-party instructors. A review of this training found the following with respect to the pilots' general knowledge:

- There were gaps in aircraft system knowledge with regard to the stall warning system (e.g., they could not identify circuit breaker names and locations) and the cockpit indications that would ensue if a single AOA transmitter sensed a stall condition.
- There was very little understanding of the function of the AURAL WARN INHIBIT switch and the situations when it could be used.

On the subject of simulator training, the review found that

- it centred largely around United States airfields;
- emergency turnbacks often involved a left turn;
- stall warning system malfunctions focused on inadvertent pusher activation; and
- pilots conducted rejected takeoffs from various heights after rotation.

Although an inadvertent activation of the shaker does not affect how the aircraft responds to flight control inputs, it does present a number of challenges, particularly for a pilot who has never experienced this situation. Although the incidence of inadvertent shaker emergencies has been relatively low, during the life of the PC-12, it has occurred on a number of occasions. In several occurrences involving the inadvertent operation of the shaker, pilots did not action the published emergency procedure.

Although the documentation surrounding these events is limited, an example (Appendix A) reported through the United States National Aeronautics and Space Administration (NASA) aviation safety reporting system made it clear that, even for 2 pilots, this emergency can be challenging to manage. In that particular example, the pilots reported the aural stall warning to be “very distracting” and that the warning made it difficult for them to communicate with the air traffic controller and with each other.

Following the occurrence, the RCMP conducted numerous simulator sessions to recreate the occurrence scenario. As had been reported in the NASA occurrence described above, RCMP pilots participating in the simulator recreations reported that the aural stall warning, if left uninterrupted, was very distracting. One of the RCMP pilots attempted to carry out the published emergency procedure. This pilot, who was well within the anthropometric criteria for the cockpit, found it difficult to reach and pull the STALL WARN 2 circuit breaker while maintaining control of the aircraft.

As discussed, one of the best ways to reduce the likelihood, and effect, of surprise events for pilots is to expose them to similar situations in training. The more a pilot is conditioned to react to surprise and startle events, the better the pilot will be equipped to manage the stress response that can occur. This type of training creates resilience as pilots become adept at preparing for and dealing with time-critical decisions.

For this to be effective, it must also encourage pilots to anticipate possible problems and mentally rehearse the actions to take in the event that such a problem does arise. Otherwise, pilots may become proficient in dealing with rehearsed scenarios but experience difficulty processing and dealing with novel, time-critical situations.

In the case of the RCMP Air Services Branch, simulator training focused on an inadvertent pusher activation scenario, given the potential severity of this emergency at a low height above the ground. As a result, RCMP PC-12 pilots were not exposed to an inadvertent shaker emergency during training. This meant that these pilots, who were also unaware of previous instances of inadvertent shaker emergencies, had an incomplete understanding of the symptoms of, and actions to take in response to, an inadvertent shaker emergency.

Because the RCMP’s PC-12 stall warning system malfunction training focused on an inadvertent pusher activation, it is understandable that pilots, in an inadvertent shaker emergency situation, would first revert to something they had been taught, especially when conditioned to understand that an inadvertent pusher activation is particularly dangerous at low heights.

It is also understandable how pilots in novel situations that are perceived to involve high risk can experience cognitive overload due to acute stress while they are trying to resolve unexpected and confusing cockpit indications that they have never previously encountered.

Finding as to causes and contributing factors

The RCMP's training for stall warning system malfunctions on the PC-12 focused solely on an inadvertent pusher activation. As a result, the occurrence pilot did not fully understand the symptoms of a false stall warning or the options available to mitigate the risks associated with this emergency.

2.5.3 Procedures

The emergency section of the PC-12 POH begins by highlighting Pilatus' recommended "PPAA" work process for dealing with abnormal or emergency situations. The 4-step process consists of power, performance, analysis, and action. Beyond this guidance, pilots are expected to rely on section 3 of the POH for procedures to follow in response to an emergency situation.

