Australian Government

Australian Transport Safety Bureau

# Pitch trim runaway (uninterrupted) and partial loss of control, Pilatus PC-12/47E, VH-OWJ

4 km west of Merredin, Western Australia on 14 April 2019

**ATSB Transport Safety Report**

Aviation Occurrence Investigation

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**Addendum**

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# Safety summary

## What happened

On 14 April 2019, the pilot of a Pilatus PC-12/47E aircraft, registered VH-OWJ and operated by Royal Flying Doctor Service - Western Operations (RFDS), was conducting a medical transport flight under instrument flight rules from Merredin to Jandakot within Western Australia. A RFDS aeromedical crew consisting of a flight nurse and doctor were on board with a non-critical patient who was being transferred to a hospital in Perth. For the midnight departure, there were almost clear skies with minimal ambient and celestial lighting.

About 1.5 minutes after take-off, 'Pitch Trim Runaway' warnings activated and the pitch trim continued to move nose-down without any pilot or autopilot inputs. The pilot initiated the applicable emergency procedure but inadvertently selected the Flap Interrupt switch rather than the Trim Interrupt switch. Consequently (before the next checklist item was actioned), the pitch trim continued to runaway until it reached full nose-down with associated serious control difficulties.

The pilot did not identify the mis-selection and continued to address the emergency procedure without resolving the full out-of-trim condition. With the assistance of the doctor seated in row 2, the pilot managed to return to Merredin for a flapless landing. The aircraft was undamaged and the occupants uninjured.

## What the ATSB found

The ATSB found that the pitch trim runaway occurred because of a malfunctioning relay in the manual (main pilot-engaged) stabiliser trim system.

As the (uninterrupted) pitch trim runaway progressed, the reinforcing cycle of increasing control loads, forced descent, and increasing airspeed was initially exacerbated by high engine torque. The airspeed reached 210 kts with increased risk of descent into terrain before the pilot reduced engine torque and airspeed to partially alleviate the control loads and arrest the descent.

After the pilot addressed items 2 and 3 of the emergency procedure, the malfunction was neutralised and the alternate stabiliser trim system was available to adjust the trim. However, the pilot did not identify those positive conditions and continued with items 4 to 8 of the procedure, which disabled the alternate stabiliser trim system, prevented pitch trim adjustment and prolonged the serious control difficulties.

The similarities between the Trim Interrupt and Flap Interrupt switches and the proximal location of the two switches, unnecessarily increased the risk of mis-selection and contributed to the excessive out-of-trim condition.

The ATSB found that the emergency procedures and systems information in the PC-12 Pilot Operating Handbook/Airplane Flight Manual and Quick Reference Handbook did not provide effective guidance or sufficient information for pilots contending with a pitch trim runaway. If the pilot selects the Trim Interrupt switch early in the sequence and does not need to adjust the pitch trim, the risk is not significant. In this incident, the lack of effective guidance and systems information probably had an adverse influence on the pilot's capability to resolve the uninterrupted trim runaway condition and was a critical factor.

As a factor that increased risk, the effectiveness of RFDS training and checking processes for pitch trim runaway was undermined by incomplete systems knowledge and unrealistic practice exercises associated with training/checking in the aircraft (non-simulator).

## What's been done as a result

Pilatus advised that a design change, to reduce the likelihood of a trim runaway, was developed before the occurrence to replace the mechanical pitch trim relays with solid-state relays but was not fully implemented due to limited parts availability. Both applicable service bulletins have now been published.

Pilatus also advised that the probability of erroneous activation of the Flap Interrupt switch instead of the Trim Interrupt switch has been reduced by the publication and active distribution of a Safety Information Letter (SIL-003) to all customers, operators and service centres. This includes a reminder of procedures when encountering a trim runaway condition.

The ATSB acknowledge these positive safety actions but notes that the Trim interrupt and Flap Interrupt switches on the PC-12 do remain identical and co-located, and there is potential for engineering controls to eliminate the mis-selection of the interrupt switches.

RFDS investigated the occurrence and implemented safety action such as increasing pilot awareness about the pitch trim systems and enhancements to their related training and checking processes.

## Safety message

The ATSB advises operators of PC-12 aircraft to review their training/checking processes related to the pitch trim system to ensure that pilots are adequately prepared to manage a runaway emergency. More generally, operators and pilots are advised to enhance awareness of expected system behaviour from switch and other control selections.

For flight control emergencies such as out-of-trim conditions, there is an imperative to maintain control while resolving the technical problem. A critical factor for pilots to consider is control of airspeed and associated engine power.

Operators are encouraged to submit reports of PC-12 pitch trim defects to the Defect Reporting Service to facilitate the Civil Aviation Safety Authority’s monitoring of continuing airworthiness data.

# Contents

# The occurrence

## Background

On 13 April 2019, a pilot employed by Royal Flying Doctor Service - Western Operations (RFDS) based at Kalgoorlie, Western Australia was rostered for a night standby duty between 1800 and 0600 Western Standard Time (WST). Soon after starting duty, the pilot and rostered medical crew was tasked to transfer a patient from Kalgoorlie and a patient from Albany to Jandakot within Western Australia. After consideration of the weather forecasts and medical status of the respective patients, the decision was made to proceed direct to Jandakot then conduct a flight to Albany and return, followed by a positioning flight to Kalgoorlie.

For this series of flights, the pilot was operating a Pilatus Aircraft Ltd. PC-12/47E aircraft, registered VH-OWJ, as a medical transport flight in the aerial work category under the instrument flight rules. At 2032, the pilot departed Kalgoorlie with a patient, flight nurse and doctor on board.

During the flight to Jandakot, the RFDS operations centre advised the pilot and medical crew of a patient at Merredin that required transfer to Jandakot as a higher medical priority than the Albany patient. For on-board patient care reasons, the flight continued as planned to Jandakot, landing at 2213. The pilot and medical crew were then re-tasked to conduct a flight to Merredin for the previously advised patient transfer.

The pilot departed Jandakot at 2253 and landed at Merredin aeroplane landing area (ALA) at 2341. This flight was described as normal except for diversions around storm cells that added 15 minutes to the planned flight time. The weather observed at Merredin was almost clear skies with a few scattered clouds to the south of the aerodrome and light winds.

Just after midnight, the pilot taxied the aircraft for runway 28 at Merredin ALA with the patient, flight nurse, and doctor on board. The pilot was seated in the front left control seat and the doctor was seated in the second row on the right, facing backwards.

The pilot conducted a normal take-off and was airborne at 0008:34. For the departure, the pilot was manually flying with the intention to engage the autopilot when the aircraft was established in the climb. As was typical for the phase of flight, the pilot was intermittently engaging the trim switches on the control wheel to make pitch trim adjustments. There was minimal ambient and celestial lighting for the departure.

## Emergency condition and initial pilot response

At 0010:05 (about 1.5 minutes after becoming airborne), as the aircraft was on climb through 2,700 ft AMSL (1,400 ft above ground level)[1] at a (calibrated) airspeed[2] of 140 kt, the following occurred without any apparent precursors:

- master warning light illumination
- 'pitch trim runaway' voice annunciation
- 'pitch trim runaway' warning message in red on the multi-function display
- continued pitch trim movement in a nose down direction without pilot or autopilot input at the time (uncommanded).

The pilot recalled hearing and seeing those warnings and that the aircraft pitched nose-down violently shortly afterwards. With both hands pulling on the control column to raise the nose, the pilot found that the force required to move the control column was extremely high and required

[1] Merredin ALA is at an elevation of 1,300 ft above mean sea level (AMSL).

[2] Calibrated airspeed (CAS) is the indicated airspeed corrected for instrument error.

maximum effort. The pilot was unable to counteract the nose-down force and the aircraft developed a high rate of descent at approximately 2,000 ft/min.

In response to the warnings, the pilot initiated the Pitch Trim Runaway emergency procedure from memory. The pilot recalled that:

- The first action was to select the Trim Interrupt switch on the centre console from NORM (normal) to INTR (interrupt). At the time, the pilot believed that this was carried out and that it was difficult to reach because of the high control column loads.
  (A 'Flaps Caution' was recorded at 0010:11, 6 seconds after the initial trim warning. This caution is consistent with operation of the Flap Interrupt switch instead of the Trim Interrupt and was not noticed by the pilot at the time.)
- After a short interval to focus on raising the nose, the pilot pulled the Pitch Trim circuit breaker on the essential bus to the OPEN position.
  (An Autopilot Fail Advisory was recorded at 0010:39, 34 seconds after the initial trim warning. This was coincident with cancellation of Pitch Trim Runaway warning and consistent with opening of circuit breaker)
- The Trim Interrupt switch was selected back to NORM.
  (Based on the first action, this was probably the Flap Interrupt switch.)

Following those actions, the pilot was concerned that there was no change to the condition of the aircraft. This was contrary to the pilot's expectations from training, which was that the Trim Interrupt switch should have stopped the dive and the opened circuit breaker should have relieved the situation. (Either or both actions would stop the manual trim motor from further operation but would not relieve the control loads existing at the time this action was taken.)

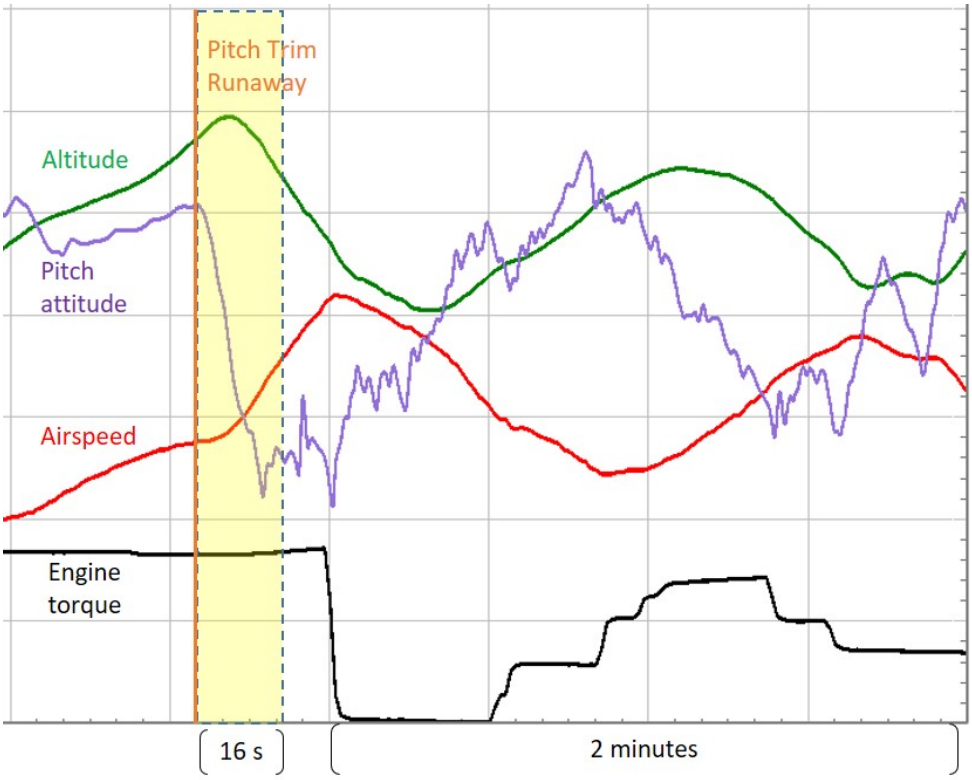
According to the recorded data, the pitch trim continued to operate in the runaway condition until it reached full nose down position 16 seconds after the warnings were issued. During that 16-second period, the following data was recorded (see the indicative flight data plot in Figure 1):

- engine torque remained at the take-off and initial climb setting of 42 lb (black trace)
- pitch attitude went from +9.5 degrees (nose-up) down to -7.5 degrees (purple trace)
- airspeed increased from 135 kt to 182 kt (red trace)
- altitude initially continued to climb until 3,000 ft then reduced to 2,600 ft (green trace)

Over the next 6 seconds, the situation continued to deteriorate until the pilot reduced engine torque. At about that point, the airspeed had reached 210 kt and the altitude was down to 2,400 ft. The pilot recalled that the control forces eased somewhat following reduction of engine torque.

During the next 2 minutes, the pilot managed initially to raise the pitch attitude to 12 degrees, arrest the descent at 2,000 ft and climb to 2,700 ft, while reducing the airspeed to 125 kt. However, this was momentary as the pitch attitude cycled down to -3 degrees then back to 12 degrees with corresponding descent/climb and airspeed increase/decrease.

**Figure 1: Indicative data plot showing key aircraft parameters before, during, and in the 2 minutes after the active phase (yellow band) of the pitch trim runaway.**




Parameter scales not shown but are available in Figure 3.
Source: ATSB

## Continuation of emergency condition and return to Merredin

By the end of that 2-minute sequence, the pilot was making a slow left turn to return to Merredin ALA and the master caution and pitch trim runaway warning activated for a short period (coincident with cancellation of the autopilot fail advisory). It is not clear from the pilot's recollection why that occurred but it is consistent with the closing and reopening the pitch trim circuit breaker.

The pilot continued to experience severe control difficulties with another sequence of pitch attitude down to -7.5 degrees and back up to 8 degrees. The aircraft descended to a minimum altitude of 1,700 ft (400 ft above ground level) and reached a maximum airspeed of 180 kt (Figure 3).

After this sequence, the pilot decided that it was not possible to overpower the elevator force alone and requested the assistance of the doctor seated in the adjacent row. The doctor turned in the seat, reached into the cockpit, and pulled on the right control column. This had a positive effect on the variation of pitch attitude and associated airspeed and altitude parameters, although full control was not established.

At this point, the pilot continued with the Pitch Trim Runaway procedure from memory and sought to select the Trim Interrupt switch to INTR again and pulled the Alternate Trim circuit breaker. The pilot then pushed the Alternate Stab Trim switch intermittently, which appeared to have no effect in relieving elevator pressure. (At about this time the master caution and pitch trim runaway warning activated again for a short period, coincident with cancellation of the autopilot fail advisory and consistent with the closing then reopening the Pitch Trim circuit breaker).

As the aircraft was now in the Merredin circuit area, the pilot's attention was on preparation for landing. When the flaps were selected to 15 degrees, the pilot noticed the 'Flap' caution on the crew alerting system (CAS) and realised the flaps were not available.

On the downwind circuit leg for runway 28, the pilot extended the landing gear. This was followed by a rapid descent from 2,150 ft to 1,650 ft (350 ft AGL) with a ground proximity warning system

(GPWS) alert (Figure 2). In response, the pilot (with the doctor's continuing assistance) pulled on the control column to raise the nose, and increased engine torque. Altitude was recovered to a maximum of 2,200 ft.

The pilot turned onto the base circuit leg and allowed the aircraft to descend. As the pilot turned onto the final approach, the aircraft overshot the runway centreline and required adjustment. On short final, the aircraft was high and the pilot was coordinating with the doctor to adjust the pitch attitude for landing. At one point, the pitch attitude was too high and activated the aural stall warning.

