Air Accidents Investigation Branch

AAIB Bulletin 2/2024

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01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
Press enquiries: 0207 944 3118/4292
http://www.aaib.gov.uk

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(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

A Field Investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

Serious Incident

Aircraft Type and Registration:	Bombardier CL-600-2B16 (604 Variant), D-AAAY
No & Type of Engines:	2 General Electric CF34-3B turbofan engines
Year of Manufacture:	2004 (Serial no: 5602)
Date & Time (UTC):	10 August 2022 at 1640 hrs
Location:	In the climb after departing Farnborough Airport, Hampshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew – 3 Passengers – 7
Injuries:	Crew – None Passengers – None
Nature of Damage:	Damage to the No 1 flap retract relay
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	13,091 hours (of which 5,655 were on type) Last 90 days – 102 hours Last 28 days – 41 hours
Information Source:	AAIB Field Investigation

Synopsis

In the climb, after departing Farnborough Airport, D-AAAY had an uncommanded[1] flap movement above the maximum flap extension speed during which the flaps moved to their fully extended position. The aircraft returned to Farnborough with the flaps extended where it landed without further incident.

An uncommanded and unarrested flap movement requires the flaps to move without movement of the flap lever and then for a failure in the flap arrest system to stop this movement. The flap surfaces are moved by two drive motors that are commanded by the sequencing of four extend and retract relays. These four relays also form part of the system to arrest an uncommanded flap movement.

The reason for the uncommanded movement of the flaps during the flight, and later during fault finding on the ground, could not be determined.

It was established that there had been a latent failure in the No 1 flap retract relay for at least the previous 64 flights, which caused the flaps to retract at half their normal retraction speed and prevent the arrest of an uncommanded flap movement. The failure of the relay resulted

Footnote

[1] Throughout the report the term 'uncommanded flap movement' means movement of the flap that was not commanded by the pilot by operation of the flap control lever.

from damage to the D contacts which provide electrical power to the flap Brake Detector Units. This damage was caused by electrical arcing resulting from an unsuppressed back-EMF generated when the Brake Detector Units were de-energised to apply the flap brakes when the flaps reached their selected position.

The AAIB published two Special Bulletins in which four Safety Recommendations were made: S2/2022[2] on 22 September 2022, and S1/2023[3] on 2 March 2023. A number of Safety Actions have been taken by Transport Canada and Bombardier Aviation, and additional action is planned in response to the recommendations.

Introduction

This serious incident occurred on 10 August 2022. On the evening of 14 August 2022, the AAIB was informed of the uncommanded and unarrested flap movement and commenced a field investigation on 15 August 2022.

On 9 January 2023 the AAIB was advised by the operator of D-AAAY that, while carrying out a manufacturer's Service Bulletin (SB) on two other Challenger 604 aircraft, they found the flaps to be operating at half-speed. The AAIB deployed a field team who, with representatives from the aircraft manufacturer, undertook an examination and test of the flap systems on these aircraft. The operator also permitted the examination of a third Challenger 604 aircraft, where the flaps operated at the correct speed while actioning the SB. These additional aircraft are identified in this report as Aircraft 2, 3 and 4. The flap extend and retract relays from all four aircraft were examined as part of the AAIB investigation.

History of the flight

The crew arrived at Farnborough Airport at 1300 hrs to operate a private charter flight to Málaga – Costa Del Sol Airport, Spain. The aircraft took off at 1618 hrs from Runway 06 using flap 20, after which the crew selected flap 0 and the flaps fully retracted. Following a standard instrument departure to the south-west, the flight was cleared to climb to FL350. As the aircraft passed through FL190 at approximately 300 KIAS, with the autopilot engaged, the crew saw a FLAPS FAIL caution[4] on the EICAS display primary page. The copilot, who was the PF, reported that the aircraft pitched nose-up slightly and started to decelerate. The EICAS primary page also displays a flap position indicator which indicated to the crew, by an animated green bar extending from left to right on the display, that the flaps were extending (Figure 1). The crew reported that the flap overspeed audio warning did not operate, which was contrary to their expectation[5]. The crew checked the flap control lever and noted that it was still in the flap 0 position.

Footnote

2 https://www.gov.uk/aaib-reports/aaib-special-bulletin-s2-slash-2022-bombardier-cl-600-2b16-604-variant-d-aaay [accessed January 2024].

3 https://www.gov.uk/aaib-reports/aaib-special-bulletin-s1-slash-2023-bombardier-cl-600-2b16-604-variant-d-aaay [accessed January 2024].

4 An amber caution indicates '*information that is considered important and may negatively impact the safe outcome of the procedure or lead to adverse effects or damage if not considered by the crew'* (Non-normal procedures PSP 604-15-QRH Vol. 2, REV 111, Nov 19/18. Bombardier Aerospace).

5 The aircraft manufacturer stated that the audio warning is not intended to operate in this scenario.

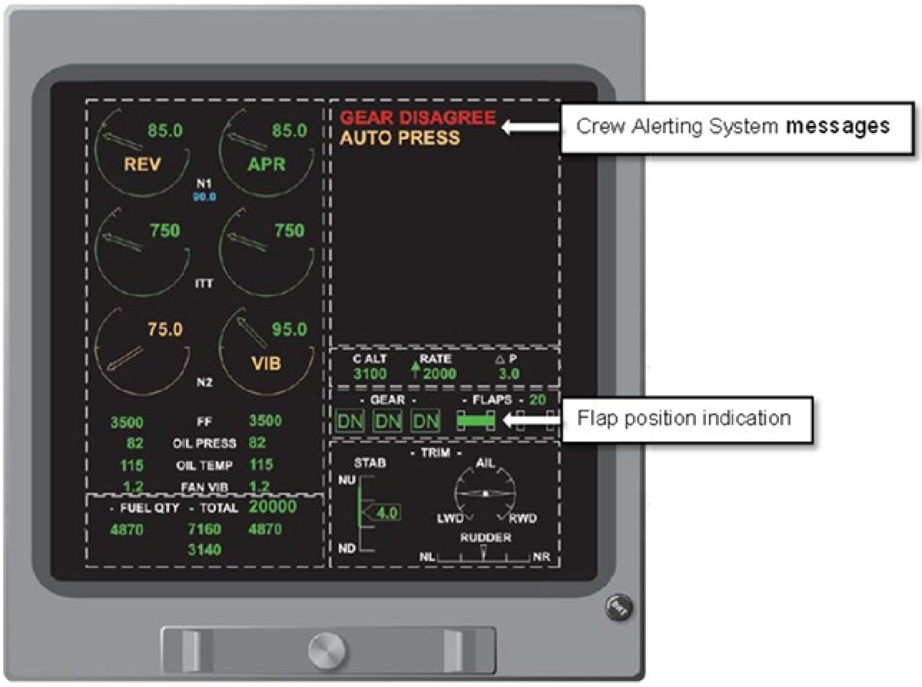


Figure 1

Illustration of EICAS primary page information

The commander switched on the seatbelt sign and took control of the aircraft. He disengaged the autopilot, reduced thrust to slow down, and initiated a descent. The crew informed ATC of the situation, requesting a descent to FL100 and radar vectors to Gatwick Airport. Subsequently, they decided to divert to Farnborough as it was closer than Gatwick and avoided extending the flight longer than necessary.

The crew established that the aircraft was responding normally to control inputs and decided to maintain FL150 at approximately 180 KIAS, which was below the V_{FE}[6] of 189 KIAS for flap 45. They reported that it required nearly full engine power to maintain this condition. The autopilot was re-engaged. The flight attendant made a visual inspection of the flaps from the cabin and reported that they appeared to be fully extended and symmetrical. The crew consulted the *'FLAPS FAIL'* procedure in the '*Non-normal Procedures*' section of the Quick Reference Handbook and found that no further actions were required. They established that they would land approximately 1,000 lbs over the maximum landing weight of 38,000 lbs and planned to increase the landing reference speed accordingly.

The aircraft was positioned for an ILS approach to Runway 06 at Farnborough and the crew configured the aircraft for landing, selecting the flap control lever to the flap 45 position (fully extended) to match the observed flap position. The aircraft landed without further incident at 1651 hrs, at an airspeed of 135 KIAS.

Footnote

6 V_{FE} is the maximum speed with flaps extended for a given flap position.

Meteorology

High pressure dominated across the south of the UK bringing clear, dry and warm conditions to the region. The forecast and actual conditions at Farnborough relevant to the time period of the occurrence flight reflected the stable conditions.

Challenger aircraft fleet size

The CL600-2B16 Challenger 604 is predominantly used for private business operations. The total Challenger 600 series fleet, which includes the Challenger 600, 601, 604, 605 and 650, is approximately 1,000 aircraft.

Description of flap operating system

General description

The aircraft has two double-slotted flap panels (inboard and outboard) which are externally hinged on the trailing edge of each wing. A flap lever on the cockpit centre pedestal sends an electric signal to the Flap Control Unit (FCU) to initiate flap movement.

The flap lever incorporates two sets of break-before-make[7] electrical contacts that provide the position of the lever. One set of contacts is connected to the FDR system and the second set to the flap overspeed warning and FCU.

When the FCU commands a change in flap position, the flap brakes in the Brake Detector Units (BDU) are released, and two 200 V 3-phase AC-powered motors mounted on a flap gearbox are energised by relays located in junction boxes. The motors and gearbox, which are part of the Power Drive Unit (PDU), rotate flexible shafts to move the flap ball-screw actuators, extending or retracting the flaps. When the desired flap position is reached, measured by a flap position sensor on the PDU, the motors are de-energised and the brakes in the BDUs are applied. The flaps are mechanically interconnected for simultaneous movement of the inboard and outboard flap sections. A schematic diagram of the flap system is shown in Figure 2.

The flaps can be set to one of four positions: 0°, 20°, 30°, and 45°. Flap position is displayed on the EICAS primary page and the Flight Controls Synoptic Page in both analogue (coloured bar) and digital formats. This EICAS indication comes from a separate flap position sensor attached to the right inboard flap. The indications on the EICAS primary page are only shown if the flaps are extended, or if the landing gear is not up and locked.

Footnote

[7] A switch that is configured to break (open) the first set of contacts before engaging (closing) the new contacts.