The inadvertent shaker procedure is found within section 3.13, titled "Inadvertent Pusher/Shaker Operation." This section details the actions to take in the event of an inadvertent pusher activation, followed by those to take in response to an inadvertent shaker activation. These events constitute 2 separate emergency situations.

In the occurrence, the pilot experienced difficulties understanding the severity of the situation and determining the appropriate actions to deal with the inadvertent shaker emergency. The investigation also noted that other RCMP PC-12 pilots possessed varying degrees of understanding of this emergency, its causes, and the actions that can be taken to resolve it. As a result, the investigation sought to better understand the procedure intended to support pilot decision making when pilots are faced with the inadvertent shaker emergency.

In particular, the investigation attempted to identify which, if any, aspects of the inadvertent shaker procedure in the POH may have contributed to the difficulties encountered by the occurrence pilot, as well as to the general misunderstanding of this particular emergency situation among other RCMP PC-12 pilots. The following observations were made:

- The title of the procedure, "Inadvertent Pusher/Shaker Operation," could be construed to mean that it addresses a situation involving the inadvertent activation of both the pusher and the shaker. This could create confusion and lead to a mistaken belief that the procedures are linked.
- The procedure identifies "non-commanded shaker operation" as the sole indication of an inadvertent shaker emergency. It makes no mention of power or performance considerations to assist the pilot's analysis and action selection. In addition, there is no mention of the aural stall warning or the Flight Alerting System (FAS) visual "Stall" warning, which are 2 indications that, on the PC-12, are linked with the activation of the shaker and could help the pilot determine that it is appropriate to carry out the inadvertent shaker emergency procedure.
- The inadvertent shaker procedure provides no alternate way for the pilot to silence the aural stall warning during periods of high workload, when it may be impractical to pull the STALL WARN 1 and STALL WARN 2 circuit breakers. For example, the

procedure makes no mention of the AURAL WARN INHIBIT switch as a possible way to quickly silence an aural stall warning that may be creating a serious distraction hazard.

- The emergency procedure offers no possible explanation for the cause of the false stall warnings (e.g., no mention of an erroneous signal from a single AOA transmitter). This could contribute to pilots not fully understanding the severity of the situation.

In addition to these aspects of the inadvertent shaker procedure that may have contributed to the occurrence pilot's confusion, the investigation identified another step in the procedure that could affect a pilot's ability to carry out the appropriate action. In particular, one of the steps directs the pilot to pull the STALL WARN 2 circuit breaker, located on the right side of the cockpit.

This could prove challenging for pilots depending on their reach and workload. Although this step did not play a role in this occurrence, it was noted in discussions with other PC-12 pilots that it may, in some instances, be unrealistic for a pilot to pull the STALL WARN 2 circuit breaker because it would take the pilot's attention away from flying duties.

For pilots to understand the nature of the emergency situation they are in, they must have a clear understanding of the indications of that emergency and what may be causing it. Generally speaking, and as seen in this occurrence, understanding the emergency situation and its severity will influence how pilots respond to it.

Unlike some emergency procedures in the POH, and as outlined above, the inadvertent shaker procedure omits potentially significant indications that could help pilots diagnose this emergency, allow them to better understand its implications, and direct them to the appropriate steps.

As a result, pilots who encounter this emergency situation may experience difficulty attempting to reconcile actual indications to those published in the emergency procedure, particularly if the situation is stressful for them. For this reason, pilots need to be provided with clear information to help them identify emergency situations.

Finding as to risk

If an emergency procedure does not clearly identify the various indications of an emergency, a pilot can be delayed in, or prevented from, taking action to mitigate the risk of the situation.

As seen in this occurrence and in others, an inadvertent shaker emergency can manifest itself shortly after the aircraft lifts off. Depending on a number of variables, pilot workload can be very high during the take-off phase of flight, especially in a single-pilot operation, in which a pilot has to assess what is happening while making time-critical decisions, such as whether to reject the takeoff, continue and enter cloud, or continue visually.