At about 30 ft above the runway, the pilot asked the doctor to let go of the control column and reduced engine torque to idle. The aircraft touched down firmly at 0017:15 and the pilot applied full reverse thrust and normal braking to bring the aircraft to a stop about 200 m from the end of the runway. The pilot taxied the aircraft to the parking area and shut down.

The RFDS operations centre dispatched an aircraft to Merredin to transfer the patient and RFDS personnel to Jandakot.

**Figure 2: Aircraft track and vertical profile**


Source: Google earth, annotated by ATSB

## Post-occurrence examination and rectification

RFDS maintenance engineers travelled to Merredin to inspect the aircraft, download data, and remove the lightweight data recorder (LDR) for the ATSB. The engineers reported that the:

- pitch trim was in the full nose-down position (leading edge of adjustable stabiliser fully up)
- Trim Interrupt switch was selected to NORM
- Flap Interrupt switch was selected to NORM
- Pitch Trim circuit breaker was closed (pushed in)
- Pitch Trim Alternate circuit breaker was open (pulled out)
- other switches and circuit breakers were in normal positions.

The engineers secured a copy of the aircraft condition monitoring system (ACMS) and fault history database (FHDB) files for analysis by system technical specialists and provision to the ATSB. The LDR was removed and dispatched to the ATSB laboratory in Canberra where cockpit voice and flight data was recovered and analysed. A flight data plot for the complete flight follows as Figure 3.

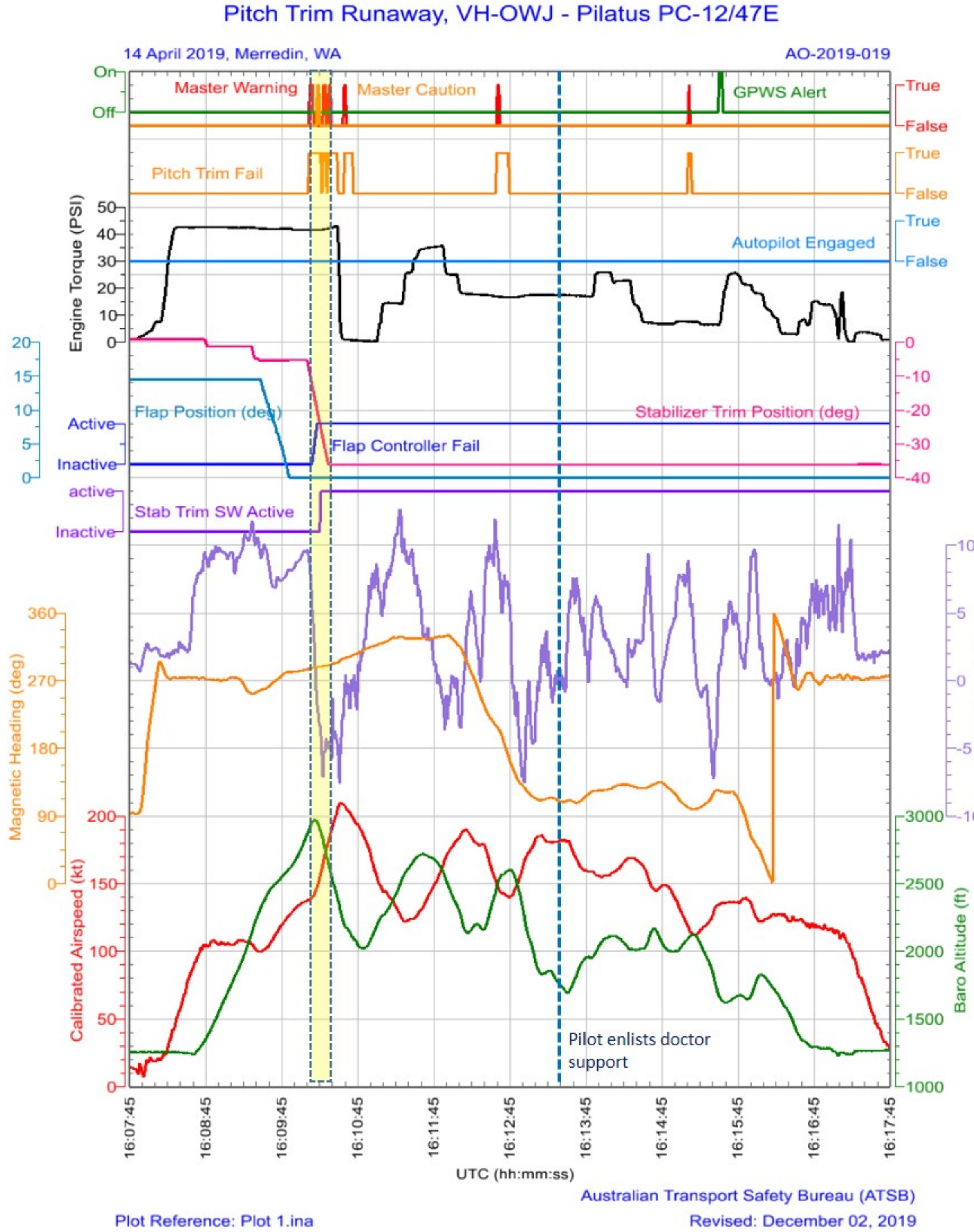
When the aircraft was powered up, the Pitch Trim Runaway warning was immediately active. When the Trim Interrupt switch was selected to INTR, it cleared the warning and stopped the trim from operating. Based on the FHDB fault codes and continuing Pitch Trim Runaway warning, the technical specialists advised that the troubleshooting focused on the relays in the left relay panel.

RFDS maintenance engineers found that the manual pitch trim DOWN relay (identification number K161E2) had malfunctioned in a mode consistent with contacts that were stuck closed rather than being open (as would be expected with the coil de-energised). This relay was replaced and applicable operational and functional tests carried out with no further defects identified. The aircraft was certified as serviceable and flown back to Jandakot Airport without incident.

The ATSB notes that based on recorded data, for the last part of the occurrence flight, both the Pitch Trim circuit breaker and Pitch Trim Alternate circuit breaker remained open. Based on correlated parameters in the recorded data, the Pitch Trim circuit breaker was then closed when the aircraft was subsequently powered up on the ground by the pilot.

From other correlated parameters in the recorded data, the Trim Interrupt switch was not selected to INTR at any time during the flight.

**Figure 3: Recorded data plot for complete flight showing the key parameters and active phase (yellow band) of the pitch trim runaway with start of doctor assistance (blue line).**




Source: ATSB

# Context

## Pilot information

The pilot held a commercial pilot licence with aeroplane category rating, an instrument rating with multi-engine aeroplane endorsement, and a Flight Instructor Rating. On application to RFDS in May 2018, the pilot's total aeronautical experience was 1,587 hours. This included 1,370 hours as pilot in command, 384 hours multi-engine (Piper PA-31 Navajo and PA-34 Seneca), and 154 hours instrument flight time.

After joining RFDS in July 2018, the pilot received the specified training and assessment for a new pilot without prior PC-12 or similar aircraft type operating experience. This included:

- Pilot induction training – including use of flight check system
- Ground school - PC-12/47E (NG) Engineering Course
- Human Factors and Non-Technical Skills Refresher Course
- Flight training with flight review in PC-12/47E aircraft
- Line Oriented Flight Training (medical transport flights with supervisory pilot)
- Instrument Proficiency Check
- Check-to-line assessment – passed in September 2018.

Training and check records indicate that the pilot progressed without any significant difficulties. The training/check pilot who approved the pilot for line operations recommended that, due to the pilot's relatively low experience level, a follow-up check be conducted earlier than the required 6 months.

During the first three months of PC-12 operation as a line pilot, the pilot inadvertently exceeded an engine limit on take-off, and extended the landing gear above the maximum landing gear operating airspeed. RFDS investigated the landing gear exceedance and found that the pilot accepted an amended route, was then high on approach, and checked the airspeed, but did not recognise the high speed before extending the gear. As recommended, the pilot was debriefed/counselled with plans to simulate a similar scenario at the next check.

In February 2019, the RFDS Head of Training and Checking (HOTAC) conducted a Progress Check with the pilot during daylight in visual meteorological conditions. This included a pitch trim runaway scenario after take-off that required the pilot to carry out the emergency procedure. The HOTAC advised that the pilot's response was in accordance with the Pilatus PC-12 Quick Reference Handbook (QRH). There was no record of a specific scenario similar to the landing gear exceedance. The overall assessment was satisfactory/competent and the pilot continued as a PC-12 line pilot for the next two months until the occurrence.

At the time of the occurrence, the pilot's total aeronautical experience was 2,108 hours including 521 hours on the PC-12/47E aircraft type. The pilot held a Class 1 medical certificate valid until February 2020.

## Aircraft information

The PC-12/47E is a large single-engine turboprop pressurised aircraft designed and built by Pilatus Aircraft Ltd in Switzerland. This aircraft was manufactured as serial number 1411 in July 2013 and registered VH-OWJ in October 2013. At the time of the occurrence, the total time in service was recorded as 7,377 hours.

The aircraft was maintained by the CASA-approved RFDS maintenance organisation in accordance with an authorised system of maintenance based on the Pilatus Progressive

Inspection Phases. At the time of the occurrence, a maintenance release[3] was in effect for the aircraft.

The most recent scheduled maintenance was a Progressive Mini Inspection completed on 28 March 2019 at 7,311 hours' total time in service. This included a functional check of the Trim Interrupt switch, Alternate Stabiliser Trim switch and runaway aural warning system. No defects were recorded.

There were no significant deferred defects or line maintenance recorded before the occurrence. The pilot who operated the aircraft on the previous shift earlier that day did not record any issues with the aircraft.

## PC-12 flight control systems

### *Pitch trim system*

The primary flight controls—aileron, elevator and rudder—are actuated through a conventional system of push-pull rods and carbon steel cables. Each primary control is equipped with an electrically operated (DC) trim system to alleviate the variable aerodynamic loads transmitted by the control system. A visual indication of trim position is displayed to the pilot on the multi-function display (see *Pitch trim runaway warnings*).

For pitch trim (nose up/down, related to elevator control loads), the leading edge of the 'T-tail' horizontal stabiliser is moved up and down through a defined range by an actuator. This actuator contains two separate electric motors that operate independently according to three different control inputs. The ATSB developed a schematic diagram of the three pitch trim power circuits (Appendix A). Refer to Figure 4 for trim system features.

One of those trim motors—manual stabiliser trim motor—provides the primary means for the pilot or copilot to adjust the pitch trim. When the pilot selects the pilot trim engage switch and trim up/down switch on the control wheel simultaneously, the trim control circuit energises the up or down pitch trim relay.[4] That connects power from the Essential Bus and Pitch Trim circuit breaker through the applicable relay contacts to the manual stabiliser trim motor then circuit to earth via the de-energised relay.

In normal operation, trim movement will cease once the pilot releases the switches. However, in this occurrence, the pitch trim down relay stuck closed and continued to provide power to the manual stabiliser trim motor until the pitch trim circuit breaker was opened.

The other trim motor—alternate stabiliser trim motor—is utilised by either the autopilot or the alternate stabiliser trim switch (labelled as 'Alternate Stab Trim'). When the autopilot is controlling the pitch trim, the auto drive circuit (from the Modular Avionics Unit) energises the up or down auto pitch trim relay in the Trim Adapter. That connects power from the Essential Bus and Pitch Trim circuit breaker through the respective relay contacts (and auto pitch trim engage relay) to the alternate stabiliser trim motor then circuit to earth via the relays.

The Alternate Stab Trim switch is located on the front centre console. When the autopilot is disengaged, selection of the switch to the nose up or down position provided power from the Main Bus and Pitch Trim Alternate circuit breaker (through the de-energised auto pitch trim engage relay in the Trim Adapter) to the alternate stabiliser trim motor.

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3 Maintenance release: an official document, issued by an authorised person as described in Regulations, which is required to be carried on an aircraft as an ongoing record of its time in service (TIS) and airworthiness status. Subject to conditions, a maintenance release is valid for a defined period of operation, in this case 210 hours TIS or 6 months from issue.

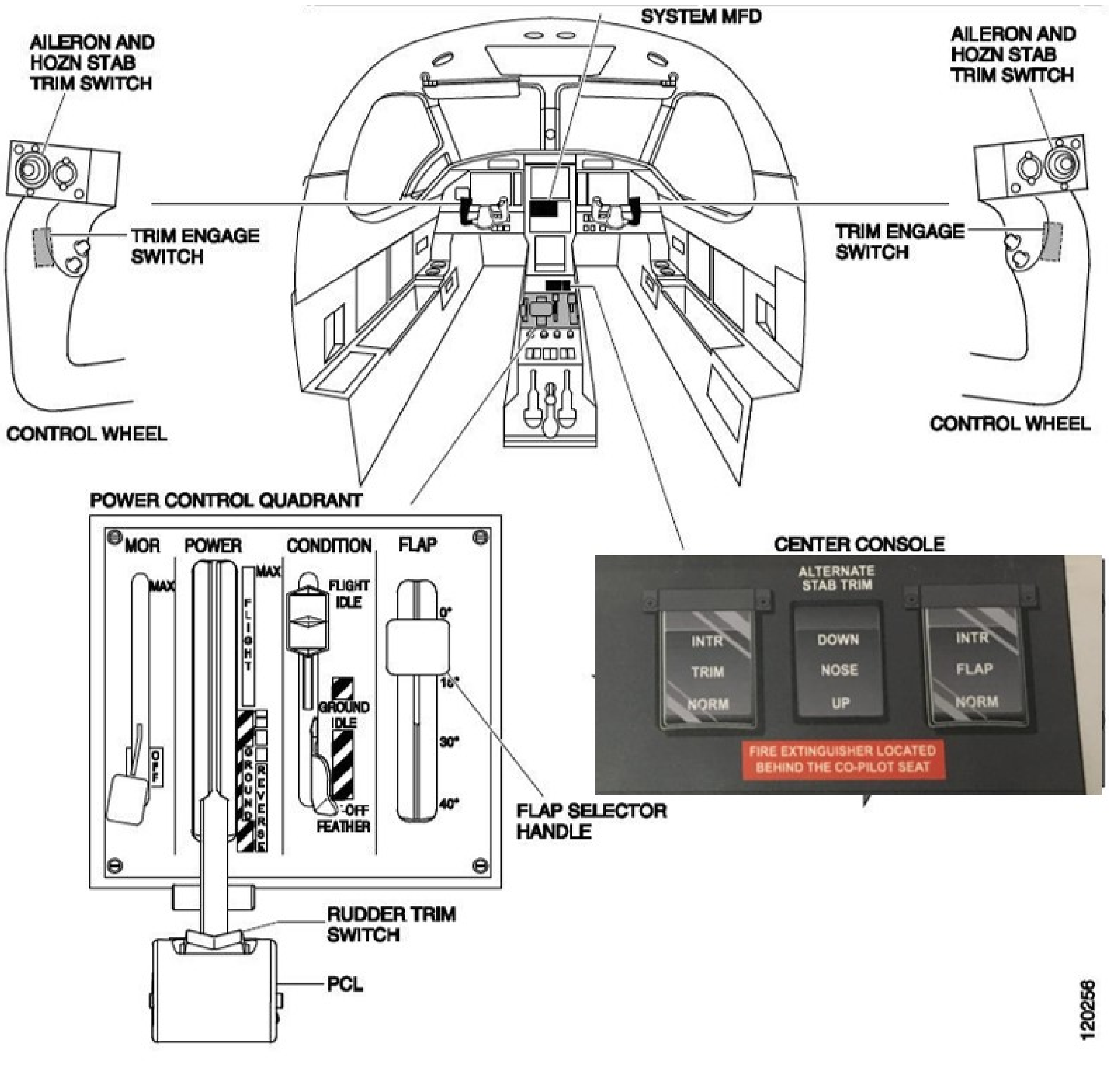
4 A relay is an electrically controlled device that opens and closes electrical contacts. The relays used in the pitch trim system were a mechanical type that utilised the electromagnetic force of an inductor to change contact positions.