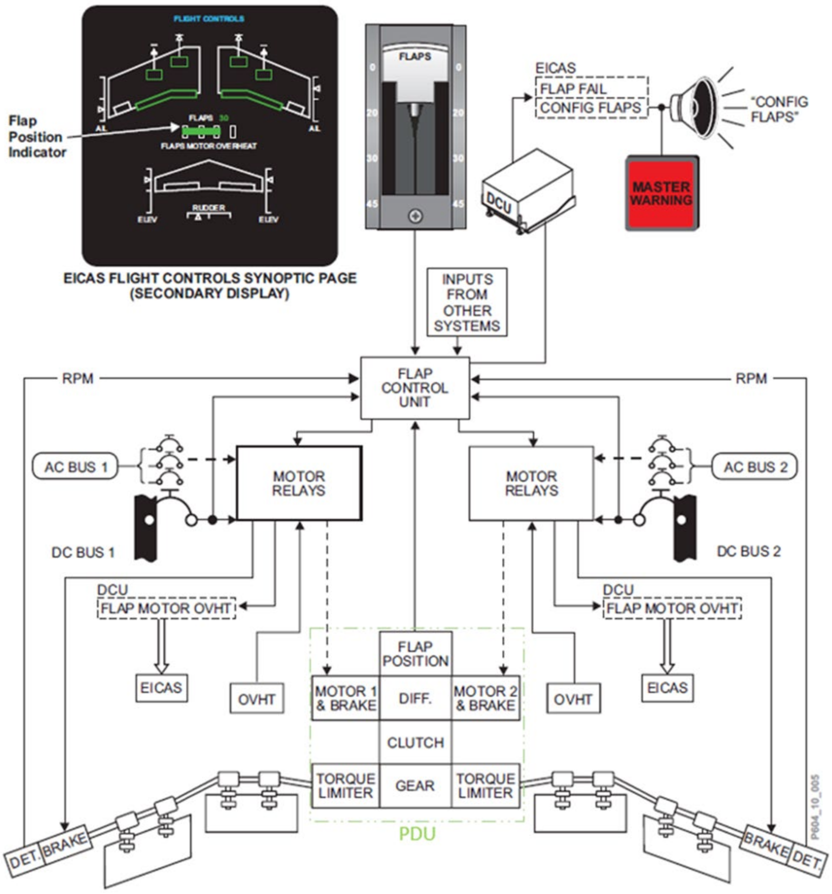


Figure 2

Schematic diagram of flap system
(Image from 2004 Pilot Training Guide amended to show PDU components)

When both motors operate, the flaps move at normal speed. If one motor fails or is not commanded to operate due to a failure in its control system, the remaining motor will continue to drive the system, but the flaps will move at half-speed due to the gearbox arrangement in the PDU. If a motor fails due to overheating, a FLAPS MOTOR OVHT EICAS status message will be displayed.

If a complete failure of the flap system occurs, such as both motors failing to operate, an asymmetry of greater than 2.75°, or an uncommanded flap movement, a FLAPS FAIL caution will be displayed on the EICAS.

Flap extend and retract relays

Control of the flap motors and the BDU is through four relays[8] with one extend and one retract relay in each of the two motor channels. The relays are identical and contain four sets of contacts identified as A, B, C and D. Each contact consists of two parts, a stationary contact and a moving contact. All four moving contacts are mounted on a single 'rocker' assembly, so if one set of contacts sticks, it can stop the other contacts from changing state.

Footnote

[8] Part number K-D4L-050.

The schematic layout of the relay is shown in Figure 3.

- Contacts A1, B1, C1 and D1 are normally OPEN.
- Contacts A2, B2, C2 and D2 are the input to be switched.
- Contacts A3, B3, C3 and D3 are normally CLOSED.
- Contacts +X1 and -X2 are for the operating coil.

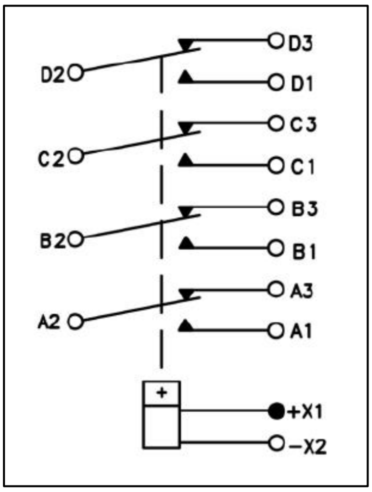


Figure 3
Schematic of relay arrangement

Relay contacts A, B and C are used to switch each of the three 115 V AC phases to the flap drive motors. The D contacts switch the 28 V DC power supply to the BDU brake solenoid coils, which are an inductive load. The manufacturer's datasheet for the relay states that, for an inductive load, the relay contacts are specified for a minimum operating cycle life of 20,000 operations.

The aircraft manufacturer reported that the relays are sourced as commercial off-the-shelf components (COTS). During this investigation the aircraft manufacturer established that the relay manufacturer changed the contact material in 1993; no amendments were made to the relay datasheet.

The aircraft manufacturer also observed that the shape of the contacts on relays taken from one aircraft, no longer in-service, were a different shape to the contacts in relays removed from in-service aircraft as part of this investigation.

Brake Detector Units

The aircraft has two BDUs. Each consists of a 28 V DC solenoid operated brake and a speed sensor detector unit (Figure 4). To provide redundancy each brake solenoid has two operating coils, one powered by each operating system, and each system powers an operating solenoid in each of the two BDUs; these are connected in parallel. The brake solenoids are energised to release the brake and are de-energised to apply the brake.

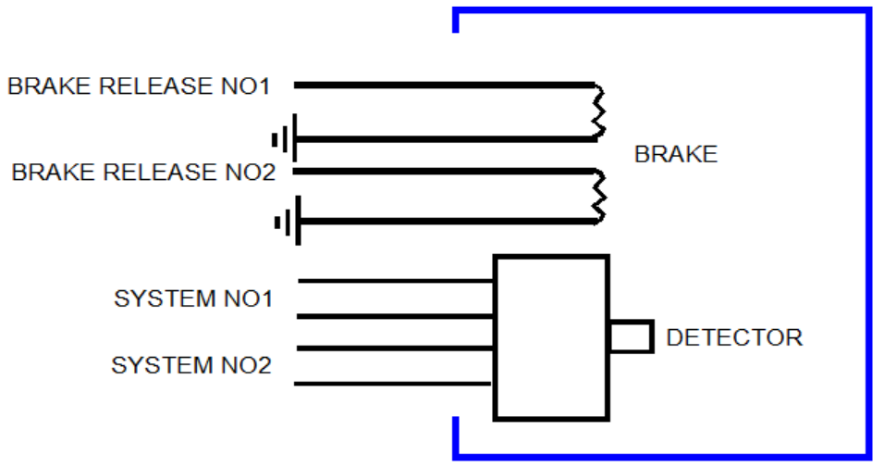


Figure 4

Schematic of BDU Brake Solenoid arrangement

Uncommanded flap movement arrest system

The FCU monitors for uncommanded movement of the flaps. If the flap position provided by the PDU exceeds the commanded position by more than 3°, the FCU activates the flap arrest system to apply power to both flap motor extend and retract relays. This:

- Engages the flap brakes, by de-energising the BDUs.
- Removes power from both flap drive motors, arresting their movement.

At the same time a FLAPS FAIL caution is displayed on the EICAS. This condition remains latched until the FCU power is cycled.

PDU flap position sensor fault protection

The FCU monitors the PDU flap position sensor for faults. If a short circuit to the sensor supply voltage or a loss of the sensor output signal occurs for more than about 7 milliseconds (ms), the FCU simultaneously provides power to the flap motor extend and retract relays. This removes power from both flap drive motors and engages the flap brakes, and a FLAPS FAIL EICAS caution is displayed. This condition remains latched until the FCU power is cycled.

Flap lever fault protection

If more than one flap lever position signal is simultaneously received by the FCU, power is removed from the flap motor extend and retract relays and a FLAPS FAIL EICAS caution is displayed. This condition remains latched until the FCU power is cycled.

Maximum flap operating speeds

The maximum flap operating speeds are shown at Table 1:

Flap setting	Maximum operating speed (V_{FE})
20°	231 KIAS
30°	197 KIAS
45°	189 KIAS

Table 1

Maximum flap operating speeds

If the flap lever is set to a flap position other than flap 0, and the aircraft's airspeed is above the limiting speed for that position, an aural 'clacker' warning will sound in the cockpit and an overspeed awareness cue will be presented on the airspeed tape on the PFD. The aural clacker will not sound in the event of an uncommanded flap movement when the flap lever remains at flap 0.

Flight Recorders

Recorded data

Data for the occurrence flight was available from the aircraft's FDR, which provided a recording of the last 154 hours of operation and the aircraft's previous 64 flights. The FDR parameters included the aircraft's indicated airspeed, the position of the flap lever and right-wing flaps. The CVR recording of the incident flight had been overwritten during subsequent maintenance activity, which had taken place prior to the AAIB being informed of the occurrence. The aircraft's track during the flight was captured by radar and recordings of RTF communications with the flight crew were also available.

Interpretation of recorded data

Prior to takeoff, the flaps extended to 20° at the normal rate of about 2.4°/sec. During their retraction after takeoff, they moved at half the normal speed at about 1.2°/sec.

As the aircraft climbed through FL190, at a recorded airspeed of 305 KIAS, the flaps started to extend while the flap control lever remained in the flap 0 position (Figure 5, Point A). The rate at which the flaps extended was about 1.1°/sec. The flaps extended at a near linear rate from the flap 0 position, with no evidence of prior flap creep[9]. The autopilot remained engaged, and the aircraft's speed started to progressively reduce while the aircraft pitched down from 4° nose-up. Shortly after, a FLAPS FAIL caution was recorded which occurred when the flaps had extended by about 3°.

As the flaps reached 20°, the airspeed was 296 KIAS which was 65 kt above flap 20 V_{FE}. This coincided with the flight crew disconnecting the autopilot and reducing engine thrust from

Footnote

9 Where the flaps gradually extend by a small amount but then stop for a period of time before extending again.

91% to 47% N1 (Figure 5, Point B). The flaps continued to extend over the next 21 seconds until reaching 45° where they stopped, at which point the airspeed was 234 KIAS, 45 kt above flap 45 V_{FE} (Figure 5, Point C).

The aircraft's speed continued to reduce over the next 10 seconds, and as it approached 200 KIAS the crew started to increase engine thrust. This coincided with the aircraft starting to descend, having briefly climbed to FL200. The crew subsequently stabilised the aircraft's speed at about 183 KIAS with the engine thrust set at 92% N1. The autopilot was then engaged (Figure 5, Point D), and the aircraft levelled off at FL150. The flaps had experienced an overspeed for a period of about 170 seconds, which was the time between the flaps starting to extend from 0° and the airspeed stabilising at just below 189 KIAS with the flaps at 45°. During this period, the maximum flap overspeed was about 103 KIAS.