Some pilots who have experienced this emergency in-flight opted to forgo trying to pull the STALL WARN 1 and STALL WARN 2 circuit breakers, as the inadvertent shaker procedure stipulates, because of workload and risk considerations. Also, some pilots who have experienced this emergency reported that the aural stall warning can make it very difficult to communicate with other crew members or aircraft traffic control and that it can be very distracting. This places pilots in the difficult position of having to try to pull circuit breakers at a potentially inopportune time or having to attempt to land the aircraft while the aural stall warning is competing for their limited attentional resources.

The aircraft is equipped with another means of silencing nuisance alarms; however, it is discussed only in general terms in the POH, and, other than after maintenance is performed, it is not normally used by PC-12 pilots. The emergency procedures, particularly the inadvertent shaker emergency procedure, make no reference to the AURAL WARN INHIBIT switch as an alternate means of removing a potentially significant distraction and a risk to aviation safety.

As seen in this occurrence, the lack of formal guidance in the POH with regard to the potential use of the AURAL WARN INHIBIT switch, in the context of an emergency situation involving a continuous alarm, makes it more likely that a pilot, who is not accustomed to using this switch in an operational context, will overlook it as a means of eliminating a potentially serious distraction caused by a continuous aural warning.

Finding as to causes and contributing factors

The PC-12 POH provides limited guidance with regard to the potential use of the AURAL WARN INHIBIT switch during emergency situations. As a result, the occurrence pilot was unaware that this switch could be used to quickly eliminate the false aural stall warning that was a distraction for the duration of the flight.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. During the final moments of the flight, the aircraft's right turn in excess of 45° of bank, while it was operating at a low height above the ground and just above the calculated stall speed, likely resulted in the aircraft entering an aerodynamic stall, with insufficient height to recover before impacting the terrain.

2. The stainless steel belt in the left AOA transmitter experienced a fatigue crack likely attributed to the wet-etch design process. Owing to the fact that the belt is an on-condition component, the fatigue cracking went undetected until the belt failed at, or just before, takeoff on the occurrence flight, causing the AOA transmitter to transmit a false stall signal when the aircraft became airborne.

3. While attempting to align the aircraft for landing, the pilot experienced attentional narrowing due to an intense stress reaction in response to a surprise event. As a result, the pilot's attention was focused outside the aircraft, and the pilot unknowingly placed the aircraft in a flight regime that likely resulted in an aerodynamic stall at a very low height above ground.

4. The Royal Canadian Mounted Police's training for stall warning system malfunctions on the PC-12 focused solely on an inadvertent pusher activation. As a result, the occurrence pilot did not fully understand the symptoms of a false stall warning or the options available to mitigate the risks associated with this emergency.

5. The PC-12 pilot operating handbook provided limited guidance with regard to the potential use of the AURAL WARN INHIBIT switch during emergency situations. As a result, the occurrence pilot was unaware that this switch could be used during high-workload situations to quickly eliminate the false aural stall warning that was a distraction for the duration of the flight.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If standard operating procedures for single-pilot operations exclude elements traditionally associated with multi-crew operations, such as pre-takeoff briefings, there is increased risk that pilots engaged in single-pilot operations will be inadequately prepared for an emergency situation.

2. If an emergency procedure does not clearly identify the various indications of an emergency, a pilot can be delayed in, or prevented from, taking action to mitigate the risk of the situation.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Royal Canadian Mounted Police

Following the occurrence, the Royal Canadian Mounted Police (RCMP) took the following safety actions:

- Maintenance-related safety actions:
  - Reviewed technical records of the RCMP Pilatus Aircraft Ltd. PC-12 fleet related to angle of attack transmitters
  - Consulted the manufacturer about new angle of attack transmitters
- Operations-related safety actions:
  - Added “Inadvertent shaker/pusher” emergency scenarios to the PC-12 initial and annual recurrent training syllabi.
  - Incorporated a discussion about the circumstances of the occurrence into the ground school portion of initial and annual recurrent training for RCMP PC-12 pilots.
  - Incorporated an updated Pilatus PC-12 syllabus with the initial and recurrent training provider, emphasizing single pilot departure briefings during ground and simulator training exercises—with emphasis placed on decision-making processes, abnormal situations, and situational awareness.