All of the trim power circuits (including rudder and aileron trim) were routed through a ‘Trim Interrupt’ switch located on the front centre console. When this switch was in the default position of NORM (normal), it closed the circuit between the various circuit breakers and related components in each system to allow normal operation. If this switch was selected to INTR (interrupt), it opened every trim power circuit simultaneously and prevented all trim operation until the switch was returned to NORM. (This switch was guarded with a clear perspex cover. All switch labels were backlit).

The ATSB highlights that although the autopilot trim system utilises the alternate stabiliser trim motor, it is powered from the same source as the manual trim system (Pitch Trim circuit breaker) rather than the power source for alternate stabiliser trim (Pitch Trim Alternate circuit breaker). This detail was not explicitly covered in the *PC-12 Pilot’s Operating Handbook and Airplane Flight Manual* (POH/AFM) and RFDS pilots advised they were not aware of that design characteristic. As discussed in *Safety analysis*, this had a subtle effect on training/checking practices and interpretation of the pitch trim runaway emergency procedure.

A representative of Honeywell Aerospace, the designer and provider of in-service support for the pitch trim system, advised the ATSB that there was no documented instance of a runaway attributed to the alternate stabiliser trim circuit (Appendix A – blue lines).

**Figure 4: Pilatus PC-12/47E trim system features**




Source: Pilatus and ATSB

### *Pitch trim runaway warnings*

The pitch trim system monitored the power and control circuits for both trim motors and detected when there was power applied but no corresponding manual trim engagement, autopilot trim drive signals, or alternate stabiliser trim command. In any of those cases, the crew alerting system (CAS) produced the following effects:

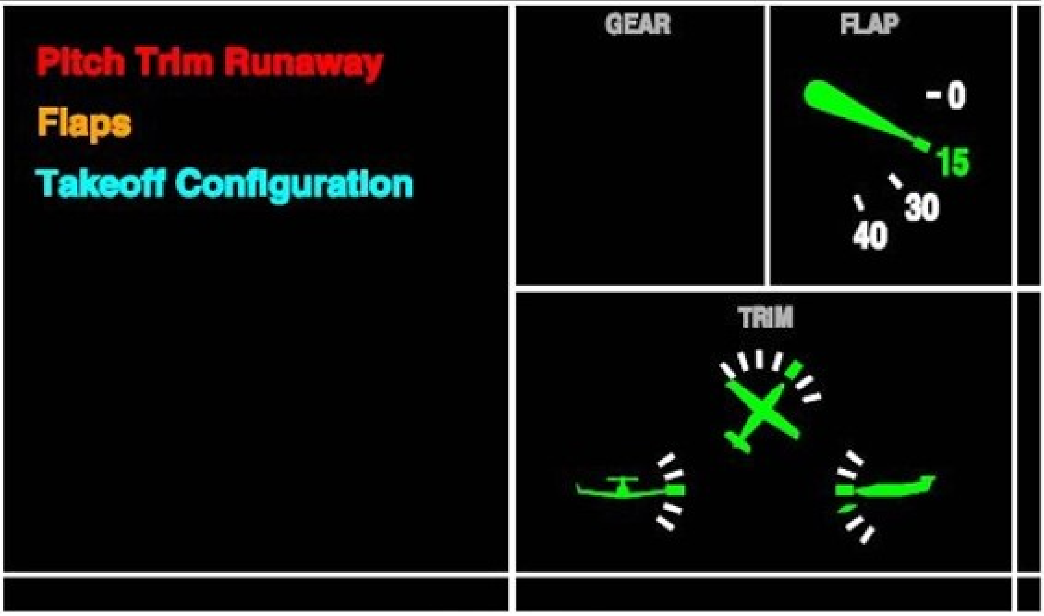
- master warning or caution light illuminated
- 'Trim Runaway' aural alert
- 'Pitch Trim Runaway' message displayed in the CAS window of the systems multi-function display (Figure 5).

Once the master warning or caution is acknowledged, the aural alert is cancelled but the message continues to display while the out-of-limit condition such as a trim runaway is operative. In the case of a malfunctioning relay in the manual trim system (such as this occurrence), the message will disappear if any of the following actions are carried out:

1. Manual trim engage switch on control wheel is activated
2. Trim Interrupt switch is selected to INTR
3. Pitch Trim circuit breaker is pulled open.

The ATSB notes that conditions 2 and 3 will cancel the message and stop a related runaway but condition 1 will only cancel the message without any effect on a runaway condition. The recorded data showed that the pitch trim runaway warning was cancelled and reactivated three times in the 32-second period after the initial warning. This was consistent with the pilot attempting to use the manual trim, which was ineffective in resolving the runaway.

**Figure 5: Sample multi-function display showing acknowledged CAS messages**




Source: Pilatus

### *Wing flaps*

The wing flap system is electrically actuated and controlled by a selector handle on the centre console to the right of the engine control quadrant. Located forward of the flap selector handle is a Flap Interrupt switch (Figure 4) that disables normal operation of the flap system and generates a 'Flap' caution message on the CAS if the switch is selected to INTR. Irrespective of subsequent switch selections, the flaps will not operate until reset on the ground.

In this occurrence, there was evidence from flight data of power being removed from the flap system at the beginning of the initial 16-second trim runaway event, consistent with the operation of the Flap Interrupt switch (see Figure 3 - dark blue trace coded as Flap Controller Fail).

Pilatus advised the ATSB that the Flap Interrupt switch was utilised in the original PC-12 wing flap design as part of the alternate flap switch circuit that allowed the pilot to correct a flap asymmetry. In the PC-12/47E model, there is no pilot access to the alternate flap switch and no requirement for the pilot to operate the remaining Flap Interrupt switch.

The ATSB notes that, as can be seen in Figure 4 (bottom right), the Flap Interrupt switch and Trim Interrupt switch appear to be the same type of switch and are located on the same panel, either side of the Alternate Stab Trim switch (refer to the following *Safety analysis* section).

## Aircraft operating procedures - Pilatus

### *Pilot's Operating Handbook and Quick Reference Handbook*

The primary reference for operation of the PC-12/47E is the *Pilot's Operating Handbook and EASA Approved Airplane Flight Manual* (POH/AFM) produced by Pilatus. In Section 3 Emergency Procedures, the general comments include the following guidance:

> Some situations require rapid action, leaving little time to consult the emergency procedures. Prior knowledge of these procedures and a good understanding of the aircraft system is a prerequisite for safe aircraft handling.

The emergency procedures included a sequential list of action items in case of a pitch trim runaway. These procedures were also presented in the *Quick Reference Handbook Emergency Procedures* (QRH) booklet produced by Pilatus and available in the cockpit for the pilot to consult as required and as circumstances permitted (Figure 6).

**Figure 6: Quick Reference Handbook Emergency Procedures – Pitch Trim Runaway**

**Pitch Trim Runaway**

Voice callout "Trim Runaway"

| | |
|---|---|
| **1. TRIM INTERRUPT switch** | **INTR** |
| **2. PITCH TRIM CB (Essential Bus LA1)** | **Pull** |
| **3. TRIM INTERRUPT switch** | **NORM** |

If trim runaway continues:

| | |
|---|---|
| **4. TRIM INTERRUPT switch** | **INTR** |
| **5. PITCH TRIM ALTN CB (Main Bus RA1)** | **Pull** |
| **6. PITCH TRIM CB (Essential Bus LA1)** | **Close** |
| **7. TRIM INTERRUPT switch** | **NORM** |

NOTE

Reduce speed if control forces are high.

The autopilot will disconnect when Trim Interrupt is operated. If the Pitch Trim has failed, the autopilot is not operative.

If main Stabilizer Trim has failed:

| | |
|---|---|
| **8. Pitch trim** | **Use ALTERNATE STAB TRIM** |

-------------------- END --------------------

Source: Pilatus

Pilots could also select this procedure as one of the electronic emergency checklists on the multi-function display. This operation required a number of button pushes to select the checklist and scroll through the items. RFDS did not advocate use of this feature and that practice was not a factor in this occurrence.

Pilatus advised that if item 1 of the procedure was carried out immediately following a pitch trim runway warning, the control forces would be acceptable and the pilot would be able to perform the subsequent actions without acute stress.

The ATSB noted that in the scenario where items 1-3 would neutralise a pitch trim runaway condition, the subsequent control forces experienced by the pilot could be uncomfortably high due to timing of the trim interrupt or changes to phase of flight and/or aircraft configuration. If that occurs, the pilot can only adjust pitch trim using the alternate stabiliser trim. The procedure, however, did not communicate that clearly and specified alternate stabiliser trim as item 8.

It should also be noted that item 8 will not be effective if the complete procedure is actioned in numerical sequence. In that case, action in accordance with item 5 to open the Pitch Trim Alternate circuit breaker disconnects power from the alternate stabiliser pitch trim circuit. As the pilot in this occurrence found, any subsequent attempts to use the alternate stabiliser trim switch in accordance with item 8 will be futile.

### *Supplementary information*

In February 2017, Pilatus issued *Safety Information Letter* (SIL) 003 to all customers, operators and service centres as an ‘Important reminder of procedures and operations of PC-12 (all models) when encountering a trim runaway condition.’ For reference, a copy of this letter is at Appendix B.

Some points from the letter that are relevant to this occurrence:

> In the case of a trim runaway condition, as an immediate action, activate the guarded “Trim Interrupt” switch (refer to POH Section 3).
>
> Hands-on training reduces the activation time and minimizes the risk of erroneously activating the “Flaps Interrupt” system switch (which cannot be reset in-flight).
>
> By pulling its associated Circuit Breaker (CB), the affected trim motor will be isolated before the pilot can attempt to regain control of the unaffected systems (refer to POH Section 3).
>
> To regain control of the unaffected systems, simply reposition the “Trim Interrupt” switch to NORM (refer to POH Section 3).
>
> A reduction in airspeed will significantly reduce the existing out-of-trim forces and will help the pilot regain full control of the aircraft (refer to POH Section 3).
>
> The PC-12 trim system is designed to assure that the pilot does not have to counteract continuous or excessive control forces after encountering a trim runaway. In case of a runaway on one of the pitch trim motors, the remaining one can be used to regain normal control forces.

Pilatus advised the ATSB that RFDS confirmed receipt of the transmittal notice for SIL-003 on 7 March 2017. Since then, the SIL has been listed as one of the additional technical information items on the Pilatus document portal accessible to RFDS. Pilatus noted that the SIL is also publically available on their website.

The ATSB notes that RFDS did not have a record of having received or formally considered the operational implications of this letter. One of the training/check pilots recalled the letter and advised that RFDS incorporated the pitch trim runaway response from the QRH into check flights. The content of the letter and potential effect in this occurrence is considered in the following *Safety analysis* section.

### *Normal procedures*

As part of the POH/AFM Normal Procedures section, the daily Pre Flight checklist included items to confirm that the Trim Interrupt and Flap Interrupt switches were in the NORM/GUARDED positions. These were visual checks that did not involve operation of the switches. RFDS normal procedures were consistent with the POH/AFM.

For PC-12 aircraft operated under Transport Canada airworthiness approval, Pilatus specified a daily check of the pitch trim interrupt system in the 'Before Starting Engine Procedure'. This originated in 1997 as part of the aircraft certification review process by Transport Canada. Transport Canada considered that the trim interrupt system was the sole means of disconnection for an uncommanded runaway and the system failure analysis did not take into account all of the factors. Pilatus responded by including a periodic check of the trim interrupt function in airworthiness limitations and integrating the daily check into the Canadian-specific POH/AFM.

## Aircraft operating procedures – RFDS

The RFDS *Operations Manual* specified general aircraft operating procedures and PC-12 operating procedures. As a general principle, RFDS required pilots to comply with all requirements, instructions, procedures, or limitations in the applicable POH/AFM and QRH.

In an emergency, pilots were required to action the defined recall items from memory and then refer to the appropriate written procedures for confirmation. The subsequent actions were then to be actioned/confirmed as necessary and any notes/warnings reviewed. It was acknowledged that in some circumstances, pilots might need to continue subsequent actions from memory.

The pilot advised that the physical demands of counteracting the serious out-of-trim condition did not allow for review of the procedure in the QRH booklet. In context, this was an unavoidable constraint of single-pilot operation and was not considered to be a factor in the occurrence.

From March 2019 onwards, the RFDS PC-12 operating procedures nominated the first four items of the Pitch Trim Runaway procedure as recall items. These items were recorded in the operations manual and were the same as the POH/AFM and QRH except for item 3 which incorporated a conditional phrase:

> 3. TRIM INTERRUPT switch if trim runaway continues … NORM

In the POH/AFM and QRH, this conditional followed item 3 and applied to item 4 onwards rather than item 3.

Item 3, as presented by RFDS, could be interpreted to mean that the power to the trim systems was only to be reinstated if the trim runaway continued. However, the trim runaway could not continue without the reinstatement of power through the Trim Interrupt switch (and almost certainly the Pitch Trim circuit breaker), so the phrasing was nonsensical. In the context that the trim interrupt remained in NORM, and the POH/AFM/QRH procedures were primary references, it is unlikely that the procedural inconsistency had any effect on this occurrence.

RFDS advised that the recall items for emergency procedures had recently been added to their PC-12 operating procedures as an update to reflect current practices. They were aware that the RFDS pitch trim runaway procedures varied from the POH/AFM and QRH as a result of inaccurate transcription but this had not been communicated to pilots. This was corrected after the occurrence.