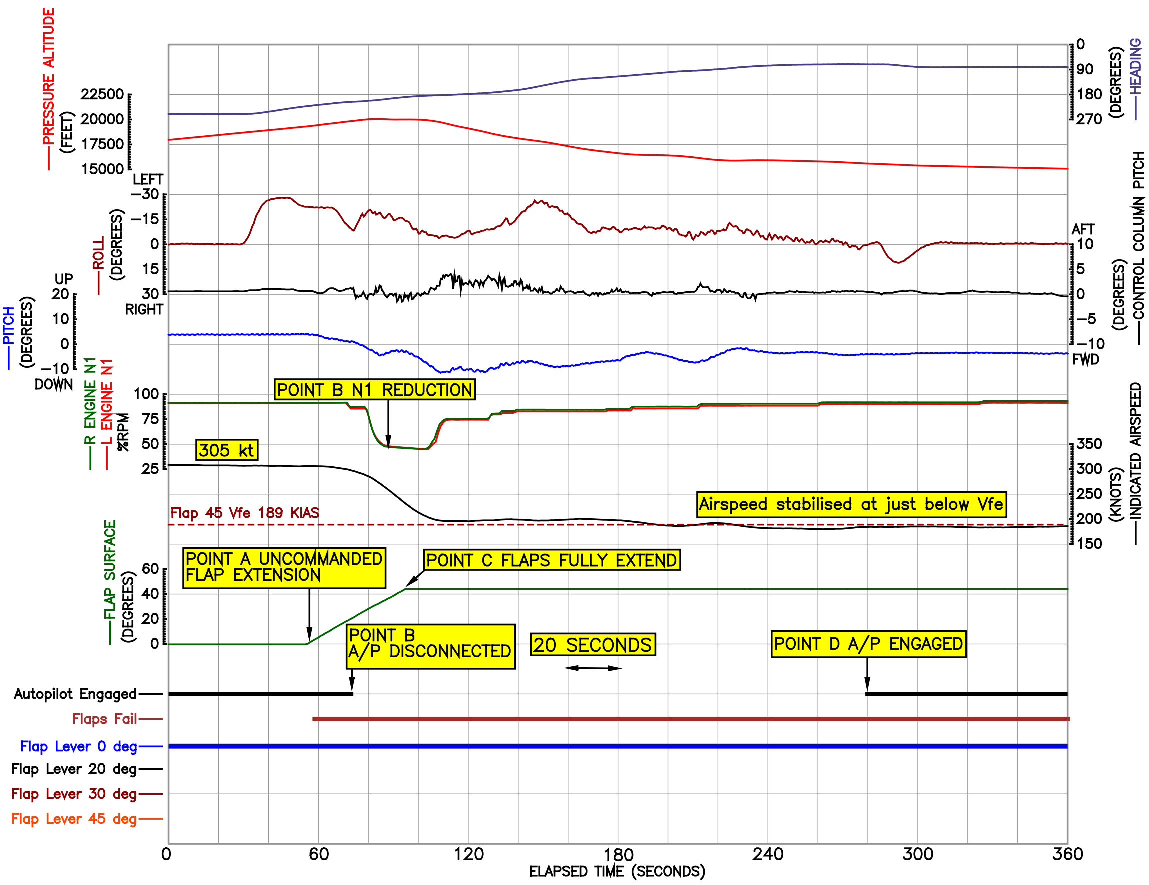


Figure 5

FDR data of uncommanded flap extension

During the 64 previous flights recorded on the FDR, flap extension occurred at normal speed, but retraction was at half-speed. There was no evidence in these flights of uncommanded movement of the flaps or flap creep. The oldest flight recorded on the FDR was on 4 July 2022.

Review of FDR data from Aircraft 2, 3 and 4

FDR data from Aircraft 2, 3 and 4 showed the following:

> Aircraft 2 FDR download contained 260 flights recorded between 22 May 2022 and 30 December 2022. From the 6 October 2022 onwards, the flaps extended at half-speed. During all the recorded flights, the flaps retracted at normal speed.
>
> Aircraft 3 FDR download contained 34 flights recorded between 22 November 2022 and 11 January 2023. During all the recorded flights, the flaps extended at half-speed and retracted at normal speed.
>
> Aircraft 4 FDR download contained 25 flights recorded between 22 December 2022 and 17 January 2023. During all the recorded flights, the flaps extended and retracted at normal speed.

Aircraft examination

Findings prior to AAIB involvement

Engineers from a maintenance organisation began fault finding on D-AAAY after it landed. During this activity the aircraft was left unattended with electrical power applied and after approximately two hours, the flaps moved to their fully extended position, despite the flap lever being in the flap 0 position.

Testing and examination

The aircraft manufacturer, maintenance organisation and the AAIB worked closely during the extensive on-aircraft testing and examination, which included:

- Visual checks, where possible, of the electrical wiring, connectors and components in the flap operating system.
- Voltage, resistance, and continuity checks.
- Testing of the flap operating system using dedicated test equipment (break-out box). The tests were conducted with the existing and replacement flap extend and retract relays fitted.
- Structural examination of the flaps.

Structural damage

The flaps and associated structure were undamaged, but as a precaution the aircraft manufacturer recommended the replacement of several bolts and fasteners.

Findings

The examination and testing of the aircraft found that:

- No cause could be identified for the uncommand extension of the flaps.
- The flaps extended at normal speed but retracted at half-speed.
- The BDUs became warm when the flaps were not operating, indicating that electrical power was still being supplied to them when they should have been de-energised.
- When the No 1 flap retract relay was replaced the flaps operated at the normal speed during extension and retraction.

Scheduled check of the operation of the flaps

A check of the flap extension and retraction time is included in a regular inspection of the flap system. This is carried out every 600 flight hours on the Challenger 600 and 601 aircraft and every 1,200 flight hours on the Challenger 604, 605 and 650 aircraft.

A functional check of the uncommanded flap movement arrest system is carried out every 4,800 flying hours on the Challenger 604, 605 and 650 aircraft. At the time of this occurrence, D-AAAY had flown 8,151 hours and the last check was carried out in December 2018, approximately 1,696 flight hours prior to the occurrence.

Recent maintenance on the flap operating system

D-AAAY had recently undergone a 96-month *'Major Check'*, which was completed in June 2022. The only work carried out on the flap system at this time was the replacement of one flap ball-screw actuator.

In August 2021, approximately 500 flight hours before this occurrence, the PDU flap position sensor was replaced. The technical records stated that the reason for the removal was '*flap fail at 45 degrees. Intermittent signal loss during flap movement.'* As part of the maintenance task, an operational test of the flaps was carried out which included measuring flap extension and retraction time; they were both within acceptable limits. The removed flap position sensor was subsequently tested by its manufacturer and no fault was found.

Manufacturer's Service Bulletins

Requirement

On 29 December 2022, the aircraft manufacturer issued five SBs for operators to check the flap system on the Challenger 600 series of aircraft.

The SBs recommended an operational test to verify the extension and retraction time of the flaps. The test was to be carried out within 100 flight hours, and repeated every

100 flight hours for 600/601 series aircraft and every 400 hours for 604/605/650 series aircraft. The frequency of the checks aligned with existing scheduled maintenance tasks. On 10 February 2023, Transport Canada issued an Airworthiness Directive requiring the initial test to be carried out within 100 flight hours or 15 months, and repeated at the interval specified in the relevant SB.

Initial findings from the Service Bulletins

On 9 January 2023, the AAIB was contacted by the operator of D-AAAY after two of their Challenger 604 aircraft failed the SB because the flaps were operating at half-speed. The AAIB deployed a field team who, with representatives from the aircraft manufacturer, undertook an examination and test of the flap system. The operator also permitted the examination of a third Challenger 604 aircraft where the flaps had operated at the normal speed during the test. The extend and retract relays from these three aircraft were examined as part of the AAIB investigation. The following summarises the significant findings from the aircraft testing:

<u>Aircraft 2</u>

Aircraft 2 was manufactured in 2006 and had accumulated 10,300 hours and 4,687 flight cycles since new.

The results of the test were as follows:

- The flaps extended at half-speed; the flap retraction speed was normal.
- A break-out box was connected between the aircraft and the FCU to allow a functional test of the uncommanded movement arrest system to be conducted and the following was observed:
  - During step E3 of the procedure, the system operated normally; flap movement stopped within the specified limits and a FLAPS FAIL caution was annunciated on the EICAS display.
  - During Step E8 of the procedure, the system did not operate normally; the flaps stopped at 20° without the expected, slight, overtravel and the expected FLAPS FAIL caution did not annunciate on the EICAS display.

Following extensive testing during which the flaps continued to extend at half-speed, the flaps started operating normally without any corrective action having been taken. The cause of the half-speed flap operation was believed to be sticking contacts in the No 1 flap extend relay.

All four extend and retract relays were replaced and examined as part of this safety investigation.

Aircraft 3

Aircraft 3 was manufactured in 2000 and had accumulated 8,915 hours and 4,344 flight cycles since new. The results of the test were as follows:

A break-out box was connected between the aircraft and the FCU to allow a functional test of the uncommanded flap movement arrest system to be conducted.

- During Step E3 of the procedure the system did not operate normally; the flaps stopped at 20° without the expected slight overtravel and the expected FLAPS FAIL caution was not annunciated on the EICAS display.

- During Step E8 of the procedure the system did not operate normally. The flaps moved past 20° and stopped momentarily at 23° and a FLAPS FAIL caution was annunciated, which was as expected. But the flaps then retracted, uncommanded, until reaching the up-limit stops; the No 2 motor circuit breaker tripped after the flaps had been in this position for a few seconds.

Extensive testing of Aircraft 3 established that the contacts on the No 2 motor extend relay were stuck in their energised positions. The relay was replaced, and the system operated normally.

Aircraft 4

Aircraft 4 was manufactured in 2002 and had accumulated 6,487 hours and 4,241 flight cycles since new.

The SB was carried out and the flaps were found to operate normally. As a precaution, and to provide additional evidence to the safety investigation, the operator replaced the four extend / retract relays so that they could be examined by the AAIB.

Examination of the flap extend and retract relays

Relays removed from D-AAAY

The relays from D-AAAY were subject to electrical testing and forensic examination. The testing found that the contacts in the No 1 retract relay did not always change state (switch) when the relay coil was energised.

When the relays were disassembled, the D contacts were found to exhibit varying amounts of damage that was typical of electrical arcing:

- On the No 1 extend relay, material had transferred from the moving contact to the stationary contact which reduced the airgap between the contacts.
- On the No 2 extend relay, the contact was significantly discoloured (blueing) indicating that it had been subject to localised heating. There was no significant material transfer between the moving and stationary contacts.
- On the No 1 retract relay, the material forming the stationary contact had melted and reformed and there was distortion of the moving contact which reduced the airgap. Figure 6 shows the damaged D contact alongside the undamaged C contact.