This report concludes the Transportation Safety Board of Canada’s investigation into this occurrence. The Board authorized the release of this report on 12 March 2025. It was officially released on 03 June 2025.

APPENDICES

Appendix A – Service difficulty reports associated with false stall warnings on the PC-12 aircraft

Date	Crew composition	Summary of report	Source of report
August 2021	Not specified	On departure, the shaker activated. The aircraft returned for an emergency landing without incident. Maintenance found the left angle of attack (AOA) transmitter to be faulty.	Federal Aviation Administration (FAA) Service Difficulty Report #6CBA2021080921208
June 2016	2 pilots	Shortly after takeoff, the amber “PUSHER” message illuminated on the crew alerting system (CAS) panel, along with the red “STALL” warning message on both primary flight displays. The shaker and aural stall warning activated. The pilots agreed that the aircraft was not actually stalling. They elected to complete a circuit and return for landing. The pilots also decided to keep the airplane configured (i.e., gear down and flaps at 15°) as it had been on departure because the pattern would be a quick one. On touchdown, the shaker and the aural stall warning stopped, along with the other warnings that had appeared. After shutdown, the pilot examined the AOA vanes and did not notice anything out of the ordinary on either side. In the report, the pilot noted that this “[…] was a scenario that I had never encountered before.” The report included additional detail provided by the reporter (i.e. the captain). The reporter stated that the aural stall warning was “very distracting” while the aircraft was in the traffic pattern. The reporter further states: “[…] I could barely hear ATC [air traffic control] even with the volume turned all the way up because the aural warning system kept yelling ‘STALL STALL STALL’ the entire time. In addition to this, I found it difficult to communicate with my crew member because I had to have ATC turned up to the max volume. We both found this distracting. I looked for an aural inhibit button on the FMS [flight management system] panel quickly, but could not	National Aeronautics and Space Administration Aviation Safety Reporting System (NASA ASRS) Report #1364014

		see anything. […] We were both glad to get on the ground.” The reporter discussed, as a lesson learned, the AURAL WARN INHIBIT switch, stating, “I learned that I should remember that the Aural Warning Inhibit rocker switch is located on the Captain's side of the cockpit. During the hurry with everything going on, I unfortunately forgot this. If I had remembered this rocker switch, I could have activated it to mute the aural ‘STALL’ warnings, making it a much better flight environment. My thoughts go to ’out of sight, out of mind’ in regards to why I forgot the switch was over there.”	
October 2014	2 pilots	Before takeoff, systems were checked and deemed serviceable. 3 seconds after rotation, the shaker activated. According to the report, the low-speed awareness bar was very active. In particular, it was “[…] going full fast to full slow at odd intervals and there was not much wind […].” The first officer, who was flying, depressed and held the PUSHER INTR switch and flew a right-hand circuit for landing. Once the aircraft was on downwind, the captain took control. The shaker continued, and there were approximately 3 instances when it stopped for 1 to 2 seconds and then returned. The flight crew landed with the shaker activated. The flight crew reported the incident to maintenance, indicating that it was possibly related to AOA anomalies.	NASA-ASRS Report #1212987
March 2014	Not specified	Shortly after takeoff, the shaker activated. The pilot returned for landing at the departure airport. The problem was probably was caused by a faulty right AOA transmitter.	FAA Service Difficulty Report #GBBR20140331001
September 2013	Not specified	The system was checked and found to be serviceable before takeoff. During takeoff, the shaker activated. The aircraft returned to base without incident. Maintenance determined that the left AOA transmitter was unserviceable. As the report states, “[t]he vane on the AOA moved freely and seemed unattached to any internal workings.” The AOA transmitter was replaced and the aircraft was returned to service.	FAA Service Difficulty Report #CA131104008

February 2010	Not specified	On departure, the shaker activated. The aircraft returned for landing. The left AOA transmitter was found to be sending a shaker signal regardless of the position of the vane.	FAA Service Difficulty Report #CA100225001