## Pilot training and checking - RFDS

### *Training and checking framework*

RFDS held a Civil Aviation Safety Regulation (CASR) Part 141 certificate and operated a CASA-approved Training and Checking organisation under Civil Aviation Regulation (CAR) 217. The Part 141 certificate authorised RFDS to conduct the required class rating flight training and flight review to qualify pilots for the PC-12 aircraft type. (RFDS referred to this as conversion training.) The CAR 217 approval authorised RFDS to conduct recurrent training and checking including regular operator proficiency checks (OPCs).

The first stage of the RFDS PC-12/47E ‘conversion training’ was a 6-day ground school facilitated by an experienced PC-12 instructor in accordance with a Facilitators Guide. Reference material included the POH/AFM, QRH, engineering training manual, PowerPoint presentations, videos, cockpit mock-up, components, and an aircraft. Information about the pitch trim system was available from the POH/AFM and a guided inspection of an aircraft. Learning assessments were carried out during and at the end of the course.

The second stage of PC-12/47E conversion training was flight training in the aircraft in accordance with a flight training syllabus. This was usually carried out over 5 flights and approximately 12 flight hours. The syllabus included review of CAS warnings/cautions such as Pitch Trim Runaway and use of the QRH. A flight review was incorporated into this training.

Following conversion training, pilots completed 50-100 hours of line oriented flight training (LOFT) with a training/check pilot or supervisory pilot in the aircraft. RFDS specified a number of competency items and discussion topics to be covered during LOFT. These did not specifically include Pitch Trim Runaway.

When pilots had completed all of the LOFT elements and were considered ready, a check pilot conducted a check-to-line assessment consisting of at least two sectors, one night sector, and a minimum of two instrument approaches. RFDS specified a number of elements to be assessed during normal operation and some emergency/abnormal scenarios. These did not include Pitch Trim Runaway.

Once a pilot was checked to line, recurrent checking consisted of two checks in any 365-day period. One of those checks was an instrument proficiency checks (IPC) to satisfy the regulatory requirements of CASR Part 61. The alternate check was an OPC that consisted of a technical quiz and flight sequences to assess pilot response to at least four emergency scenarios. In addition, an annual line check was carried out to allow assessment of a medical flight sector.

### *Training and checking practices - pitch trim runaway*

In the RFDS training and checking framework, it was a requirement that the emergency procedures in the QRH were addressed during PC-12 conversion training, check-to-line, OPC, and as required for IPC. RFDS identified six critical manoeuvres with an increased level of threat (such as emergency descent and engine failure after take-off) that required specific assessment during OPCs. Other emergencies, such as Pitch Trim Runaway, could be addressed in an OPC at the discretion of the check pilot.

Pilatus did not recommend a method for in-flight practice of Pitch Trim Runaway, other than the guidance provided in Safety Information Letter SIL-003 that there was a benefit to hands-on training for correct operation of the Trim Interrupt switch. Although RFDS specified techniques for their training/check pilots to use in simulating some emergencies such as engine failures, there was no documented method for pitch trim runaways. The ATSB derived information about practices from interviews with RFDS training/check pilots including those involved in the pilot’s training and checking.

It was not possible to replicate a pitch trim runaway in a serviceable aircraft nor would that be desirable in-flight. As such, it was common practice for RFDS training/check pilots to introduce a pitch trim runaway scenario by annunciating the warning callout ‘Trim Runaway’ and advising of the associated CAS warning message. The physical effects might be described by the training/check pilot, or represented either by using the alternate stab/manual trim to provide trim input or by application of a progressive force to the control column.

Training/check pilots expected pilots to respond by recalling and following the Pitch Trim Runaway procedure, starting with item 1 - identification of the Trim Interrupt switch. There was variation as to whether the switch was actually selected to INTR or whether this action was indicated in accordance with the touch drill principle. At this point, the training/check pilot would generally stop trim inputs or release force on the control column, as the case might be. The ATSB notes that trim interruption will stop trim inputs but will not alleviate control forces developed to that point.

If the training/check pilot initiated the pitch trim runaway on final approach, the likely outcome was a landing without a requirement for further actions from the emergency procedure. In all other situations, training/check pilots would expect that the pilot would proceed with further items of the procedure. For actions involving circuit breakers (items 2, 5, 6), it was a general principle that these were not pulled opened during practice of emergencies to prevent inducing problems in electrical systems. As such, the circuit breaker action items would be effected through touch drills or referenced by the pilot in discussion with the check pilot.

Although the end-point of a pitch trim runaway scenario was not defined and could vary according to the operational context, it was common for check pilots to facilitate the exercise so the complete procedure was addressed. This was consistent with a general misunderstanding in RFDS that the autopilot trim was powered through the Pitch Trim Alternate circuit breaker (rather than Pitch Trim circuit breaker). Consequently, it was perceived that items 4 onwards of the emergency procedure (Figure 6) may be required to address a malfunction in the autopilot trim system. On completion of the procedure, the check pilot could restore normal trim operation or might advise the pilot to use the alternate stab trim for trim operation during the next phase of flight.

In assessing pilot response to a pitch trim runaway scenario, training/check pilots were focussed on pilot recall of the QRH emergency procedure items and correct identification/confirmation of the applicable switches and circuit breakers. The representation of pitch trim runaway and effects of indicative actions did not consistently reflect actual behaviour of an aircraft during such an emergency.

The pilot of this occurrence expected that the control problems would be rectified when the Trim Interrupt switch was selected to INTR. If the pilot had promptly made that selection as intended, the control loads would have been manageable but the loads would not have been alleviated.

Following the occurrence, RFDS training/check pilots noted that the power control lever could obscure the Trim Interrupt switch when the lever was in the maximum position (used for take-off and initial climb). The ATSB confirmed that this was the case if the pilot’s seat was adjusted to provide a standardised field of vision with reference to the visual alignment device.

## Pitch trim runaway occurrences

### *RFDS Western Operations*

RFDS advised of seven pitch trim runaway events involving their PC-12 aircraft, including this occurrence. The ATSB requested data about these events and compiled the following table. For context, please note that all of the aircraft were PC-12/47E NG models and each of the events involved different registrations.

**Table 1: RFDS Western Operations Pilatus PC-12/47E pitch trim runaway events**

| Ref | Occurrence date | Aircraft hours | Occurrence description | Fault |
|---|---|---|---|---|
| 1. | 10 June 2013 | N/A | Single pilot operation – Day.<br>On approach at 500 ft, pitch trim runaway nose-up.<br>QRH recall items including Trim Interrupt carried out.<br>Nil use of Alternate Stab Trim. Reported use of manual trim.<br>Missed approach, normal landing. | Manual trim relay. |
| 2. | 5 May 2015 | 7,631 | Two pilot (LOFT) operation - Day.<br>On approach at 300 ft, pitch trim runaway nose-up.<br>QRH first recall item – Trim Interrupt only carried out (due context).<br>Nil use of Alternate Stab Trim – not applicable.<br>Normal landing. | Manual trim relay. |
| 3. | 17 February 2017 | 3,821 | Single pilot operation - Day.<br>On final approach, pitch trim runaway nose-down.<br>QRH recall items including Trim Interrupt carried out.<br>Alternate Stab Trim switch used to adjust trim.<br>Normal landing. | Manual trim relay. |
| 4. | 22 August 2018 | 11,912 | Two pilot (LOFT) operation - Day.<br>On downwind approach, pitch trim runaway nose-up.<br>QRH recall items including Trim Interrupt carried out.<br>Nil use of Alternate Stab Trim.<br>Normal landing. | Trim adaptor (autopilot related). |
| 5. | 19 January 2019 | 3,431 | Single pilot – Day.<br>On descent with autopilot on, pitch trim runaway.<br>QRH recall items including Trim Interrupt carried out plus Pitch Trim – Alternate circuit breaker pulled.<br>Nil use of Alternate Stab Trim.<br>Diversion and normal landing. | Trim adaptor (autopilot related). |
| 6. | 14 April 2019<br>(occurrence) | 7,377 | Single pilot – Night.<br>After take-off, pitch trim runaway nose-down.<br>QRH recall items carried out but Trim Interrupt mis-selected. Control difficulties. Further items.<br>Nil use of Alternate Stab Trim.<br>Return for flapless landing with control difficulties. | Manual trim relay. |
| 7. | 3 August 2019<br>(post occurrence) | 12,272 | Two pilot (LOFT) operation - Day<br>After take-off, pitch trim runaway nose-down.<br>Recall items including Trim Interrupt carried out.<br>Alternate Stab Trim switch used to adjust trim.<br>Return for normal landing. | Manual trim relay. |

The ATSB reviewed the occurrence descriptions and maintenance records for the five pitch runaway events recorded before the occurrence, and interviewed the pilots involved except for one trainee pilot who was no longer with RFDS.

In one of those events (Ref. 2), the aircraft was on short final and the pilot operating under supervision carried out item 1 of the procedure then landed the aircraft. The training/check pilot advised the ATSB that the aircraft was controllable and there was no requirement or time to action further items of the procedure before landing.

In another event (Ref. 3), the pilot was on approach and the pilot actioned the recall items followed by appropriate use of the Alternate Stab Trim switch. The pilot advised the ATSB that knowledge of the system was gained from RFDS training/checking and from self-study.

In the other three events (Ref. 1, 4, 5), the same pilot was involved as pilot in command including one event under supervision of a training pilot. The pilot involved in the three events had joined RFDS in 2012. Prior to that, the pilot was employed as a corporate jet pilot for 3 years. In 2019, the pilot's total experience was 11,900 hours including 3,000 hours on the PC-12. These three events are noteworthy in that the Alternate Stab Trim switch was the only means available to adjust trim but was not utilised following the recall items, and there were anomalies in the pilot in command's technical understanding of the events and pitch trim system.

The pilot response to the first pitch trim runaway was consistent with the recall items of the procedure but the pilot did not realise that manual trim was consequently inoperative and was not aware that the Alternate Stab Trim could be used for trimming. In response to the two other events, the pilot continued the emergency procedure beyond the recall items and in at least one case pulled the Pitch Trim Alternate circuit breaker. That was not consistent with the recorded fault and it is not clear if and how the pilot trimmed the aircraft as reported.

### *RFDS Central Operations*

The ATSB requested pitch trim runaway occurrence data from RFDS Central Operations (RFDSCO), as another operator of similar PC-12 aircraft. RFDSCO advised that there was no record of any verified pitch trim runaway events involving their PC-12 aircraft in the 9 years prior to the occurrence that such data had been recorded. For context, RFDSCO operate a mix of PC-12/47E NG aircraft and earlier series aircraft.

### *ATSB database*

The ATSB conducted a search of the occurrence database for pitch trim runaway events involving the PC-12 aircraft type and a comparative aircraft type, the Beechcraft/Raytheon/Textron King Air. Apart from this occurrence, no pitch runaway events for either type were recorded in the ATSB database.

As reported in a previous section, RFDS identified six other pitch trim runaways involving their PC-12 aircraft. These were not reported to the ATSB.

In response to a query from the ATSB, RFDS advised that the other pitch trim runaways were considered to be routine defects and handled via the incident reporting and/or maintenance reporting systems. Each of the events recorded in the incident reporting system were reviewed by the Head of Flying Operations and considered to have been handled appropriately.

The Transport Safety Regulations 2003 stipulate reporting of certain events to the ATSB. For a non-air transport operation such as RFDS, the use of any procedure for overcoming an emergency was prescribed as a routine reportable matter. The ATSB considered that a pitch trim runaway required a pilot to action the applicable emergency procedure and was therefore a routine reportable matter.

### Pilatus records

At the request of the ATSB, Pilatus provided pitch trim runaway occurrence data for the PC-12 aircraft type. Pilatus recorded 56 pitch trim runaway events world-wide between 1999 and 2019. These occurred in all phases of flight and included at least 45 events involving the PC-12/47E model.

In 47 of the pitch trim runaway events, the recorded maintenance action was replacement of one or both of the manual trim relays or the (autopilot-related) trim adapter unit. None of the recorded maintenance actions were applicable to the alternate stabiliser trim circuit.

The amount of detail in the event descriptions varied and some did not provide information about pilot actions. For 10 events, there was recorded alternate stab trim use by the pilot and for three events, the pilot reported having insufficient time to action the emergency procedure before landing. In one event, the pilot tried to use the alternate stab trim but it did not operate.

Where pilot action was reported, it was common for the Trim Interrupt switch to be selected with associated stopping of the pitch trim runaway. There were no reports of pilot mis-selecting the Flap Interrupt switch instead of the Trim Interrupt switch.

## Instructions for Continuing Airworthiness - Pilatus

As the aircraft manufacturer and type certificate holder, Pilatus produced specifications and instructions for continued airworthiness of the PC-12 aircraft type. Those instructions included periodic functional checks of the pitch trim system and procedures for troubleshooting and component replacement. Up to the month before the occurrence, there were no specific maintenance requirements for the manual trim system relays or trim adapter unit. As such, the relays remained in service 'on-condition' until a defect was detected.

In March 2019, Pilatus issued Service Bulletin SB 27-024 to provide for replacement of the trim adapter unit that used electro-mechanical relays (auto pitch trim) with a unit that uses solid-state relays. At the time of the occurrence, Pilatus had prepared Service Bulletin SB 27-023 to provide for replacement of the two electro-mechanical relays in the manual pitch trim system with one solid-state relay. This was not issued until March 2020 due to limited parts availability.

Pilatus advised that the two Service Bulletins were developed to address a known reliability issue with the electro-mechanical relays. Due to frequent switching at their load limits, the relay contacts had a decreased operational life of approximately 25,000 cycles.

## Examination of PC-12 pitch trim system relays

The electro-mechanical relays used in the PC-12 pitch trim system were a two-pole, double-throw design. Each pole consisted of a common terminal that was switched between a normally open contact and a normally closed contact. For this installation, only one pole was utilised.

### Defective relay removed from VH-OWJ

The ATSB examined the manual pitch trim DOWN relay (identification number K161E2) removed from VH-OWJ to characterise the failure mode and assess the implications for continuing airworthiness. A visual inspection of the relay did not identify any anomalies (Figure 7). The markings were consistent with the specifications.