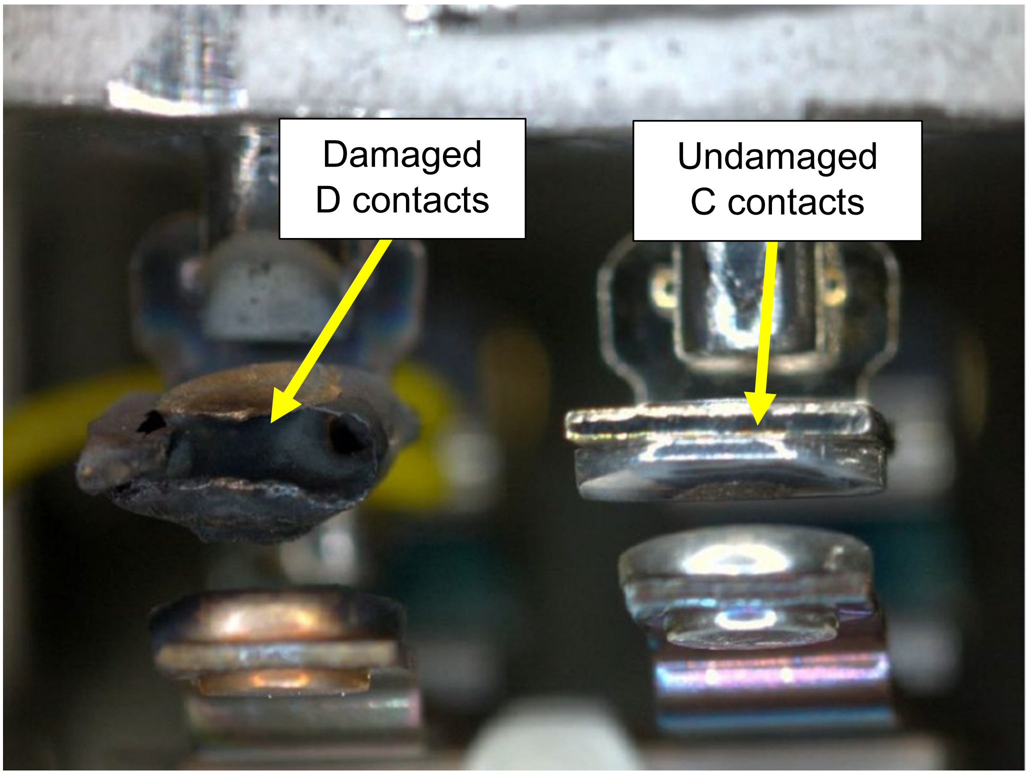


Figure 6

Damaged D contact (left) and undamaged C contact (right)

Relays from Aircraft 2, 3 and 4

Externally, the relays from Aircraft 2, 3 and 4 appeared to be in good condition; however, computerised tomography scanning found damage on some of the D contacts. In comparison, no obvious damage was found on the A, B or C contacts. The significant findings from the examination of the relays from the three aircraft was as follows:

Aircraft 2

There was evidence of erosion and material transfer between the D contacts on the No 1 extend relay (Figure 7). It is possible that the contacts were initially welded together, which would explain why the flaps extended at half-speed during the on aircraft testing. Failure of the weld after the flaps had been cycled a number of times would allow the contacts in the relay to move, and the flaps operate at their normal speed.

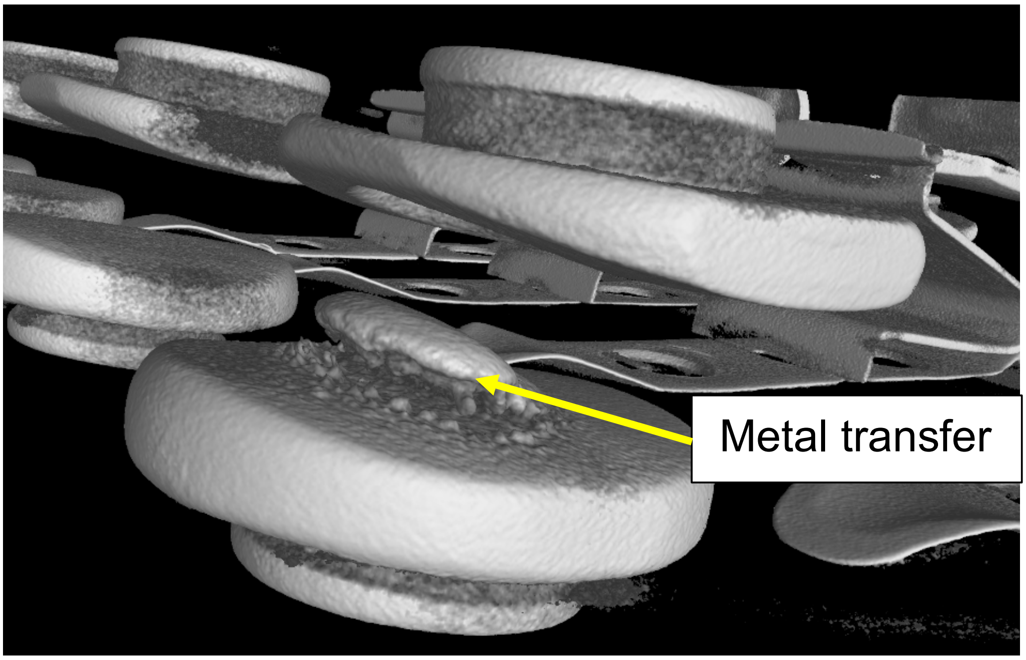


Figure 7

Erosion and metal transfer on the D contacts

The No 2 extend relay, which had been in-service for approximately 2,700 flight hours and 1,372 flight cycles, showed evidence of material erosion and transfer between the D contacts (Figure 8). The aircraft maintenance records showed that this relay was fitted in April 2018 following a defect that generated a FLAPS FAIL EICAS caution; it was found that the BDU brake solenoids were permanently energised.

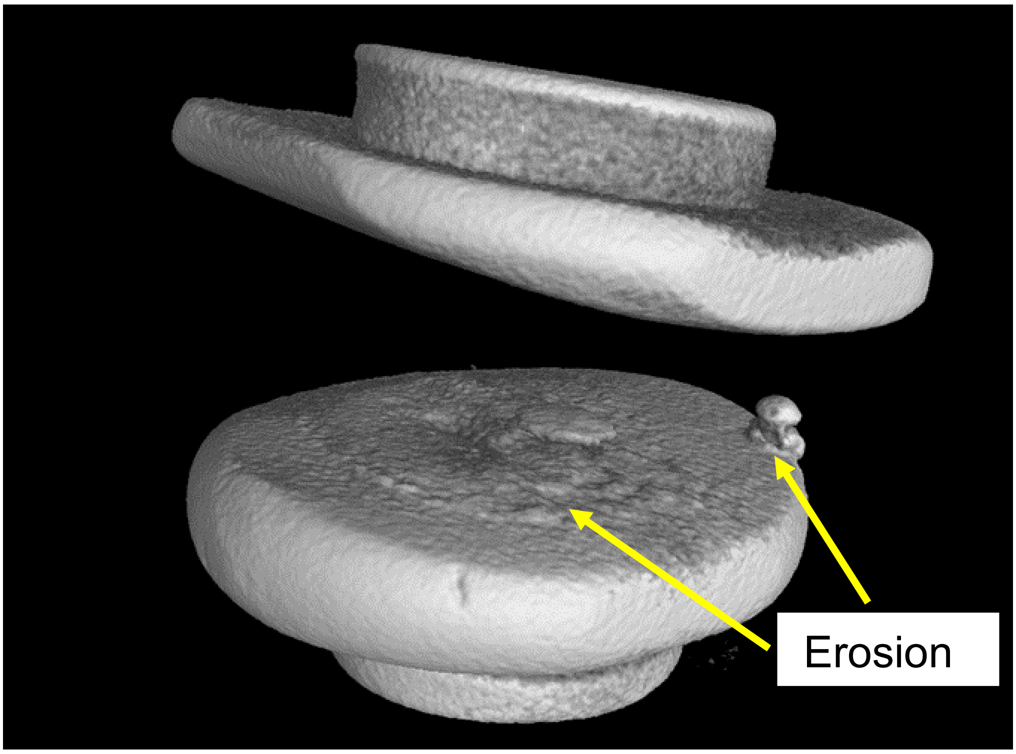


Figure 8
Material erosion on D contact

Aircraft 3

The D contacts on the No 2 extend relay were welded closed (Figure 9). In normal operation, when the relay is in a de-energised condition, these contacts would be open. In the welded condition, if the uncommanded flap movement arrest system was activated, the flaps would retract instead of their movement being arrested. This was observed during the testing of Aircraft 3.

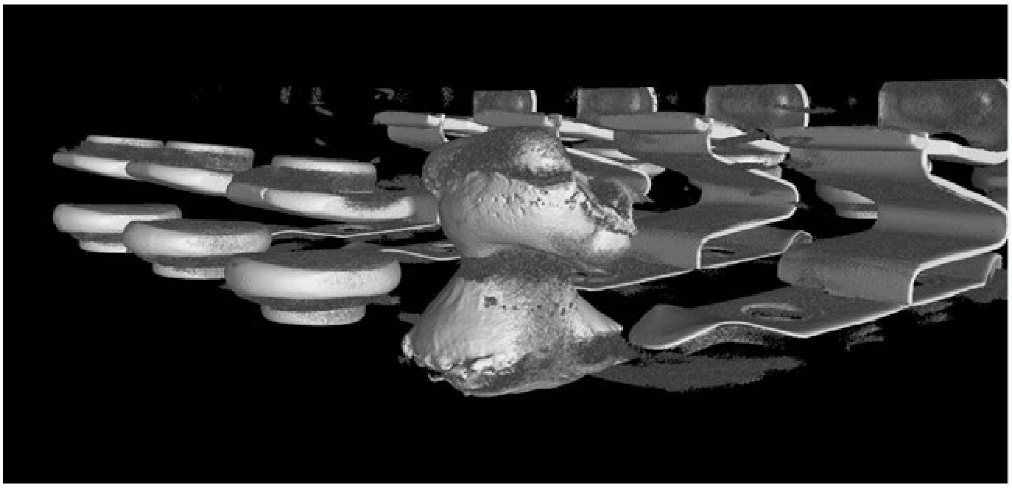


Figure 9
D contacts welded closed

Aircraft 4

While the flaps operated normally during testing, on the No 1 retract relay, material had transferred across the D contacts. This damage was typical of electrical arcing, which leaves a 'pit' where material is eroded and a 'pimple' where it accumulates (Figure 10).

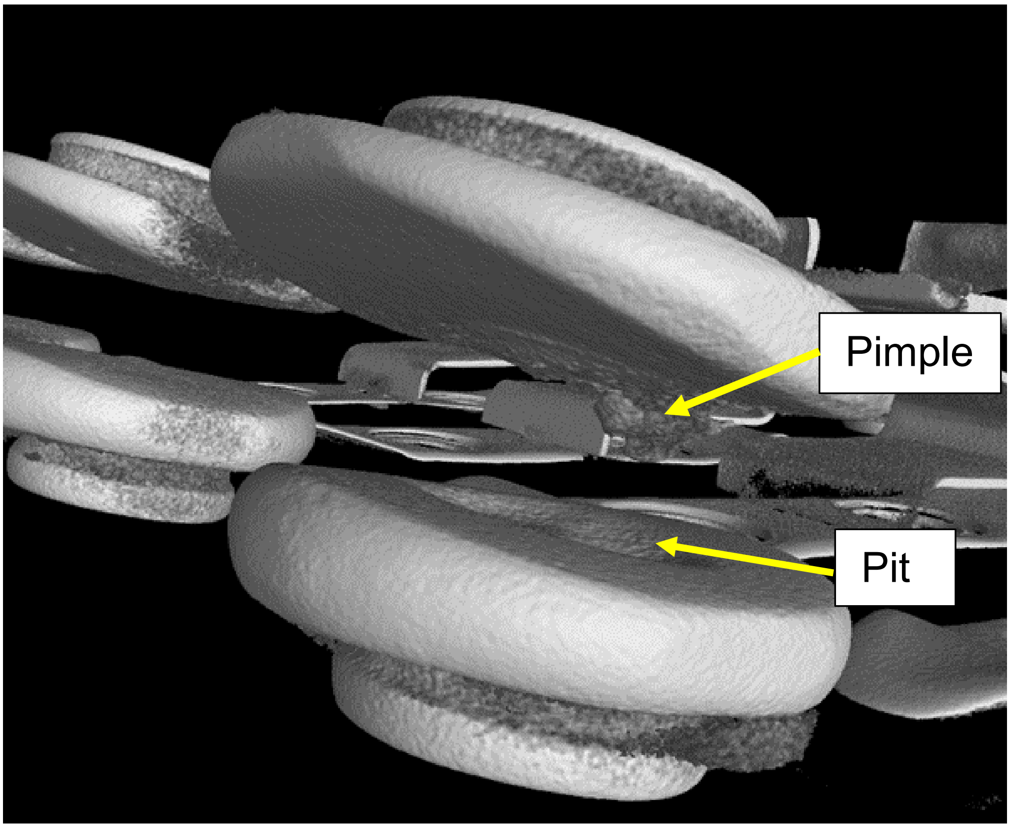


Figure 10
Metal transfer between the D contacts as seen by the pit and pimple effect

Examination of the Brake Detector Units

Independent testing commissioned by the AAIB

The resistance of the BDU brake solenoid coils was within specification.

The current and voltage during solenoid switching was measured using an oscilloscope (Figure 11). When the solenoid was de-energised a maximum transient voltage spike of 300V was seen; this spike regularly exceeded 150V during repeated switching of the BDU. The voltage spike is caused by a back electro motive force (EMF), which occurs when removing electrical power from inductive loads such as the solenoid coils. There was no protection or suppression provided within the flap operating system to prevent or reduce this back-EMF, which could cause arcing across the D contacts.

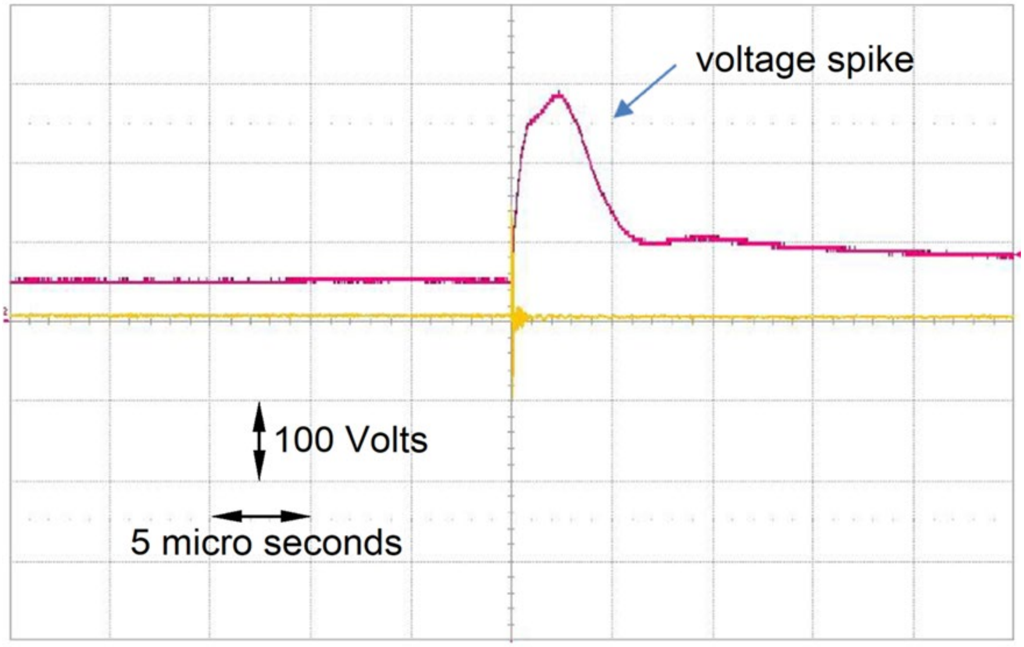


Figure 11

Oscilloscope output showing voltage spike after de-energising coil

Testing performed by the aircraft manufacturer

The aircraft manufacturer explored the electrical switching characteristics of the BDUs during laboratory tests and on a representative aircraft. Their testing indicated that the damage to the D contacts of the relay was probably associated with a back-EMF and arcing under initial low voltage, high current conditions.

The aircraft manufacturer is conducting additional testing to support their response to the safety recommendations made during this investigation.

Examination and testing of flap operating system components

Detailed examination of the FCU, PDU, and flap position sensor from D-AAAY were carried out at their respective manufacturer's facilities. No faults were found during testing that would have caused the uncommanded flap movement or contributed to the flap arrest system failing to operate correctly.

Testing of the FCU showed that if the flap position sensor signal was lost for more than about 7 ms, the FCU would apply power to both the extend and retract relays and the FLAPS FAIL caution would be displayed on EICAS. Testing of the flap position sensor included a check for an intermittent loss of signal of greater than 1ms. No fault was found.

The manufacturer of the flap position sensor advised that of the 116 sensors tested during the previous five years, one sensor had failed the intermittent signal test. No details were available as to whether the fault was repeatable or not.

Examination of flap actuators

Following the serious incident the maintenance organisation removed three of the eight flap actuators from D-AAAY after finding 'excess play'. The actuators are classified as 'oncondition[10]' and the hours / cycles since installation were:

Actuator	Hours since installed	Cycles since installed
Left inboard flap inner	5,791	2,926
Left inboard flap outer	8,151	3,847
Right outboard flap inner	8,151	3,847

Uncommanded flap movement on a second aircraft

The aircraft manufacturer advised that they had investigated an uncommanded flap movement that occurred on a second Challenger 604 on three occasions during March and April 2023.

On the first occasion the operator reported that the flaps "failed" at 2° while the aircraft was on the ground with the engines running. The crew reset the flap control circuit breakers and the flaps extended, uncommanded, to 45° after which the No 2 flap motor circuit breaker tripped. The flap lever and the flap control circuit breakers were reset, and the flaps extended normally. The aircraft departed with the No 2 flap motor circuit breaker tripped.

On the second and third occasion the operator reported that the flaps "failed" on the ground while extending to 20°. On both occasions the crew reset the flaps and continued the flight. On the second occasion, when the flaps were commanded to retract after takeoff, they retracted to 18°, where they stopped for around 20 seconds before extending uncommanded to 45°. On the third occasion they retracted to 14°, where they stopped for around 20 seconds before extending uncommanded to 30° where they stopped for around 7 seconds before extending to 45°. During both flights, the movement of the flaps (retract and extend) was at half-speed and the No 2 flap motor circuit breaker tripped when the flaps reached 45°. After the pilots carried out a flap reset, by cycling the flap circuit breakers, the flaps were reported to have worked normally.

The manufacturer reported that the FDR data showed that the flaps had been retracting, and occasionally extending, at half-speed for some time. The manufacturer's SB, which had been issued on 29 December 2022 to verify the extension and retraction time of the flaps, had not been carried out.

The manufacturer's assessment of the FDR data from the three fights was that the flaps 'crept' when the engines were running. This 'creep' would have gone unnoticed until the flaps had travelled 3° from their selected position, when the uncommanded flap movement protection system would operate. They concluded that a dormant failure in one of the flap control relays had prevented the flap protection system from stopping the movement, and instead caused the flaps to fully extend at half-speed.

Footnote

10 On-condition maintenance is only performed when the condition of an item requires it.

The manufacturer reported that wear and backlash was found in the flap operating system. They concluded that flaps travelling at half-speed could excite the natural frequency of the flap driveshaft, potentially leading to increased wear and backlash in the flap operating mechanism. This would make the system more susceptible to flap 'creep' under vibration.

Certification standard

The Type Certificate[11] for the Challenger 604 aircraft was issued by Transport Canada and, with a number of listed exemptions, is compliant with Title 14 of the Code of Federal Regulations Part 25 (FAR 25).

FAR 25.1309 covers equipment, system and installations and the following sections are applicable to the arrest of an uncommanded flap movement:

> *'(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that -*
>
> > *(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and*
> >
> > *(2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.'*

Flight safety risk

As part of the certification process for the aircraft, a safety analysis was conducted by the aircraft manufacturer. For the flap system, a Fault Tree Analysis was conducted which considered multiple failures and identified an uncommanded and unarrested flap extension in cruise as a potentially catastrophic event. The analysis concluded that this would require two concurrent failures, and the probability of this occurring was calculated as being extremely improbable[12].

The manufacturer's original safety case considered that failure of a relay would go undetected for one flight at most. It was assumed that the flight crew would observe that the flaps were either extending or retracting at half-speed.

Endurance testing

The aircraft manufacturer carried out endurance testing as part of the Challenger aircraft certification programme. This included rig testing the flap system and the related electrical components and wiring.

Footnote

[11] Transport Canada, Type Certificate Data Sheet, Number A-131, Issue 18, Issue Date September 20, 1995.
[12] FAA Advisory Circular 25.1309-1A, which outlines acceptable means of compliance, defines extremely improbable as '*failure conditions are those so unlikely that they are not anticipated to occur during the entire operational life of all airplanes of one type*'.

Test reports indicated that the flaps were operated for 67,880 extend operations and 40,728 retract operations; the manufacturer said that this equated to 16,970 flight cycles (extend) and 20,364 flight cycles (retract)[13]. No relay failures were mentioned in the endurance test reports and no records could be found to show the internal condition of the relays at the end of the testing.

Communications

Communication with ATC during the flight

Following the occurrence, the crew of D-AAAY informed ATC that they were descending to FL100. From this communication up to their final vectors for an ILS approach at Farnborough, the crew were asked if they were declaring an emergency on five separate occasions by air traffic controllers on London Control and Farnborough Radar frequencies. At each prompt the crew declined to declare an emergency; however, they did request Farnborough Radar to "ARRANGE PRIORITY" for the ILS approach.

Guidance to pilots

The CAA publishes Civil Aviation Publication (CAP) 413 '*Radio telephony Manual'* and CAP 493 '*Manual of Air Traffic Services – Part One'.* These CAPs are based on national and EU legislation, and ICAO Standards and Recommended Practices. They are published to provide guidance and clarification on the means of complying with UK regulatory requirements.

CAP 413 provides the following guidance to pilots:

> *'Pilots are urged – in their own interests – to request assistance from the emergency service as soon as there is any doubt about the safe conduct of their flight. <u>Even then, the provision of assistance may be delayed if a pilot does not pass clear details of their difficulties and requirements, using the international standard RTF prefix 'MAYDAY, MAYDAY, MAYDAY' or 'PAN PAN, PAN PAN, PAN PAN' as appropriate'</u>.*

In CAP 493, the CAA informs air traffic controllers that,

> *'Pilots have been advised that, in the event of an emergency situation, an ATSU can only provide the necessary priority and handling if the controller is made aware of the emergency by the crew's formal declaration on the RTF. Pilots have also been advised that the extent to which an ATSU will be able to offer assistance will depend on the amount of information provided and on its being transmitted at the earliest opportunity. Furthermore, it is preferable that if pilots believe that they are facing an emergency situation, to declare it as early as possible and cancel it later if they decide that the situation allows'.*

Footnote

[13] The aircraft manufacturer assumed four flap extension selections per flight and two flap retraction selections.

and that,

> *'When a pilot has given certain items of information normally associated with an emergency message but has not prefixed the transmission with 'MAYDAY' or 'PAN', the controller is to ask the pilot if he wishes to declare an emergency. If the pilot declines to do so, the controller may, if he thinks it appropriate, carry out the necessary actions as if the pilot had declared an emergency.'*

In the absence of a declaration of an emergency by the pilot, the nature and extent of the actions taken by the controller can be open to individual interpretation. National Air Traffic Services (NATS) explained that when an aircraft is transferred between controllers, the interpretation of each controller may change, especially in situations of high workload. A PAN or MAYDAY call removes the potential for ambiguity and can play an important part in the safe and successful resolution of an emergency.