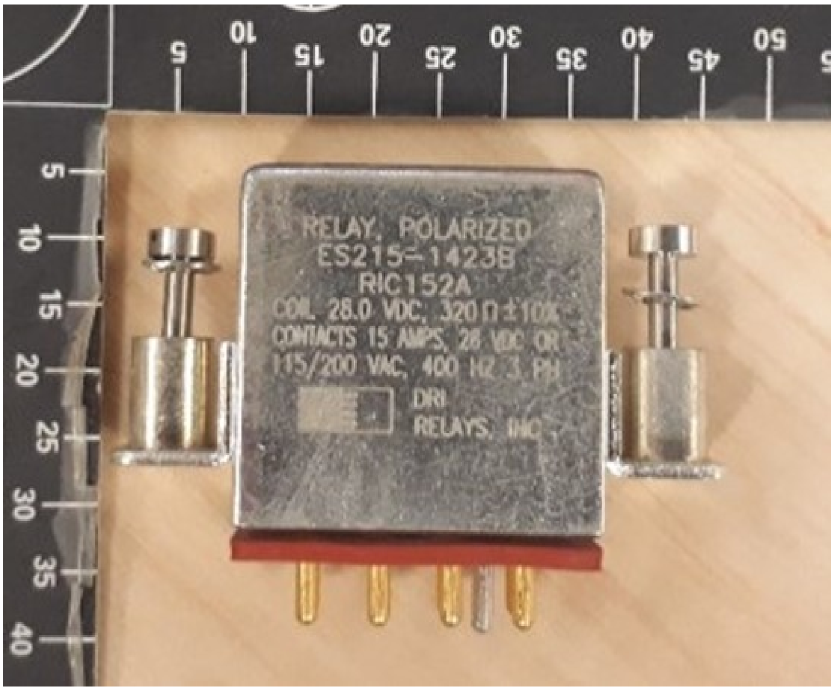
To record the internal configuration of the relay, the ATSB arranged for an x-ray before the relay was altered (Figure 8). This showed that for both poles of the relay, the normally open contacts were closed and the normally closed contacts were open. Electrical continuity checks of the pins were consistent with that anomalous configuration.

The ATSB detached the casing from the base of the relay to examine the internal mechanism (Figure 9). A visual inspection of the mechanism confirmed the anomalous configuration of the contacts and revealed the failure type for the normally open contacts.

For the relay pole connected to the pitch trim circuit (active), the normally open contact was melted and fused close. There was sooting on surfaces near the contacts and black contaminant from the black caps that covered the contacts. Beads of gold-coloured metallic material was observed on surfaces near the contacts. As a result of the fused contact, the other contacts were fixed in anomalous positions.

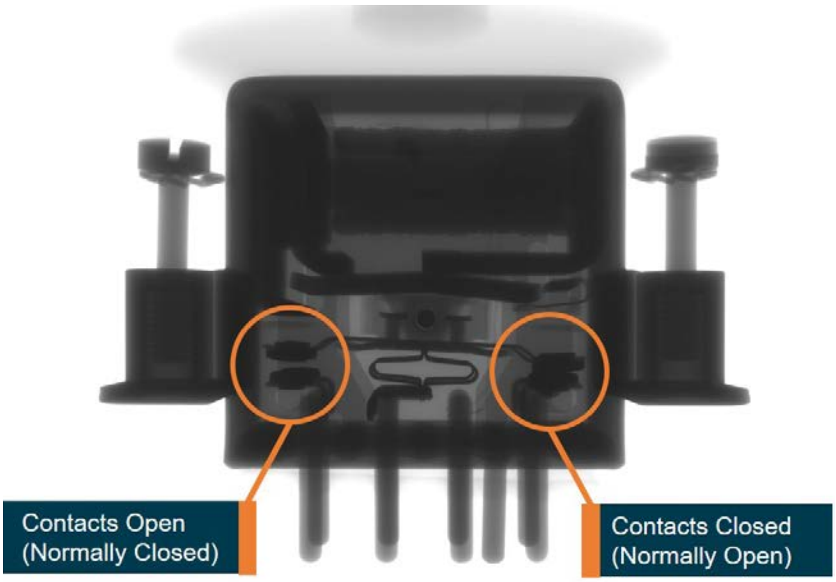
The relay manufacturer advised the ATSB that the condition of the contacts was consistent with a significant high-energy event that occurred while the relay was energised. The melting and welding of the contacts without circuit breaker activation is indicative of a short-duration high-current event such as a lightning strike. It was not possible for the manufacturer to determine the root cause of the relay failure.

**Figure 7: External condition of defective relay**




Source: ATSB

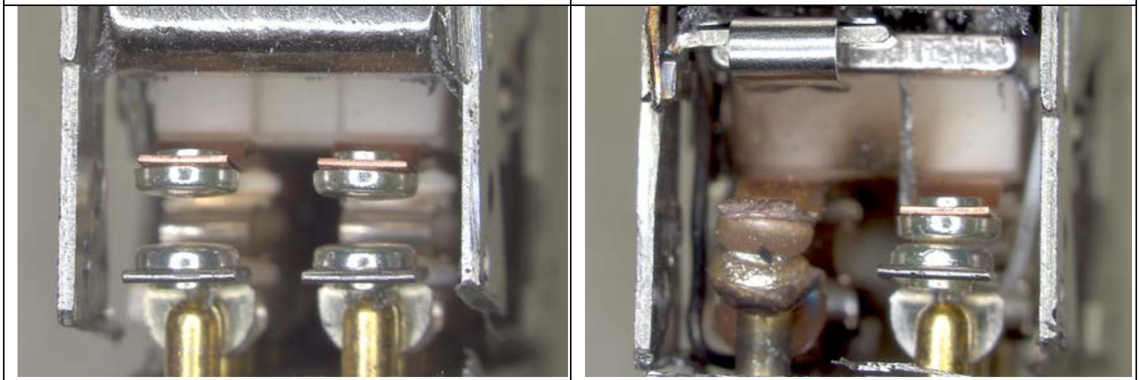
**Figure 8: X-ray of defective relay showing anomalous configuration of the contacts (circled).**



Source: ATSB

**Figure 9: Opposite end views of relay mechanism showing the two sets of anomalous contact conditions**

| a. Contacts Open (Normally Closed) | b. Contact Fused & Contact Closed (Normally Open) |
| --- | --- |



Source: ATSB

### *Other relay removed from VH-OWJ*

The ATSB obtained and examined the manual pitch trim UP relay (identification number K161D2) from VH-OWJ. This relay was installed in the aircraft at the time of the occurrence and was functioning normally at the time of removal.

A visual inspection of the relay did not identify any anomalies and the markings were consistent with the specifications. The ATSB detached the casing from the base of the relay to examine the internal mechanism.

The active normally-closed contacts showed a localised build-up of metallic material on one contact surface (pimple-shaped) with corresponding loss of material from the other surface. This was consistent with electrical arcing.

### *Defective relay from other PC-12*

The ATSB obtained and examined the manual pitch trim DOWN relay (identification number K161E2) from the RFDS aircraft that sustained a trim runaway on 3 August 2019 (Table 1, item 7).

A visual inspection of the relays did not identify any anomalies and the markings were consistent with the specifications. The ATSB detached the casing from the base of the relay to examine the internal mechanism.

The internal condition of the relay was similar to the defective relay from VH-OWJ. The active normally-open contact was melted and fused close. There was sooting on surfaces near the contacts and beads of gold-coloured metallic material was observed on surfaces near the contacts. As a result of the fused contact, the other contacts were fixed in anomalous positions.

The active normally-closed contacts showed localised material transfer that was similar to that observed to contacts in the manual pitch trim UP relay from VH-OWJ.

## PC-12 Pitch trim defect reports

The ATSB provided details of the relay examination and analysis to CASA. They conducted a search of the CASA Defect Reporting Service (DRS) database for reports of defects in the PC-12 autopilot and flight control systems. This identified a number of reports including one report of a faulty pitch trim adapter (to a non-RFDS aircraft). No reports of manual pitch trim relay defects were identified.

For aircraft maintained under the Civil Aviation Regulations, it was a requirement that major defects be reported to CASA immediately. This included defects that caused, or that could cause, a control system failure. The list of examples published by CASA included serious malfunction of flight controls without specifying any types.

CASA uses defect reports as a means of identifying trends in design and maintenance reliability for the benefit of aviation safety. Reports are collected by CASA and maintained in a database. It is of benefit to both CASA and the aviation industry that the database contains accurate and relevant information. From this database, information may be:

- obtained to provide reliability statistics and trend monitoring of aircraft, engines, propellers, systems and components - CASA shares this information with other regulatory authorities
- used as a basis for development or review of an Airworthiness Directive (AD)
- used for the development of other advisory publications, such as Airworthiness Bulletins
- used for other appropriate regulatory purposes.

RFDS advised that no defect reports were submitted to CASA in relation to the malfunctions that resulted in pitch trim runaway events. This practice was based on the definition of a major defect as that which affects the safety of an aircraft or cause the aircraft to become a danger to persons or property. As there were secondary systems to manage a pitch trim runaway, RFDS did not consider the associated malfunctions to be major defects.

The ATSB was unable to establish if relay malfunction with pitch trim runaway was classified as a major defect as described in the Civil Aviation Regulations. Nevertheless, operators are encouraged to submit reports of PC-12 pitch trim defects to the DRS to facilitate CASA monitoring of continuing airworthiness data.

# Safety analysis

In the early stages of a medical transport flight, the pilot was confronted with a pitch trim runaway emergency condition. Despite pilot actions intended to stop the runaway, the runaway was not interrupted and the pilot struggled to control the aircraft for the rest of the flight. The pilot made a good decision to enlist the assistance of the doctor and managed to coordinate their inputs to land the aircraft.

The pilot was qualified to conduct the flight and had about 7 months experience of similar operations in the PC-12 type. This patient transfer from Merredin was not a high priority flight and the aircraft was serviceable for the departure. Although the pilot was on a night shift and the take-off from Merredin was just after midnight, there were no indications of fatigue.

The safety analysis following seeks to explain how the event developed and identify the important safety considerations.

## Technical failure and warnings

During normal operation of the PC-12 aircraft with the autopilot off, the pilot seeks to minimise control wheel forces by intermittently selecting the engagement switch in conjunction with the up/down switch on the control wheel. These actions energise the applicable relay and power the trim motor to move the horizontal stabiliser as directed. When the pilot releases the switches, the control circuit de-energises the applicable relay with the usual effect of opening the power circuit to the manual trim motor and stopping trim movement.

Soon after take-off from Merredin, the pitch trim system continued to operate in a nose-down direction without pilot input or autopilot commands because of a malfunctioning relay in the manual (main pilot-engaged) stabiliser trim system. The trim system immediately detected a pitch trim runaway and triggered the applicable Crew Alerting System (CAS) warnings.

The Master Warning, ‘Trim Runaway’ callout, and the Pitch Trim Runaway message on the Multi-function Display (MFD) provided an effective alert as to the nature of the emergency and correlated with the anomalous control forces experienced by the pilot. In this fully electric trim system (no trim wheel), the other indication available to the pilot was the trim indicator on the MFD.

As was typical for aircraft such as the PC-12, the CAS warnings did not specify the malfunctioning circuit/components or the required actions. In such cases, the pilot is required to action the applicable emergency procedure to stop the runaway, identify the affected circuit, disable the affected circuit, and utilise the unaffected circuit to make any required trim adjustments.

## Initial pilot response

In response to the CAS warnings, the pilot sought to carry out the first recall item of the Pitch Trim Runaway emergency procedure by selecting the Trim Interrupt switch to INTR (interrupt). The pilot managed to action this item about 6 seconds after the warnings activated. However, recorded flight data shows that the pilot inadvertently selected the Flap Interrupt switch to INTR rather than the Trim Interrupt switch and did not identify the mis-selection.

Common aviation operational practice, also advocated by RFDS, involves an ‘identify-confirm-action’ process to minimise the inadvertent selection of wrong switches and buttons. In that context, the ATSB considered the following factors that might have influenced the pilot to mis-select the interrupt switch:

- emergency flight control condition at low altitude on dark night
- visibility of the Trim Interrupt switch and label
- similar location and appearance of the two interrupt switches

- lack of familiarity with operating the Trim Interrupt switch during training/checking.

In the situation where there is sudden onset of an emergency condition affecting control forces at low altitude on a dark night, it is natural for the pilot to feel a sense of concern and urgency. This might have been heightened by unfamiliarity with the scenario that could not be realistically simulated in the aircraft. As such, it would be expected that the pilot would be experiencing some level of stress.

As the trim runaway progressed, the pilot's attention was primarily focussed on controlling the aircraft and counteracting the developing pitch-down forces with both hands on the control wheel. Given the pilot reported that any hand movements from the control wheel were quick, it is likely that the pilot allocated a low level of attention to identifying and confirming the appropriate interrupt switch.

During take-off and initial climb the power lever was in a forward position. In a pilot's normal field of view, the power lever obscured the Trim Interrupt switch but not the Flap Interrupt switch. This rendered the Flap Interrupt switch as relatively more accessible and in the circumstances, at higher risk of being mis-selected. At the same time, the cockpit lighting was dimmed for the dark-night take-off in accordance with standard practice and that unavoidably reduced the readability of the backlit switch labels.

The Trim Interrupt switch and Flap Interrupt switches were both located in the centre console and appeared to be the same type of switch with a similar function (Figure 4 bottom right). Although the switches were differentiated by being located either side of the Alternate Stab Trim switch, and the Flap Interrupt switch was located forward of the Flap Selector Handle, the similarities increased the risk of mis-selection.

Training and checking practices were generally oriented towards touch drills and it was unlikely that the pilot was familiar with physical operation of the Trim Interrupt switch. Given the Pilatus advice that hands-on training minimises the risk of erroneously activating the Flap Interrupt switch, it is likely that a higher level of familiarity would have assisted the pilot.

The ATSB considered the contextual factors to identify those that increased risk and might have contributed to the occurrence. Although the operating environment and visibility of the trim interrupt switch increased the degree of difficulty for the pilot, those elements are generally unavoidable and were not considered to be safety factors. The risk associated with the other two factors —interrupt switch similarities and RFDS training/checking practices—is discussed in the following section.

Following inadvertent selection of the Flap Interrupt switch, there were indications that the results were contrary to the pilot's intention—the pitch trim continued to operate and the runaway warning message remained on the CAS display. Later, the pilot also noticed the 'Flap' caution message in association with attempted flap extension. However, the pilot did not associate those indications with the mis-selection.

One of the reasons for this was the surprise and confusion resulting from non-alleviation of the control forces in response to the attempted trim interrupt. That was a natural response that was probably influenced by the inconsistent representation of trim interrupt effects in training/checking. The pilot experienced a high level of stress that adversely affected the pilot's ability to carry out the next item immediately (which would have stopped the runway) and to problem-solve.

Research has confirmed common-sense understanding that situations involving acute stress, such as an out-of-control aircraft, are particularly harmful to higher order cognitive processes, such as decision-making (Dismukes, Goldsmith and Kochan, 2015). Acute stress impairs decision-making, leading to the consideration of fewer options and an increased tendency to make biased decisions. Attention becomes difficult to control, and tends to be easily distracted by alarms and other threatening signals. Anxious thoughts interfere with the resources needed to understand and resolve the emergency situation.

A potentially complicating factor in the pilot's response was the momentary cancellation and recycling of the CAS warnings from pilot use of the manual trim switches. This characteristic was only evident because of the unsuccessful trim interrupt and was a subtle indication that manual trim was the affected circuit that had not been de-powered. The pilot was not expected to have that level of implicit systems knowledge and did not consider the possibility of switch mis-selection. In that case, the unexpected aircraft behaviour was confusing and treated as a symptom of the underlying technical problem.

As a consequence of the Trim Interrupt remaining in NORM (normal) due to the inadvertent selection of the Flap Interrupt switch, and the Pitch Trim circuit breaker initially remaining closed, power continued to be supplied through the malfunctioning relay to the manual stabiliser trim motor. The pitch trim reached the full nose down position 16 seconds after the runaway started. This created serious control difficulty for the pilot, which was exacerbated by the increasing airspeed.

## Airspeed management

From the start of the pitch trim runaway, as the manual trim motor moved the horizontal stabiliser to a higher angle, the stabiliser produced progressively more lift that translated to nose-down force. The pilot was physically unable to fully counteract that force with the control wheel and the aircraft nose lowered. In the consequent descent, the airspeed increased with an associated increase in stabiliser lift and nose-down force. The pilot found this harder to counteract and the aircraft nose lowered further. This was a reinforcing cycle that reoccurred during the sequence relative to the counteracting effort applied to the controls.

In addition, when the pitch trim runaway began, the power lever was in the maximum engine torque position specified for take-off and initial climb. It remained in that position for the next 22 seconds and was a significant contributor to the initial airspeed increase. The airspeed reached 210 kts with increased risk of descent into terrain before the pilot reduced engine torque and airspeed to partially alleviate the control loads and arrest the descent.

The Pitch Trim Runaway procedure included a note after item 7 advising pilots to reduce speed if the control forces are high. In the circumstances, the most effective means to reduce airspeed was to reduce engine torque.

The ATSB considered that the time taken by the pilot to reduce engine torque after the pitch trim runaway warning was associated with the pilot's cognitive and physical workload as discussed in the previous section. It is likely that the pilot was prioritising aircraft control and conduct of emergency procedures, and did not perceive an immediate need to reduce engine torque. In addition, as the trim runaway developed, it became more difficult to remove a hand from the control wheel to adjust the power lever.

For flight control emergencies such as out-of-trim conditions, there is an imperative to maintain control while resolving the technical problem. A critical factor for pilots to consider is control of airspeed and associated engine power.

## Continuation of emergency procedure

As control loads allowed, the pilot managed to carry out item 2 of the emergency procedure by opening the Pitch Trim circuit breaker. This de-powered the circuit with the malfunctioning relay and manual actuator motor so that the fault condition was effectively neutralised. As the trim had already run to full nose down (due to not stopping when the pilot selected the wrong interrupt switch), the only indication that this action had been successful was removal of the CAS message from the MFD.

The pilot then sought to carry out item 3 of the procedure to return the Trim Interrupt switch to NORM. It is assumed that the pilot returned the Flap Interrupt switch to NORM instead of the Trim Interrupt, consistent with earlier mis-selection of the Flap Interrupt switch. This did not have any further effect as the Trim Interrupt switch remained in NORM throughout the flight and the wing flaps remained inoperative irrespective of subsequent switch selections.

At this point, the pilot was required to make a decision according to the status of the trim runaway. With the fault condition neutralised and power available to the operable trim circuits, the pilot could have adjusted the pitch trim using the Alternate Stab Trim switch and regained full control of the aircraft. That would have been consistent with the intent of the procedure, although it was listed as item 8 in the procedure. However, the pilot did not use the alternate stab trim and decided to proceed with further items of the procedure, consistent with the condition 'If trim runaway continues'.

The pilot opened the Pitch Trim Alternate circuit breaker as per item 5 and closed the Pitch Trim circuit breaker as per item 6. This had dual adverse effects. First, power was removed from the operative alternate trim system and second, power was restored to the malfunctioning relay and manual trim motor for a short period. (This reactivated the warnings and prompted re-opening of the Pitch Trim circuit breaker.) As a consequence of opening the Pitch Trim Alternate circuit breaker (item 5), when the pilot tried to use the Alternate Stab Trim as per item 8 of the procedure, the circuit was inoperative and this did not have any effect.

While maintaining partial control of the aircraft in difficult circumstances, the pilot managed to neutralise the malfunctioning relay in the early stages of the sequence. However, the pilot missed a critical opportunity to use the Alternate Stab Trim switch to recover control of the aircraft. By continuing the emergency procedure from item 4 onwards, the pilot disabled the operative trim system and prolonged the serious control difficulties.

The ATSB acknowledges that the serious difficulties experienced by the pilot in this phase of the emergency resulted from non-selection of the Trim Interrupt switch and consequent full nose-down pitch trim before the Pitch Trim circuit breaker was pulled. In addition to the extreme flight loads and deleterious effects of acute stress on decision-making, another consequence was absence of trim operation as an indication of runaway status. As such, when the pilot was required to assess the effect of recovery actions, the only effective indicator was activation/cancellation of the Pitch Trim Runway CAS message.

Irrespective of the ineffective actioning of item 1 of the emergency procedure, the subsequent actions required for recovery of control—items 2, 3 and 8—were unchanged. The pilot, however, did not have capability to resolve the out-of-trim condition, which relied in part on resources provided by Pilatus and training/checking provided by RFDS. These aspects are discussed in following sections.

The ATSB notes that pilot capability in this aircraft-specific context should not rely on certain levels of total aeronautical experience levels or operational experience on comparative aircraft types.

## Trim Interrupt and Flap Interrupt switches

The pilot's mis-selection of the Flap Interrupt switch in place of the Trim Interrupt switch contributed to the development of severe control forces. One of the factors identified by the ATSB was the similar location, appearance, and function of the Trim Interrupt and Flap Interrupt switches.

To manage the risk of switch mis-selection generally, RFDS training/check pilots advocated the practice of identify–confirm–action. In relation to the Trim Interrupt switch, pilots were required to identify the switch when pitch trim runaways were addressed during training/checking. RFDS pilots were also familiar with the location of both switches from the pre-flight inspection conducted on a pilot's the first flight of the day in a particular aircraft.

Pilatus inferred there was a risk of erroneously activating the Flap Interrupt switch and that hands-on training would reduce that risk. In the RFDS context, mis-identification of the Trim Interrupt switch was not evident during training and checking and, in the previous pitch trim runaway occurrences, the pilots had correctly identified and actioned the Trim Interrupt switch. However, the artificiality of the training/checking environment and the relatively benign conditions experienced by most pilots during the previous pitch trim runaways occurrences (daylight and phases of flight other than take-off/initial climb) were very different from conditions of this occurrence.

In the 57 pitch trim runaway events recorded by Pilatus, there were no reports of mis-selection of the Flap Interrupt instead of the Trim Interrupt switch. Although this indicates that the risk is generally not high, it may be sensitive to phase of flight and environmental conditions. There was insufficient information in the Pilatus data to make an assessment of that risk.

The risk of mis-identification could be reduced by pilots manipulating the switch during training/checking and by increased awareness of the effects of inadvertent selection of the Flap Interrupt switch. Consideration could also be given to daily pre-flight operation of the Trim Interrupt switch as implemented for Canadian PC-12 aircraft. Although these procedural controls reduce the risk, it would be preferable to implement an engineering control to remove the hazard.

The similarities between the Trim Interrupt and Flap Interrupt switches and the proximal location of the two switches unnecessarily increased the risk of mis-selection. While visually distinguishing close proximity switches and controls has long been shown to be an effective strategy (for example, landing gear and flap retraction levers are typically designed to resemble the lever's function), given pilots are not required to access the Flap Interrupt switch, consideration could also be given to preventing access to it altogether.

## Pilatus emergency procedure and systems information

Pilatus advised pilots in the POH/AFM that the prerequisites for safe aircraft handling in an emergency is prior knowledge of the applicable procedure and a good understanding of the aircraft systems. The ATSB used this statement as a reference point to assess the related factors in pilot capability.

Prior knowledge is taken to be familiarity with the content and application of the Pitch Trim Runaway procedure. In this case, RFDS required the pilot to memorise at least the first four items of the Pitch Trim Runaway procedure and addressed this in PC-12 flight training and the recent OPC. Despite mis-selection of the Trim/Flap Interrupt in this occurrence, the pilot demonstrated familiarity with all of the items of the procedure by addressing each in turn.

Pilatus did not nominate any recall items (also known as memory, phase-1 or bold-faced checks) for PC-12 emergency procedures. In the case of the Pitch Trim Runaway procedure, Pilatus advised the ATSB that their preference would be designation of item 1 as the only recall item to place the focus on the crucial item and positively arrest any trim runaway from any cause. Although the ATSB recognises there are benefits to minimising recall items, there is nothing to indicate that the number of nominated recall items in RFDS procedures were a factor in this occurrence.

The degree of knowledge required for a good understanding of aircraft systems is dependent in part on the complexity of the aircraft and the nature of the pilot-systems interface. Given the relative complexity of the aircraft and regulatory requirements, RFDS provided a PC-12 ground school to the pilot that covered the pitch trim system with reference to the POH/AFM. It would be natural for this theoretical knowledge to be consolidated and/or extended by the PC-12 flying training and operator proficiency checks (OPCs).

Given the pilot was able to recall the emergency procedure and was trained with reference to the Pilot Operating Handbook/Airplane Flight Manual (POH/AFM), the ATSB considered the content and format of the emergency procedure and systems information provided by Pilatus. The associated training/checking aspects are addressed in the following section.

### *Pitch Trim Runaway emergency procedure*

The copy of the Pitch Trim Runaway emergency procedure from Figure 6 is repeated here for ease of reference.

**Figure 10: Quick Reference Handbook Emergency Procedures – Pitch Trim Runaway**

**Pitch Trim Runaway** 3.14.1

Voice callout "Trim Runaway"

| | |
|---|---|
| **1. TRIM INTERRUPT switch** | **INTR** |
| **2. PITCH TRIM CB (Essential Bus LA1)** | **Pull** |
| **3. TRIM INTERRUPT switch** | **NORM** |
| If trim runaway continues: | |
| **4. TRIM INTERRUPT switch** | **INTR** |
| **5. PITCH TRIM ALTN CB (Main Bus RA1)** | **Pull** |
| **6. PITCH TRIM CB (Essential Bus LA1)** | **Close** |
| **7. TRIM INTERRUPT switch** | **NORM** |

NOTE

Reduce speed if control forces are high.

The autopilot will disconnect when Trim Interrupt is operated. If the Pitch Trim has failed, the autopilot is not operative.

If main Stabilizer Trim has failed:

| | |
|---|---|
| **8. Pitch trim** | **Use ALTERNATE STAB TRIM** |

-------------------- END --------------------

Source: Pilatus

After item 3 of the emergency procedure, the pilot was required to make an assessment and decision about the status of the runaway and act accordingly. This assessment/decision point was defined in the procedure by the condition—'If trim runaway continues'. Correctly understood, the implication is that the fault is not in the manual trim system and autopilot trim system but in the alternate stabiliser trim circuit.

The alternate stabiliser trim circuit is not used during normal operations and does not require any relays to be energised for operation. As such, the risk that this circuit would fail in an unsafe runaway condition is very low relative to a manual trim or autopilot circuit failure. This was consistent with advice from Honeywell that there was no record of any such failure.

The alternative condition at the assessment/decision point—if trim runaway does not continue—was implied but not specified in the procedure. In this more likely scenario, the fault in the manual or autopilot trim systems has been neutralised by item 2 (opening of Pitch Trim circuit breaker). Then, without any guidance from the procedure, pilots needed to understand that the procedure from item 4 to item 7 should not be continued and alternate stab trim was the only means available to trim the aircraft for the rest of the flight.

Significantly, alternate stabiliser trim was not specified in the procedure until item 8. This had two related adverse effects. First, pilots are not guided to use the alternate stabiliser trim at the point where it almost certainly would be effective at recovering from an out-of-trim condition (after item 3). Second, if the procedure is carried out in a sequential manner, item 5 (Pitch Trim Alternate circuit breaker open) will render item 8 (alternate stabiliser trim) inoperable.

Another consequence of lack of guidance and continuation of the procedure is that item 6 (Pitch Trim circuit breaker—Close) will reactivate the pitch trim runaway in almost all cases.

One of the notes near the end of the Pitch Trim Runaway procedure advised pilots to ‘Reduce speed if control forces are high’. The pilot response to the abnormal control forces was consistent with this advice but the airspeed reached high-risk figures before the pilot took effective action. In this case, the pilot was probably not prompted by the note in the procedure. However, if the note was positioned earlier in the procedure, it is possible that pilot would have acted earlier to reduce the airspeed and risk of loss of loss of control.

Pilatus advised the ATSB that instead of reliance on descriptions within the emergency procedure, the objective of the emergency procedures must be understood and ingrained during training for the procedure to be effectively executed. This was more applicable when the pilot is managing the emergency and unintended consequences. Pilots were directed to SIL-003 for a clear description of the requirements. A copy of SIL-003 is at Appendix B and ATSB assessment of the SIL is in the next section.

The ATSB considered that the PC-12 Pitch Trim Runaway emergency procedure did not clearly define the two conditions for pilot consideration after item 3. In addition, the specified action in response to the most likely condition—pitch trim runaway discontinues (as indicated by no active warnings)—was out of sequence. Given the confounding situation and complexity of the PC-12 pitch trim system, it is likely that a clearly defined and logically sequenced procedure would have assisted the pilot to regain control.

### *Pitch trim systems information*

From an operational perspective, the primary reference for systems information was the POH/AFM. This included the following information relevant to this occurrence:

- The alternate stabilizer trim motor could be used as a backup through actuation of the Alternate Stab Trim switch.
- In the case of uncommanded trim operation, all trim operation could be stopped by lifting the switch guard and pressing the Trim Interrupt switch.
- If a stabiliser trim runaway of the main system is sensed a CAS ‘Pitch Trim Runaway’ warning will be displayed and a ‘Trim Runaway’ will be heard.

The ATSB notes that although this information is helpful to a pilot contending with a pitch trim runaway, it does not provide guidance as to when the Alternate Stab Trim switch should be used or the significance of the CAS warning as an ongoing indicator of system status.

Additional information about pitch trim runaway was available in Pilatus Safety Information Letter SIL-003. However, RFDS did not incorporate the SIL into their operational reference material and the pilot was not aware of it.

The additional information would have been generally helpful to the pilot and would have emphasised the importance of reduced airspeed in managing the out-of-trim loads. Nevertheless, the ATSB identified missed opportunities in SIL-003 to explain and clarify aspects of pitch trim runaway:

- Hands-on training was advised to reduce the risk of erroneously activating the Flap Interrupt switch but pilots were not informed of the associated risk factors, symptoms or corrective action if that occurred.
- Information was provided about the purpose of pulling a circuit breaker, without further guidance as to how the affected trim motor would be identified.

- Pilots were advised that control of the unaffected systems could be regained by simply repositioning the Trim Interrupt switch to NORM, without guiding pilots to use the Alternate Stab Trim switch.

Neither SIL-003 nor POH/AFM informed pilots/operators that both the manual pitch trim and autopilot pitch trim were powered from the Pitch Trim circuit breaker. In the absence of that information, there is a risk of misapprehension that the autopilot pitch trim was powered from the Pitch Trim Alternate circuit breaker on the (correct) basis that the autopilot pitch trim utilised the alternate trim motor.