Action taken by the Operator of D-AAAY

Following the finding of damage to the D contacts on four of their Challenger 604 aircraft, the operator introduced their own precautionary life policy for the flap extend and retract relays.

Analysis

Introduction

The uncommanded and unarrested extension of the flaps was classified by the manufacturer during certification as a potentially catastrophic event that would have required an initiating event to cause the flaps to extend, and then for the uncommanded flap movement arrest system not to stop the movement.

The investigation did not identify the reason for the uncommanded flap movement. It did, however, establish that the flap movement was not arrested due to a latent failure within the No 1 flap retract relay.

Possible causes for the uncommanded flap extension on D-AAAY

The following scenarios were considered by the investigation as possible causes for the uncommanded flap extension on D-AAAY

<u>Erroneous flap lever command</u>

If an erroneous signal from the flap lever was provided to the FCU to extend the flaps, power would be applied to both flap motors causing the flaps to extend at normal speed. However, the flaps extended at half-speed, indicating that only one motor was powered. This reduction in the flap speed would have required an additional fault with one of the extend relays, but there was no evidence of the flaps having extended at half-speed during the previous 64 flights recorded on the FDR.

An erroneous flap lever signal would not cause a FLAPS FAIL EICAS caution to be displayed, but this caution was seen by both pilots and recorded on the FDR as having been generated. An erroneous signal from the flap lever to extend the flaps would have also resulted in the aural 'clacker' warning in the cockpit but the pilots did not report hearing this.

Therefore, the scenario that an erroneous signal from the flap lever caused the flaps to extend is considered unlikely.

FCU internal fault

Two possible scenarios were considered that might have resulted from an internal fault in the FCU:

- If either the No 1 or No 2 flap drive motor extend signals were inadvertently powered due to a fault in the FCU, the flaps would start to extend at half-speed. Upon exceeding 3° flap, the uncommanded flap movement arrest system would activate and apply power to both extend and retract relays. A FLAPS FAIL caution would also be displayed on the EICAS. Due to the fault in the No 1 flap retract relay, the flaps would continue to extend at half-speed.

- A FCU fault causing the inadvertent activation of the uncommanded flap movement arrest system, in conjunction with a fault within the No 1 flap retract relay, could also have resulted in the flaps extending at half-speed. A FLAPS FAIL caution would also be displayed on the EICAS.

During testing of the FCU neither of the No 1 or No 2 flap drive motor extend signals inadvertently activated. However, the possibility that an intermittent fault existed, but could not be replicated during testing, could not be discounted.

PDU flap position sensor intermittent signal

If the flap position sensor signal was lost for more than about 7 ms, the FCU would apply power to both the extend and retract relays and the FLAPS FAIL caution would be displayed on the EICAS. The flaps would have then extended at half-speed because of the fault in the No 1 flap retract relay.

No fault was found during testing of the flap position sensor during checks of the aircraft wiring between the flap position sensor and the FCU. However, it is possible that the initial fault-finding activity carried out prior to the AAIB commencing their investigation, which included disconnecting electrical connections, may have cleared a fault.

A review of the component records showed that of the 116 sensors tested during the previous five years, one sensor had failed the intermittent signal test.

Although no fault was found during testing of the flap position sensor, the possibility that an intermittent fault existed but was not replicated during testing could not be discounted.

Fault in the aircraft wiring – flap extend relays

A fault in the electrical wiring that lasted for a continuous period of at least 40 seconds, would have been required in order for electrical power to be provided to either the No 1 or No 2 flap extend relays to cause the flaps to fully extend. However, initial testing and fault finding on the aircraft prior to and after the AAIB began their investigation did not identify a wiring fault. Therefore, this scenario is considered unlikely.

Aircraft manufacturer's scenario for the uncommanded movement of the flaps

Following three occurrences of uncommanded flap movement on a second aircraft, which was investigated by the aircraft manufacturer, the manufacturer concluded that wear and backlash in the flap operating system was sufficient for the flaps to 'creep', under airframe vibration when the engines were running. When this movement reached 3° it caused the flap protection system to operate and a dormant failure in a flap relay then caused the flaps to fully extend at half-speed. The aircraft manufacturer considered this scenario to be the most likely explanation for the uncommanded flap movement on D-AAAY.

This scenario cannot be discounted as a possible explanation for D-AAAY, but the AAIB considers it unlikely because the FDR data from D-AAAY did not show any evidence of flap 'creep' during the previous 64 flights or during the event. Additionally, the uncommanded movement on D-AAAY occurred when the aircraft was stationary on the ground and the engines were not running.

Failure of the uncommanded flap movement arrest system

The arrest of an uncommanded flap movement relies on the four extend / retract relays operating correctly to remove electrical power to the flap motors. Evidence from aircraft inspected by the AAIB shows that these relays can fail and prevent correct operation of the uncommanded flap movement arrest system.

The failure of the relays on three aircraft inspected by the AAIB was caused by damage to the D contacts, which switch electrical power to the BDU brake solenoids. The damage was consistent with arcing between the contacts, which caused metal transfer and contact welding. As all the moving contacts in the relay are mounted on a common rocker, the welding of one set of contacts can stop the other three sets of contacts from working properly. Examination of relays provided to the investigation, which had not failed in-service, also found damage to the D contacts, showing that the damage accumulates over a period of time.

During testing, when the BDU brake solenoids were de-energised a back-EMF was observed, which could cause arcing across the D contacts in the flap relay. As the flap system on the Challenger aircraft has no protection to suppress this back-EMF, the following Safety Recommendation was made to Bombardier Aviation on 1 March 2023:

Safety Recommendation 2023-004

It is recommended that Bombardier Aviation introduce a modification on the Challenger 600 series of aircraft to protect the D contacts within the extend and retract relays of the flap operating system from unsuppressed back-EMF electrical arcing.

Response from Bombardier Aviation

Bombardier Aviation responded on 4 June 2023 that they are:

'…still collecting data and evaluating potential design changes to address the findings from the investigation. The AAIB's specific proposals will be taken into consideration. Bombardier has committed to introducing a design change to the Challenger 604/605/650 flaps system no later than February 28th, 2025, and a design change to the Challenger 600/601 flaps system no later than November 30th, 2025.'

AAIB assessment of response

The AAIB assessed the response to Safety Recommendation 2023-004 as Partially Adequate (Open) and provided the following feedback:

'The planned action by Bombardier Aviation meets the intent of the Safety Recommendation to prevent damage to the flap operating relays from unsuppressed back-EMF electrical arcing. The AAIB would request an update on the revised design and its implementation by 28 March 2024.'

The rate of accumulating damage on the D contacts is not known. The manufacturer's datasheet for the relays shows a minimum inductive load life of 20,000 operating cycles. Exceeding this life does not necessarily mean that a relay will fail, but it is a reasonable assumption that failure will become more likely as the relay moves towards, or into, its end-of-life operating phase. During a typical flight it is assumed there will be four flap extensions and two flap retractions, with each selection energising and de-energising the BDU brake solenoids. Consequently, the relays would reach their minimum operating life after approximately 5,000 flight cycles for the extend relays and approximately 10,000 flight cycles for the retract relays. The three aircraft on which the relays failed had flown 4,687 (extend), 4,344 (extend) and 3,900 (retract) flight cycles respectively. Certification testing replicated 19,970 (extend) flight cycles and 20,364 (retract) flight cycles without failure, but the condition of the relay contacts after this testing is not known.

Airworthiness Directive AD CF-2023-07 requires a timing check on flap movement to be conducted within 100 flight hours or 15 months and, dependent on aircraft variant, repeated every 100 or 400 flight hours. This check will determine if a relay has failed, but it does not assess the condition of the contacts and will not identify a degraded relay that is close to failure or is operating intermittently.

The aircraft maintenance programme does not reflect the component manufacturer's suggested minimum life of 20,000 operating cycles, but instead allows the relays to remain fitted until a failure is detected. However, this safety investigation established that detection of a failed relay can be many flight hours after the failure occurred. As the correct function of these relays is required for the operation of the safety critical uncommanded flap movement arrest system, the following Safety Recommendation was made to Bombardier Aviation on 1 March 2023:

Safety Recommendation 2023-005

It is recommended that Bombardier Aviation introduce a life policy for the flap operating system relays on the Challenger 600 series of aircraft, which takes account of the component's specified life and is sufficient to ensure that any in service damage on the D contacts on the extend and retract relays remains acceptable for continued operation.

Response from Bombardier Aviation

Bombardier Aviation provided an initial response on 4 June 2023 and the following response on 27 October 2023.

'Bombardier has evaluated the risk to the fleet following an industry-standard continuing airworthiness risk assessment process. This process has resulted in several mitigation actions being taken by Bombardier, as well as a terminating action to address the safety risk to the fleet, as outlined below.

On December 29th, 2022, Bombardier published Service Bulletins recommending initial and repeat measurement of the flap extension and retraction times in order to detect faulty flap relays. These Service

Bulletins have since been mandated via Airworthiness Directive (AD) by Transport Canada, EASA, and the FAA.

On January 30th, 2023, Bombardier's Corrective Action Review Board (CARB) mandated that Bombardier revise the Challenger 600 series Airplane Flight Manuals (AFMs) to include a procedure for in-flight uncommanded unarrested flaps operation, no later than June 30th, 2024. The CARB further mandated that Bombardier recommend Transport Canada issue an AD requiring that operators incorporate the new procedure in their flight manuals.

Finally, Bombardier's Corrective Action Review Board (CARB) convened again on March 31st, 2023, and committed Bombardier to introducing a design change to the Challenger 604/605/650 flaps system no later than February 28th, 2025, and a design change to the Challenger 600/601 flaps system no later than November 30th, 2025.

With the mitigating action already taken, the mitigating action scheduled for second quarter 2024, and the terminating action scheduled for 2025, Bombardier's industry-standard continuing airworthiness risk assessment process indicates that the residual safety risk to the fleet is at an acceptable level.

Bombardier believes that the AAIB's proposal to introduce a life policy for the flap operating system relays on the Challenger 600 series of aircraft represents an undue burden to operators. As the safety risk to the fleet is already at an acceptable level, Bombardier does not agree that imposing such an undue burden on its operators is justified.

Bombardier continues to monitor the in-service fleet and will re-assess the risk and mitigating actions should that become necessary.'

AAIB assessment of response

The AAIB assessed the response to Safety Recommendation 2023-005 as Not Adequate (Closed) No Planned Actions and provided the following feedback:

'The response from Bombardier Aviation has been assessed as Not Adequate as it does not satisfy the intent of the Safety Recommendation to introduce a life policy for the flap operating system relays.

The relay manufacturer has set a minimum life of 20,000 cycles; in service aircraft can exceed this life and the investigation has shown that relays have failed before reaching this minimum life. While the Service Bulletins will detect a failure at the time it is carried out, it cannot establish the condition of the D contact in the relay. Latent failures are not annunciated to the crew or engineers.

The proposed changes to the Aircraft Flight Manuals are not due to be published until mid-2024 and the proposed design changes are not expected to be introduced until 2025. Safety Recommendation 2023-006 has been made to Transport Canada to reassess the safety case for the flap operating system.

The AAIB acknowledges that, at this time, Bombardier Aviation does not intend to take any further action and has, therefore, Closed Safety Recommendation 2023-005.'

The uncommanded and unarrested movement of the flaps, which is classified by the manufacturer as potentially catastrophic, requires two concurrent failures. The original safety case considered this to be extremely improbable and assumed that a relay failure would go undetected for one flight at the most. However, it was established that on three different aircraft a relay was in a failed condition for a significant number of flights, and the failure was not detected even though the flaps moved in one direction at half-speed.

The failure of a flap extend or retract relay is a latent failure because it is not annunciated to the pilots or maintenance staff. The protection offered by the flap arrest system may no longer be available and a single failure of another part of the system could be sufficient to cause a catastrophic outcome.

At the time of certification, FAR 25.1309 required the occurrence of any failure condition that would prevent the continued safe flight of the aircraft to be 'extremely improbable'. To ensure that the Challenger 600 series of aircraft meets this requirement, the following Safety Recommendation was made to Transport Canada on 1 March 2023:

Safety Recommendation 2023-006

It is recommended that Transport Canada reassess the safety case for the flap operating system on the Challenger 600 series of aircraft to ensure it meets the requirements of Title 14 of the Code of Federal Regulations Part 25.1309.

Response from Transport Canada

Transport Canada responded on 5 April 2023 that they concurred with the intent of the Safety Recommendation and that they continue:

'… to investigate this serious incident with the full cooperation of the type certificate holder. The objective of this continuing airworthiness investigation is to determine what further mandatory corrective actions may be required to ensure that an acceptable level of safety is maintained for the CL-600 aircraft type. An assessment of the flap system Part 25.1309 safety case will be conducted as part of the investigation.'

On the 2 November 2023 they provided the following update:

'…investigation into the CL-600 series flap system performance has concluded that system improvements are required. As a result, Transport Canada has required Bombardier Inc. to develop and implement corrective actions that reduce the safety risks to an acceptable level.

Bombardier Inc., under the oversight of Transport Canada, is currently developing various corrective action options which are expected to be finalized no later than June 30th, 2024.

Airworthiness Directive CF-2023-07, which requires recurrent operational checks of the flap system, remains in effect as an interim risk mitigation measure.'

AAIB assessment of response

The AAIB assessed the response to Safety Recommendation 2023-006 as Adequate (Closed) Planned Action Complete and provided the following feedback:

'The planned action by Transport Canada meets the intent of the Safety Recommendation to reassess the safety case for the flap operating system on the Challenger 600 series of aircraft.'

Communication with ATC

Following the decision to discontinue the flight to Málaga and return to Farnborough, the crew of D-AAAY chose not to declare an emergency when prompted by ATC. This had no operational impact on the successful outcome of the flight. However, had there been a higher density of air traffic in the London Terminal Area, the decision to not formally declare an emergency might have affected the options available to the crew, or the wider traffic management by ATC.

Guidance for pilots in the Aircraft Flight Manual

At the time of the occurrence on D-AAAY, there was no guidance or procedure in the Challenger Aircraft Flight Manual to assist the pilots in handling an uncommanded and unarrested flap movement. Therefore, the following Safety Recommendation was made to Bombardier Aviation on 16 September 2022:

Safety Recommendation 2022-017

It is recommended that Bombardier inform operators of the Challenger 600 series of aircraft of the actions to take in the event of uncommanded flap operation in flight.

Response from Bombardier Aviation

Bombardier Aviation provided the following response on 14 February 2023:

'On January 30th, 2023, Bombardier's Corrective Action Review Board (CARB) mandated that Bombardier revise the Challenger 600 series of AFMs to include a procedure for in-flight uncommanded unarrested flaps operation, no later than June 30th, 2024. The CARB further mandated that Bombardier recommended Transport Canada issue an Airworthiness Directive (AD) requiring that operators incorporate the new procedure in their flight manuals.

Bombardier submits that this CARB decision meets the intent of AAIB Safety Recommendation 2022-017.'

AAIB assessment of response

The AAIB assessed the response to Safety Recommendation 2022-017 as Adequate, Planned Action Ongoing, Update Due 30 June 2024 (Open) and provided the following feedback:

'The mandated action by the CARB meets the intent of the Safety Recommendation, and Bombardier Aviation has shown that given the complexity of introducing a new AFM procedure the timescale set in the CARB is realistic as a 'Do not exceed date'. The AAIB would request an update on the actions taken by 30 June 2024.'

Conclusion

This serious incident occurred because there was an uncommanded flap movement, which the flap protection system did not stop.

The reason for the uncommanded flap extension could not be identified.

The failure to arrest the uncommanded flap movement was caused by the welding of the D contacts in the No 1 flap retract relay which prevented it from operating. This welding probably occurred because of an unsuppressed back-EMF when the BDU brake solenoid was de-energised.

Safety Actions

The following Safety Actions have been taken:

Bombardier Aviation

On 26 September 2022, Advisory Wire AW600-27-2631 was issued to advise operators of the event on D-AAAY.

On 29 December 2022, five Service Bulletins were issued for operators to check the operation of the flap system on the Challenger 600 series of aircraft.

Transport Canada

On 16 February 2023, Airworthiness Directive CF-2023-07 was issued and became effective on 24 February 2023 to mandate Bombardier Aviation's Service Bulletins to check the operation of the flap system on the Challenger 600 series of aircraft.

Safety Recommendations

The following Safety Recommendation was made on 16 September 2022:

> **Safety Recommendation 2022-017**
>
> It is recommended that Bombardier inform operators of the Challenger 600 series of aircraft of the actions to take in the event of uncommanded flap operation in flight.

The following Safety Recommendations were made on 1 March 2023:

> **Safety Recommendation 2023-004**
>
> It is recommended that Bombardier Aviation introduce a modification on the Challenger 600 series of aircraft to protect the D contacts within the extend and retract relays of the flap operating system from unsuppressed back-EMF electrical arcing.

> **Safety Recommendation 2023-005**
>
> It is recommended that Bombardier Aviation introduce a life policy for the flap operating system relays on the Challenger 600 series of aircraft, which takes account of the component's specified life and is sufficient to ensure that any in-service damage on the D contacts on the extend and retract relays remains acceptable for continued operation.

> **Safety Recommendation 2023-006**
>
> It is recommended that Transport Canada reassess the safety case for the flap operating system on the Challenger 600 series of aircraft to ensure it meets the requirements of Title 14 of the Code of Federal Regulations Part 25.1309.

The responses to these recommendations is covered earlier in the report. No additional safety recommendations are made in this report.

Published: 18 January 2024.

Incident

Aircraft Type and Registration:	Pilatus PC-24, D-CMSL
No & Type of Engines:	2 Williams International FJ44-4A turbofan engines
Year of Manufacture:	2022 (Serial no: 266)
Date & Time (UTC):	9 December 2022 at 1425 hrs
Location:	8 nm south-east of Liverpool Airport
Type of Flight:	Commercial Air Transport (Non-revenue)
Persons on Board:	Crew – 2 Passengers – None
Injuries:	Crew – None Passengers – N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	6,500 hours (of which 781 were on type) Last 90 days – 146 hours Last 28 days – 33 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft's elevator controls became stiff as the aircraft approached its cruising altitude, resulting in an uncommanded descent of 800 ft. The flight crew successfully applied the Quick Reference Handbook (QRH) procedure for jammed elevator controls and full elevator control was regained during the descent. The investigation was unable to identify the cause of the stiff elevators and a detailed examination of the aircraft did not reveal any technical faults, so the likely cause was transitory.

History of the flight

D-CMSL flew into Liverpool Airport (Liverpool) during the afternoon of 8 December 2022 and was parked overnight on the main apron. The flight crew, having rested overnight, returned to the aircraft the next day for their planned afternoon departure; a non-revenue positioning flight to Birmingham Airport (Birmingham). While the air temperature had dropped below 0°C overnight, the pilots did not detect any evidence of airframe icing during their pre-flight external check and did not require the aircraft to be de-iced before departure.

In accordance with normal procedures for an OAT ≤10°C and visible moisture in the air, the crew selected engine nacelle anti-icing ON after engine start and carried out the engine ice-shedding procedure on the runway prior to takeoff. When the pre-takeoff flight control check was carried out, no restrictions or abnormalities were detected.

At 1417 hrs the aircraft took off from Runway 27, entered cloud shortly thereafter and climbed to FL90, where the aircraft was levelled and accelerated to 250 kt. Approximately two minutes later, the autopilot disengaged and the aircraft pitched nose-down. The co-pilot who was PF for the sector, pulled back on the yoke to counter the nose-down attitude change, but the yoke appeared to be "jammed" in pitch. Applying high force levels resulted in small corresponding movements of the yoke, but it remained very stiff. The PF followed the QRH procedure for a jammed elevator and used the pitch trimmer to help regain control of the aircraft's attitude, generating a climb back to FL90. During the uncommanded descent the maximum altitude deviation from the cleared flight level was approximately 700 ft.

Having resumed the cruise at FL90, the PF maintained manual flight while establishing the level of controllability available to him. Roll was unaffected but pitch control was severely restricted. The PF then re-engaged the autopilot but the aircraft started to climb so he disengaged it and resumed manual flight. He was able to re-establish FL90 using a combination of yoke input and pitch trim. Control was briefly handed over to the commander who confirmed he could also feel the restriction through the left yoke.

Weather conditions were better at Birmingham than Liverpool, so the crew elected to continue to their destination. At one point during the transit to Birmingham, the PF was applying significant pressure to the yoke when the restriction on its movement suddenly cleared. While pitch control remained excessively heavy, the PF had, what he described as "full authority" over the elevator. The autopilot was successfully re-engaged and behaved as expected, so the crew began their approach to Birmingham.

The commander took control for the latter stages of the descent and disconnected the autopilot at approximately 4,000 ft on base leg to assess controllability before starting the final approach. The pitch control forces were still slightly heavy, but less so than at FL90. During the approach the heaviness of the controls disappeared and the aircraft was landed manually without difficulty.

The controls reportedly felt "normal" during a post-shutdown flight control check. The pilots could not see any evidence of a control surface restriction when they later carried out a visual inspection of the airframe. They had not observed any airframe or canopy icing during the climb and the aircraft ice detectors had not alerted them to the presence of ice. Nonetheless, based on the initial nature of the problem and the subsequent heavy control forces which reduced during the descent into warmer air, the pilots considered that ice affecting the elevator and/or its control system was the most likely cause of the restriction.