A consequence of this misapprehension is that pilots/operators may not realise that the first 3 items (and item 8 as required) of the pitch trim runaway procedure will almost certainly be sufficient to address a runaway condition. There is a risk that pilots will unnecessarily address all of the items in the procedure and not resolve a pitch trim runaway, as happened in this occurrence. The effect of this misapprehension on RFDS training/checking is discussed in the next section.

Another characteristic not covered in the information for pilots applies when the manual trim circuit is the active cause of a pitch trim runway. If the pilot engages manual trim, perhaps instinctively, the CAS warnings are cancelled for the duration of the engagement then reactivate on manual trim disengagement. Pilot awareness of this characteristic might be of assistance in an ill-defined emergency such as this occurrence.

In the context of this occurrence, the ATSB considered that the systems information in the PC-12 POH/AFM did not provide a detailed description of the pitch trim system or effective guidance in the management of a pitch trim runaway. Although SIL-003 presented additional information, it did not effectively compensate for the lack of detailed systems description and guidance in the POH/AFM.

### *Summary and finding*

The PC-12 pitch trim system is complex and the CAS warnings for pitch trim runaway do not specify the malfunctioning circuit or the required actions. As a result, pilots are required to recall and action emergency procedures, interpret system indications, and act accordingly to resolve a pitch trim runaway.

This occurrence demonstrates that the consequences of a pitch trim runaway can be critical if the trim is not interrupted early in the emergency. In the context of this occurrence, the applicable risk controls such as the emergency procedure and systems information did not provide effective assistance to the pilot. The other RFDS pitch trim runaway occurrences did not have critical consequences but indicate variability in the effectiveness of these risk controls.

The relatively experienced pilot involved in three of the previous pitch trim runaway events was familiar with the emergency procedure and POH/AFM but did not interpret the system indications appropriately or act according to the intent of the procedure. During post-occurrence RFDS training/checking, it was apparent that there was variability in pilot understanding of the pitch trim system and associated emergency procedures. Given that variability, the ATSB considered that the occurrence pilot's relative inexperience was not an important factor in the occurrence.

Pilatus recorded 47 pitch trim runaway events that were associated with defective relays in the manual trim system or the trim adaptor. In those events, the only method available to adjust the trim was use of the Alternate Stab Trim switch, which was reported in 11 of the events (one was unsuccessful). Taking into account those 11 events and the 3 events where the emergency procedure was not fully actioned due to the operational context, there were 33 pitch trim runaways where pilot use or non-use of Alternate Stab Trim is unknown. As such, there is insufficient information to derive a conclusion from the Pilatus data regarding pilot understanding of the pitch trim system and emergency procedure.

Given the pilot in this occurrence was familiar with the emergency procedure and trained by qualified personnel with reference to the POH/AFM, the ATSB considered the content and format of the emergency procedure and systems information in the POH/AFM in the context of RFDS and Pilatus occurrence data.

The ATSB found that the emergency procedures and systems information in the PC-12 POH/AFM and Quick Reference Handbook (QRH) did not provide effective guidance or sufficient information for pilots contending with a pitch trim runaway. If the pilot selects the Trim Interrupt switch early in the sequence and does not need to adjust the pitch trim, the risk is not significant. In this case, the lack of effective guidance and systems information probably had an adverse influence on the pilot's capability to resolve the uninterrupted trim runaway condition and was a critical factor.

## RFDS training and checking

The pilot's capability to implement the Pitch Trim Runaway emergency procedure with a good understanding of the aircraft systems relied to a large extent on the training and checking provided by RFDS. Their training and checking organisation conducted the required ground school and flight training to qualify the pilot to operate the PC-12 aircraft type. This was supplemented by supervised line flying (LOFT) and operator proficiency checks (OPC) as specified by RFDS.

The PC-12 ground school was the primary means for RFDS to equip the pilot with the requisite knowledge of a wide range of aircraft systems. This included the pitch trim system, which was addressed with reference to the POH/AFM and as part of a guided inspection of an aircraft. Given the POH/AFM did not provide a detailed description of the pitch trim system and RFDS training/checking pilots were unaware of some characteristics, the information provided to the pilot accordingly had some limitations.

By the time the pilot was trained in 2018, Pilatus had issued SIL-003 (in 2017) as a reminder of the trim runaway procedures in the POH/AFM and to highlight decision-making considerations after the trim runaway condition is stopped. RFDS had not formally considered this document and it was not a supplementary reference in the ground school. Although this document would have been generally helpful to the ground school facilitator and this pilot, the focus of the SIL was operational and it did not provide any further significant detail about the pitch trim system. As such, the absence of the SIL from the ground school references was not considered to be a factor in the occurrence.

Although systems knowledge is not the prime focus of flying training, supervised line flying or operator proficiency checks, these processes generally help to consolidate the pilot's understanding of aircraft systems and might show if there were any critical knowledge deficiencies. There was no indication of any such deficiencies.

The PC-12 flying training and operator proficiency checks were the primary means for RFDS to develop and verify the pilot's capability to manage in-flight emergencies such as pitch trim runaway. These training/checking activities were oriented to the recall and practice of the applicable emergency procedures in the QRH. As a result, it could be expected that the pilot was familiar with the content of the procedures and location of the applicable switches and circuit breakers.

Although the pilot was able to recall the items in the emergency procedure, the initial switch selection was incorrect and the pilot actioned further items of the procedure without resolving the severely out-of-trim condition. The ATSB considered two aspects of the training/checking processes that might have played a role.

First, the practice exercises for pitch trim runaway were not consistent with the likely failure modes and recovery actions. Prior to this occurrence, RFDS operated on the basis that the manual trim was powered from Pitch Trim circuit breaker and the autopilot trim (utilising the alternate trim motor) was powered from the Pitch Trim Alternate circuit breaker. As a result, in response to a practice pitch trim runaway, pilots were expected to complete the first stage (items 1-3) at a minimum and it was common to continue the procedure (items 4-8) to represent an autopilot-related runaway scenario.

Actually, both manual and autopilot systems are powered from the Pitch Trim circuit breaker so the first stage (items 1-3) and item 8 (as required) of the emergency procedure are sufficient to manage a pitch trim runaway in all recorded cases to date. In the absence of a clear definition of failure modes, the pilot was conditioned to continue the emergency procedure beyond the first stage without use of the Alternate Stab Trim.

RFDS misunderstanding of the pitch trim system can be attributed in part to the lack of specific detail in the POH/AFM and unclear definition of the likely fault conditions in the emergency procedure. Although there was a report of some consideration of SIL-003 and consequent inclusion of pitch trim runaway scenarios in checks, RFDS did not formally consider the implications for their training/checking practices.

The key piece of additional information provided by the SIL was the advice:

> Hands-on training reduces the activation time and minimizes the risk of erroneously activating the “Flaps Interrupt” system switch (which cannot be reset in-flight).

In the pre-occurrence context, with no instances of mis-selections in occurrences or training/checking, it is unclear if RFDS would have adopted that practice as an exception to the touch-drill principle. Nevertheless, Pilatus consider SIL-003 to be effective additional guidance for the management of a pitch trim runaway.

Second, the RFDS training/checking was carried out in-aircraft and this has inherent and unavoidable constraints for the practice of some emergencies. It is not technically feasible or necessarily safe to initiate a pitch trim runaway in the aircraft so the training/checking pilot described a scenario and/or discreetly made a flight control input. Accordingly, the trainee did not experience the realistic effects of a pitch trim runaway with the applicable CAS indications. Then, the pilot generally responded with a touch-drill and did not fully experience the physical action and system feedback.

As a consequence of both aspects, the occurrence pilot had developed an expectation that selection of the Trim Interrupt to INTR should have stopped the dive and the opened circuit breaker should have relieved the situation. In reality, the trim interrupt function simply stops the trim where it is and the opened circuit breaker does not provide any further relief at that point.

The ATSB found that the effectiveness of RFDS training and checking processes for pitch trim runaway was undermined by incomplete systems information and unrealistic practice exercises associated with training/checking in the aircraft (non-simulator).

## Relay failure

The ATSB examined the defective manual pitch trim DOWN relays removed from VH-OWJ and another PC-12 that sustained a pitch trim runaway. In both relays, one set of the normally open contacts were fused together in a similar way. According to the relay manufacturer, this type of damage was consistent with a short-duration high-current event such as a lightning strike.

The transfer of material between contacts in the manual pitch trim UP relay removed from VH-OWJ and the manual pitch DOWN relay from the other PC-12 showed that the related circuits had been subjected to regular arcing.

Based on examination of the three manual pitch trim relays from two different aircraft, the ATSB considered that the risk of surge voltage and over current in the PC-12 pitch trim system was probably not limited to a particular aircraft. The relay failures recorded by RFDS and Pilatus in connection with pitch trim runaway events are indicative of the same failure mode. Considering the near identical failure mode within the same pitch trim relay of varying aircraft, it is less likely that the cause would be a random event such as a lightning strike. The ATSB considers that the failure is more likely due to a characteristic associated with the pitch trim circuit, such as potential surge currents cause by switching the inductive load of the pitch trim actuator.

At the time of the occurrence Pilatus had identified a reliability issue concerning the mechanical relays in the PC-12 pitch trim system. This is consistent with the ATSB's concern that a characteristic of the pitch trim circuit may have contributed to the relay failure.

Pilatus have developed service bulletins to introduce solid-state relays into the pitch trim power circuits. The ATSB notes that solid-state relays are also susceptible to failure from surge voltages. A typical failure mode for solid-state relays is short-circuit, in which case the load would not be turned off and a pitch trim runaway would occur.

Although Pilatus service bulletins SB 27-023 and SB 27-024 address the reliability of relays in the pitch trim system, the ATSB considers that the risk of pitch trim runaway may not be significantly reduced. As such, Pilatus may need to conduct further research into the electrical loads present in the PC-12 pitch trim system to identify and address the source of the high energy events that damage relays.

# Findings

From the evidence available, the following findings are made with respect to the pitch trim runaway and partial loss of control involving a Pilatus PC-12/47E, registered VH-OWJ that occurred near Merredin, Western Australia on 14 April 2019. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

**Safety issues, or system problems, are highlighted in bold to emphasise their importance.** A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

## Contributing factors

- Soon after take-off in dark-night conditions, the pitch trim system continued to operate in a nose-down direction without pilot input or autopilot commands (pitch trim runaway) because of a malfunctioning relay in the manual (main pilot-engaged) stabiliser trim system.
- In response to the Crew Alerting System warnings, the pilot initiated the Pitch Trim Runaway emergency procedure but inadvertently selected the Flap Interrupt switch rather than the Trim Interrupt switch (item 1). Consequently (before the next checklist item was actioned), the pitch trim continued to runaway until it reached full nose-down with associated serious control difficulties.
- After the pilot addressed items 2 and 3 of the emergency procedure, the malfunction was neutralised and the alternate stabiliser trim system was available to adjust the trim. However, the pilot did not identify those positive conditions and continued with items 4 to 8 of the procedure, which disabled the alternate stabiliser trim system, prevented pitch trim adjustment and prolonged the serious control difficulties.
- **The similarities between the Trim Interrupt and Flap Interrupt switches and the proximal location of the two switches unnecessarily increased the risk of mis-selection and contributed to the excessive out-of-trim condition.**
- The emergency procedures and systems information in the PC-12 Pilot's Operating Handbook/Airplane Flight Manual and Quick Reference Handbook did not provide effective guidance or sufficient information for pilots contending with a pitch trim runaway. If the pilot selects the Trim Interrupt switch early in the sequence and does not need to adjust the pitch trim, the risk is not significant. In this case, the lack of effective guidance and systems information probably had an adverse influence on the pilot's capability to resolve the uninterrupted trim runaway condition and was a critical factor.

## Other factors that increased risk

- As the (uninterrupted) pitch trim runaway progressed, the reinforcing cycle of increasing control loads, forced descent, and increasing airspeed was initially exacerbated by high engine torque. The airspeed reached 210 kts with increased risk of descent into terrain before the pilot reduced engine torque and airspeed to partially alleviate the control loads and arrest the descent.
- The effectiveness of RFDS training and checking processes for pitch trim runaway was undermined by incomplete systems knowledge and unrealistic practice exercises associated with training/checking in the aircraft (non-simulator).

## Other findings

- The PC-12 Crew Alerting System (CAS) provided clear and salient warnings of the pitch trim runaway and indications of the ongoing status of the pitch trim system. As was typical for aircraft such as the PC-12, the CAS was not designed to specify the malfunctioning circuit.
- In difficult operational circumstances, the pilot enlisted the assistance of non-flying crew to counter the very high control loads and managed to coordinate the dual control inputs to return and land without wing flap at Merredin.
- At the time of the occurrence, the aircraft manufacturer was developing and implementing replacement components for the pitch trim system to improve reliability. Further research into the electrical loads present in the PC-12 pitch trim system may be required to find and address the source of high energy events that damage the relays.

# Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the [aviation, marine, rail - as applicable] industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions are provided separately on the ATSB website to facilitate monitoring by interested parties. Where relevant the safety issues and actions will be updated on the ATSB website as information comes to hand.

## Pilatus PC-12 trim and flap interrupt switches

| | |
|---|---|
| Safety issue number: | AO-2019-019-SI-01 |
| Safety issue owner: | Pilatus Aircraft Ltd |
| Operation affected: | Aviation: Private, Aerial work - EMS (Medical transport), Air Transport |
| Who it affects: | Operators and pilots of PC-12 aircraft |

### *Safety issue description*

The similarities between the Trim Interrupt and Flap Interrupt switches and the proximal location of the two switches unnecessarily increased the risk of mis-selection and contributed to the excessive out-of-trim condition.

#### *Proactive safety action*

| | |
|---|---|
| **Action taken by:** | Pilatus Aircraft Ltd |
| **Action number:** | AO-2019-019-NSA-010 |
| **Action type:** | Proactive safety action |
| **Action status:** | Closed |

***Safety action taken:*** Pilatus advised they took actions to minimize the risk of mis-selection and possibly resulting excessive out-of-trim conditions to ALARP by design and documentation changes.

To minimise the probability of a fused mechanical pitch trim relay, Pilatus developed a design change for the mechanical pitch trim relay. The mechanical relay is replaced with a solid-state relay. Service Bulletin SB 27-023 for the modification had been technically approved on March 4th, 2019. Publication of the SB was delayed until March 16th, 2020 due to limited parts availability.

In addition, the probability of erroneous activation of the Flap interrupt switch instead of the Trim interrupt switch has already been reduced by the publication and active distribution of SIL 003 to all PC-12 operators. This document highlights the crucial importance of correct execution of the

Pitch Trim Runaway emergency procedure and provides information about the intent of the emergency procedure, but also stresses the shared responsibility of the operators to ensure correct execution of the emergency procedure by proper training.

Further improvements to the guidance and information provided in the PC-12 operational documentation will be considered by Pilatus. The combination of these actions is considered by Pilatus to effectively minimize the risk of mis-selection to ALARP.

#### *Status of the safety issue*

**Issue status:** Closed - Partially addressed

**Justification:** The safety action nominated by Pilatus may result in less need for pilots to use the Trim Interrupt switch (due to more reliable relays) and training guidance may increase the probability of the correct switch being selected in the case of a trim runaway event. However, the two switches do remain identical and co-located, and given the Flap Interrupt switch is no longer required, there is potential for engineering controls to eliminate the mis-selection of the interrupt switches and associated possible loss of control.

## Additional safety action

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

### *RFDS Western Operations*

RFDS safety, quality and risk personnel carried out an investigation of the occurrence with a focus on the cause of the pitch trim runaway and the actions of the pilot and crew in response to the event. This resulted in six recommendations and the following safety action by RFDS:

- Pilatus was asked to investigate more reliable relays for the pitch trim system.
- Feedback was provided to Pilatus regarding the Pitch Trim Runaway emergency procedure and the potential to change it to reduce confusion.
- RFDS considered that the timing of the initial engine torque reduction (when the airspeed reached 210 kt) led directly to a situation where the aircraft and crew were placed at catastrophic risk. With reference to the RFDS Just Culture process, this was considered to be negligent and, taking into account the pilot's other incidents, the pilot's employment was terminated.
- RFDS amended the PC-12 operating procedures in their *Operations Manual* to present the first phase of the pitch trim runaway emergency procedure in accordance with the Pilatus PC-12 POH/AFM and QRH.
- The RFDS Head of Training and Checking convened a review of the adequacy of processes in regard to pitch trim runaway. This led to the following activities:
    - Briefing on revised pitch trim system information to all PC-12 pilots
    - Development of a training presentation to describe operation of the pitch trim system
    - For PC-12 conversion, addition of training between ground school and flight training to provide opportunity for pilots to review and if possible physically action emergency procedures in an aircraft on the ground
    - Refresher training for pitch trim runaway for all PC-12 pilots on next scheduled checks
    - For a practice pitch trim runaway, pilots were now expected to physically action the Alternate Stab Trim switch
    - Provision of the RFDS investigation report (with redactions for privacy) to all PC-12 pilots.

Following the occurrence, senior training and checking personnel had the opportunity to participate in a modified PC-12/47E ground school and simulator flight refresher course provided in the US by Flight Safety International. This included a pitch trim runaway scenario with similar complications to the occurrence.

A number of recommendations were proposed including:

- Enhancement to the PC-12 ground school with more emphasis on emergency procedures and their impact on aircraft systems
- Consideration of practice to retard the engine power lever as initial response to pitch trim runaway for better access to Trim Interrupt switch and enhance control of airspeed and control forces.
- Where possible, allow pilots to physically action controls such as Alternate Stab Trim that are specified in a drill
- Opportunities for training pilots and all PC-12 pilots to practice emergency scenarios in a full motion simulator.

# General details

## Occurrence details

| | | |
|---|---|---|
| Date and time: | 14 April 2019 – 0010 WST | |
| Occurrence category: | Serious incident | |
| Primary occurrence type: | Loss of control | |
| Location: | 4 km west of Merredin ALA, Western Australia | |
| | Latitude: 31º 31.428' S | Longitude: 118º 16.554' E |

## Pilot details

| | |
|---|---|
| Licence details: | Commercial Pilot Licence (Aeroplane) |
| Class Ratings: | Single Engine Aeroplane<br>Multi Engine Aeroplane |
| Operational Ratings: | Instrument Rating (Multi Engine Aeroplane)<br>Flight Instructor Rating |
| Medical certificate: | Class 1, valid to February 2020 |
| Aeronautical experience: | Approximately 2,108 hours |
| Last check: | Progress Check 15 February 2019 |

## Aircraft details

| | | |
|---|---|---|
| Manufacturer and model: | Pilatus Aircraft Ltd. PC-12/47E | |
| Registration: | VH-OWJ | |
| Operator: | Royal Flying Doctor Service of Australia – Western Operations | |
| Serial number: | 1411 | |
| Type of operation: | Aerial work - EMS (Medical transport) | |
| Departure: | Merredin | |
| Destination: | Jandakot (Landed Merredin) | |
| Persons on board: | Crew – 1 (pilot) | Passengers – 2 medical staff, 1 patient |
| Injuries: | Crew – 0 | Passengers – 0 |
| Aircraft damage: | Nil | |

# Sources and submissions

## Sources of information

The sources of information during the investigation included the:

- Pilatus Aircraft Ltd.
- Honeywell Aerospace
- Royal Flying Doctor Service – Western Operations
- Pilot and medical crew of VH-OWJ
- RFDS pilots involved in other pitch trim runaway occurrences
- Royal Flying Doctor Service – Central Operations
- Transport Canada

## References

Dismukes, R., Goldsmith, T. E., & Kochan, J. A. (2015). Effects of acute stress on aircrew performance: literature review and analysis of operational aspects.

## Submissions

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

A draft of this report was provided to the Civil Aviation Safety Authority, Transport Canada, Swiss Transport Safety Board, Pilatus Aircraft Ltd, Honeywell Aerospace, Royal Flying Doctor Service – Western Operations, the pilot and medical crew of VH-OWJ, and Royal Flying Doctor Service – Central Operations.

Submissions were received from the Civil Aviation Safety Authority, Swiss Transport Safety Board, Royal Flying Doctor Service – Western Operations, and Pilatus Aircraft Ltd. Those submissions were reviewed and where considered appropriate, the text of the draft report was amended.

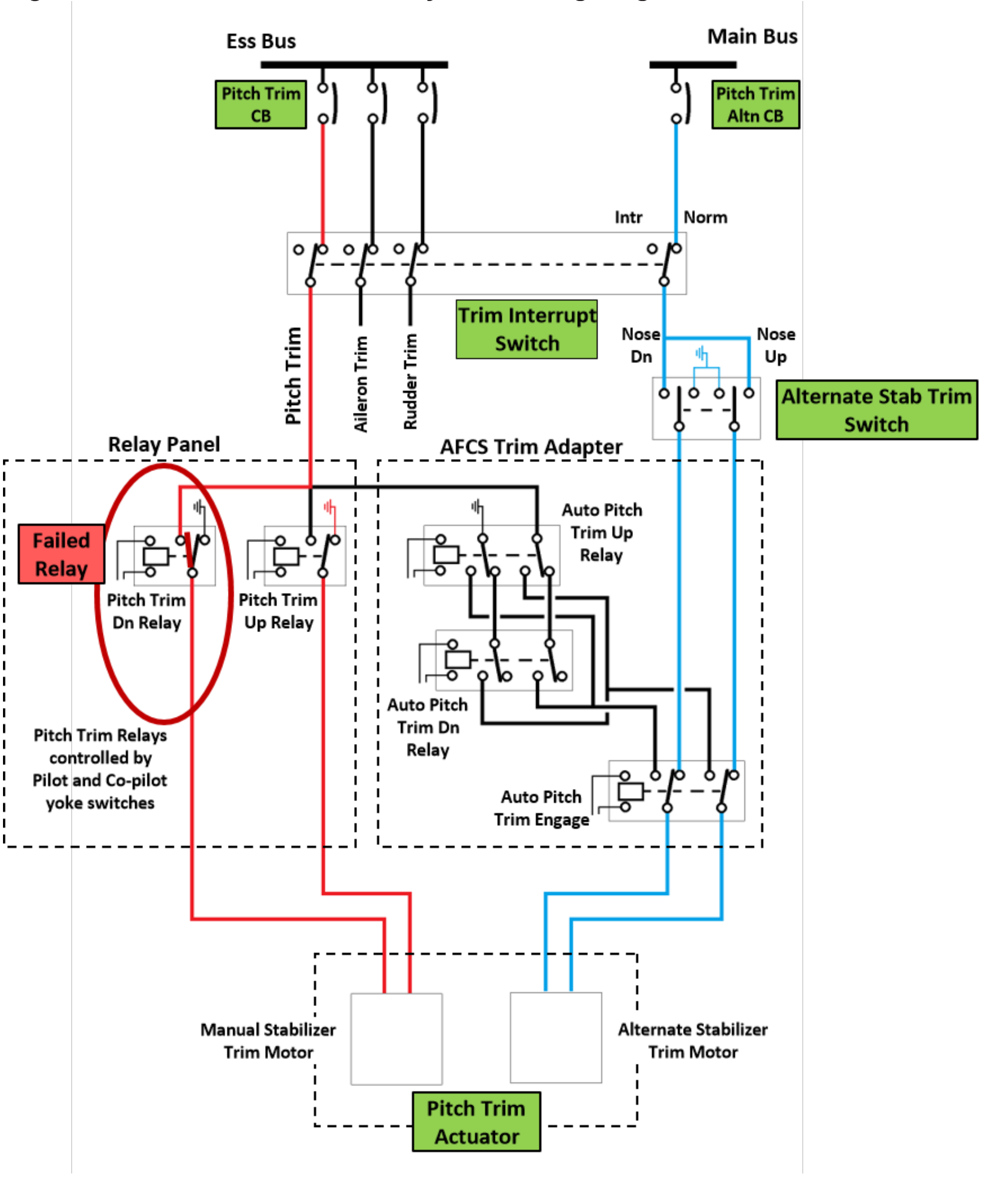
# Appendices

## Appendix A – PC-12/47E Pitch trim system wiring diagram

The ATSB adapted this circuit diagram from the maintenance data produced by Pilatus to show the status of key components of the system at the time of the pitch trim runaway. The red lines trace the active power circuit through the malfunctioning relay. That circuit can be de-energised by the Trim Interrupt switch and/or Pitch Trim circuit breaker. The blue lines trace the power circuit that can be activated by the Alternate Stab Trim switch provided the Pitch Trim Altn circuit breaker is closed and the Trim Interrupt switch is NORM.

Note, both pilot and autopilot controlled pitch trim circuits are powered via the Ess Bus and Pitch Trim circuit breaker. The Main Bus and Pitch Trim Altn circuit breaker only powers the Alternate Stab Trim circuit.

**Figure A1: PC-12/47E Pitch trim system wiring diagram**




Source: Adapted from Pilatus PC-12 maintenance data by the ATSB

# Appendix B – Pilatus PC-12 Safety Information Letter SIL-003

**PILATUS**

PILATUS AIRCRAFT LTD. STANS, SWITZERLAND

**SAFETY INFORMATION LETTER**

**PC-12**

**SUBJECT: TRIM SYSTEM**

To all Customers, Operators and Service Centers: Date: February 23/17

Effectivity: All PC-12, PC-12/45, PC-12/47 and PC-12/47E aircraft.

This Safety Information Letter is issued to draw attention to the following information:

**Important reminder of procedures and operations of PC-12 (all models) when encountering a trim runaway condition.**

From time to time, Pilatus addresses important operational issues by means of PC-12 Safety Information Letters. This time, we want to remind the PC-12 community about the trim runaway procedures set out in the Pilot's Operating Handbook (POH) and their application.

Furthermore, we highlight several items for safe flight continuation and landing for pilots to consider and to support them in the decision-making process after the trim runaway condition is stopped.

**Correct and timely application of the trim runaway procedures set out in the POH is vital to avoid or reduce the adverse effects of a trim runaway in the following respects and circumstances:**

- **Departure from initiated flight path**
- **AFCS capability**
- **Aircraft performance**
- **Increased workload and subsequent pilot fatigue.**

In addition to following the POH procedures, flight crews should be aware of the following:

1. Identification - Recognition

   Components within an electrical trim system can malfunction causing a non-commanded out of trim force operation called "Trim Runaway".

   Depending on the affected axis, an associated alert may support recognition. Non-commanded AFCS disconnects followed by departure from actual aircraft pitch and/or roll attitude or excessive slip indications are additional evidence of a trim runaway condition.

2. Refresh and visualize procedures

   In case of a trim runaway condition, as an immediate action, activate the guarded "Trim Interrupt" switch (refer to POH Section 3).

   Hands-on training reduces the activation time and minimizes the risk of erroneously activating the "Flaps Interrupt" system switch (which cannot be reset in-flight).

   Once the "Trim Interrupt" switch is activated, all four (4) trim motors and the AFCS are disconnected and the runaway is stopped (refer to POH Sections 3 and 7-3).

   By pulling its associated Circuit Breaker (CB), the affected trim motor will be isolated before the pilot can attempt to regain control of the unaffected systems (refer to POH Section 3).

   Familiarization with the positions of the four (4) trim CBs shortens the (re)action time.

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PILATUS

SAFETY INFORMATION LETTER

**PC-12**

To regain control of the unaffected systems, simply reposition the "Trim Interrupt" switch to NORM (refer to POH Section 3).

A reduction in airspeed will significantly reduce the existing out-of-trim forces and will help the pilot regain full control of the aircraft (refer to POH Section 3).

3. Awareness of effects and their consequences

Depending on the affected trim axis and the extent of the trim system departure from its previous position before it was interrupted and isolated, the pilot may expect the following consequences:

- Increase in flight control forces disproportionate to airspeed, causing the aircraft to depart from its initial flight path
- Immediate loss of AFCS functionality when the alternate pitch or rudder trim system has malfunctioned
- Possible delayed loss of the AFCS functionality following an aileron trim runaway
- Substantial impact on aircraft performance from increased drag in relation to airspeed
- Substantial increase of physical fatigue from extended counteracting of continuous flight control forces.

The PC-12 trim system is designed to assure that the pilot does not have to counteract continuous or excessive control forces after encountering a trim runaway. In case of a runaway on one of the pitch trim motors, the remaining one can be used to regain normal control forces.

To manage the worst-case scenario (non-commanded nose down trim runaway during high speed descent), a considerable reduction of engine power and pitch-up control input to reduce the airspeed is required.

To avoid pilot fatigue by regaining normal control forces after a departed rudder or aileron trim tab, the remaining trim systems can be used to establish a steady heading side-slip condition within the lower speed range.

Refer to the PC-12 POH (Sections 3 and 7-3) for a detailed description of the applicable procedures and additional system information.

Pilatus appreciates your participation in distributing safety critical information.

Sharing this Safety Information Letter and associated information with pilots will enhance the safe operation of the PC-12 aircraft.

Best regards

Your Pilatus Team



Source: Pilatus Aircraft Ltd.

# Australian Transport Safety Bureau

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

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

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

## Purpose of safety investigations

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

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

## Developing safety action

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

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

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

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

## Terminology used in this report

**Occurrence:** accident or incident.

**Safety factor:** an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

**Contributing factor:** a factor that, had it not occurred or existed at the time of an occurrence, then either:

(a) the occurrence would probably not have occurred; or

(b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or

(c) another contributing factor would probably not have occurred or existed.

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

**Other findings:** any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.