Meteorology

While D-CMSL was on the ground at Liverpool overnight temperatures dropped to -2°C at 0720 hrs but had risen to +4°C by 1150 hrs. There was no reported precipitation on the Liverpool METARs from 1720 hrs on 8 December until 1250 hrs the next day, although there were reports of showers in the vicinity of the airfield from 0950 hrs onwards. The reports showed that light rain showers and drizzle affected the airfield in the period 1250-1420 hrs.

When D-CMSL took off, the reported cloud base at Liverpool was 900 ft agl and the freezing level was approximately 1,300 ft amsl.

Aircraft information

Introduction

The Pilatus PC-24 is a twin-turbofan business jet with up to 10 passenger seats. It received an EASA CS-23 Type Certificate in December 2017 and is certified for flight into known icing conditions. More than 170 PC-24s are in service and the fleet has accumulated over 200,000 flying hours. Apart from D-CSML on 9 December 2022, the manufacturer has not received any other reports of stiff or jammed elevators from PC-24 operators.

Elevator control system

The aircraft's elevator control is a conventional, unpowered mechanical system comprising pilot and co-pilot control yokes connected via cables, pushrods, quadrants and levers to the elevator control surfaces (Figure 1).

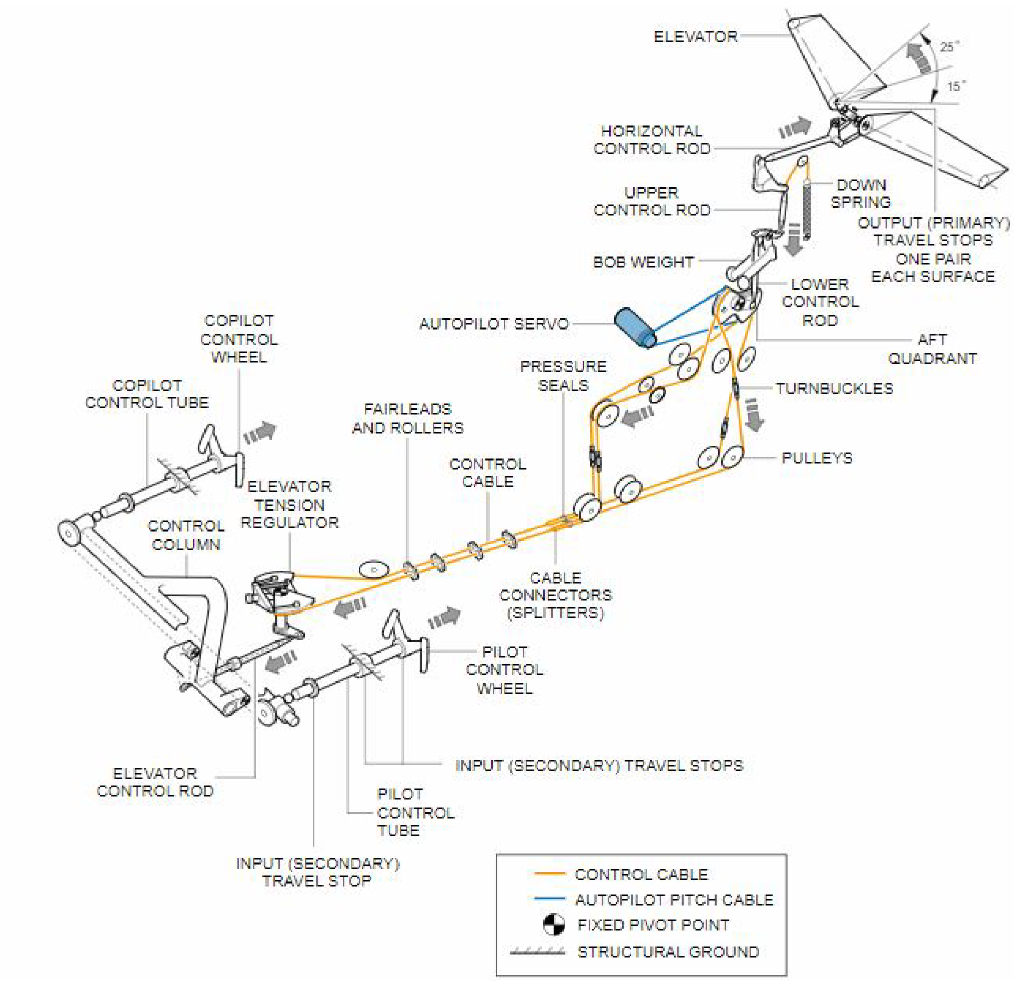


Figure 1

PC-24 elevator control system
(courtesy of manufacturer)

An elevator tension regulator, located under the right cockpit floor, maintains elevator cable tension throughout the operating temperature and cabin pressurisation ranges. The autopilot pitch servo is located behind the rear pressure bulkhead and is connected to the aft elevator quadrant via a bridle cable wrapped around a capstan on the servo output shaft. The capstan incorporates a friction clutch to allow the flight crew to move the elevators whilst the autopilot is engaged. The current drawn by each autopilot servo is monitored by the autopilot system. The autopilot (AP) directly controls the trim system in the pitch axis to off-load any steady state torque being held by the AP servos. In the case where steady state forces are being held by the AP servos for longer than a specified period, an AP HOLD NOSE UP /DOWN message will be generated. In the event that the AP servo does not have sufficient torque authority to maintain the flight director computed path/pitch targets, the AP will disconnect.

The aircraft has a trimmable horizontal stabiliser with left and right elevators attached at hinges from the stabiliser rear spar. Each elevator has a balance tab, geared to the deflection of the elevator, to reduce the force required to move the elevator against air loads. The position of the horizontal stabiliser is controlled by a pitch trim actuator attached to the stabiliser front spar. When the autopilot is engaged, the stabiliser position is moved to reduce the load on the pitch servo to achieve a desired aircraft pitch attitude.

Ice detection system

The aircraft is equipped with two ice detectors, one mounted on either side of the fuselage near the nose. The provision of two independent detectors provides redundancy, as the system will still function if one detector should fail.

Each detector has a controller and a sensing element that vibrates at a fixed frequency, controlled by an oscillator circuit. The sensing elements are exposed to airflow across the detector. When ice accumulates on them the sensing element mass increases, changing the frequency of vibration which causes the detector to send the ICE signal to the utility management system. This causes a white ICE caption to be displayed on the MFD.

The ice detectors are automatically controlled and self-monitoring. If a failure occurs, a FAIL caption appears on the ice protection system synoptic page on the MFD, and an ICE DETECTOR FAIL advisory CAS message is displayed.

Jammed elevator QRH procedure

The aircraft's trimmable horizontal stabiliser is sufficiently powerful to overcome the effects of a jammed elevator and the manufacturer provides pilots with a QRH procedure to follow in such an eventuality (Figure 2). The pilots had practised landing with a jammed elevator during their type rating course flight simulator sessions.

Flight Controls: Landing No Elevator Control **3-NAE-11**

Landing in the event of a jammed or partially available elevator control.

WARNING

WITH JAMMED ELEVATOR CONTROLS, THE STICK PUSHER MAY NOT OPERATE EFFECTIVELY. STALLS MUST BE AVOIDED.

1. Aircraft.. Use pitch trim to control aircraft pitch attitude. Make small pitch trim inputs and allow trim change to take effect before making additional inputs or aircraft configuration changes

   Consider using ≤15° angle of bank
2. L/G.. Recommend extending L/G at safe altitude and <150 KIAS to minimize pitch change due to gear extension
3. FLAP lever....................................... Extend in increments to Flaps 15°
4. Airspeed.. Decelerate slowly to Flaps 15° V_{REF} Consider using AIRBRAKE for approach
5. Landing Performance....................... Recalculate landing distance
6. THRUST levers............................... Adjust as required to maintain between 300 and 500 FPM rate of descent

At 50 feet AGL:

7. Aircraft.. Consider slowly reducing thrust and using pitch attitude to reduce rate of descent for touchdown

---------- END ----------- INDEX

Figure 2

PC-24 QRH procedure for landing with a jammed elevator
(courtesy of manufacturer)

Recorded information

Flight recorders

D-CMSL was fitted with both a CVR and an FDR. The aircraft remained in service for nine days following the event, prior to the AAIB being notified, during which the CVR was overwritten. The following significant points from the FDR data are highlighted in Figure 3:

- D-CMSL was initially level at FL90 and 245 kt, with the autopilot (AP), autothrottle (A/T) and yaw damper (YD) engaged. The OAT was -13°C. The aircraft's dual ice detectors did not record the presence of ice at any point during the flight.

- At point A, a nose-up movement of the stabiliser is recorded and D-CMSL pitched up; no stabiliser trim changes were commanded by the crew. Simultaneously and, despite no force (measured at the base of the control column) being applied, the data shows a nose-down movement of the elevator, following which the position of the elevator remained static for several seconds.

- At point B, the horizontal stabiliser also moved nose-down and D-CMSL pitched down to -8°, entering a descent during which 800 ft of altitude was lost and the airspeed increased to 264 kt.

- Eight seconds later, with an increasing rearwards force applied to the control column the AP disconnected, at point C, which was recorded in the data as an 'abnormal disconnect[1]'. This was followed by the disconnection of the A/T and YD. As the pull force applied to the control column increased, the elevator moved nose-up. However, the FDR data showed that large column forces were needed for even small deflections of the elevator and, at times, the elevator position was recorded as static despite a force being applied to the control column.

- The crew had recovered the aircraft to FL90, by point D, using stabiliser trim inputs and column movements. The A/T, A/P and YD were also re-engaged.

- After a few seconds, D-CMSL pitched up again (point E) with a nose-up movement of the stabiliser recorded before the aircraft pitched down. The AP disengaged, which was recorded as an 'abnormal disconnect,' followed by the A/T and YD. Other than an initial movement of the elevator, in response to a pull on the column of 407.5 lbf[2] (the largest recorded force – point F) and slight movements in response to other large inputs, the elevator trace now appeared static.

- The AP and YD remained disengaged, although the crew re-engaged the A/T for periods, and the aircraft was manoeuvred using the stabiliser trim until the elevator once again responded to crew input approximately seven minutes later at point G.

- Prior to landing, a further 'abnormal disconnect' was recorded, although this is not shown in Figure 1, at approximately 3,000 ft when the OAT was -2° C.

Footnote

[1] The AP's operation is continuously monitored and an 'abnormal disconnect' is triggered if one of the AP monitors senses that the aircraft's flightpath is not closing, as expected, with the target flightpath. This is considered by the aircraft's manufacturer to be the most likely cause for the series of 'abnormal disconnects' recorded during the flight. Other causes for an 'abnormal disconnect' include an elevator or aileron servo failure, or a stick shaker activation.

[2] A load of -407.5 lbf in the elevator control rod, which is where the force transducer that is recorded by the FDR is located, equates to a rearward pull on the control yoke of 92 lbf.

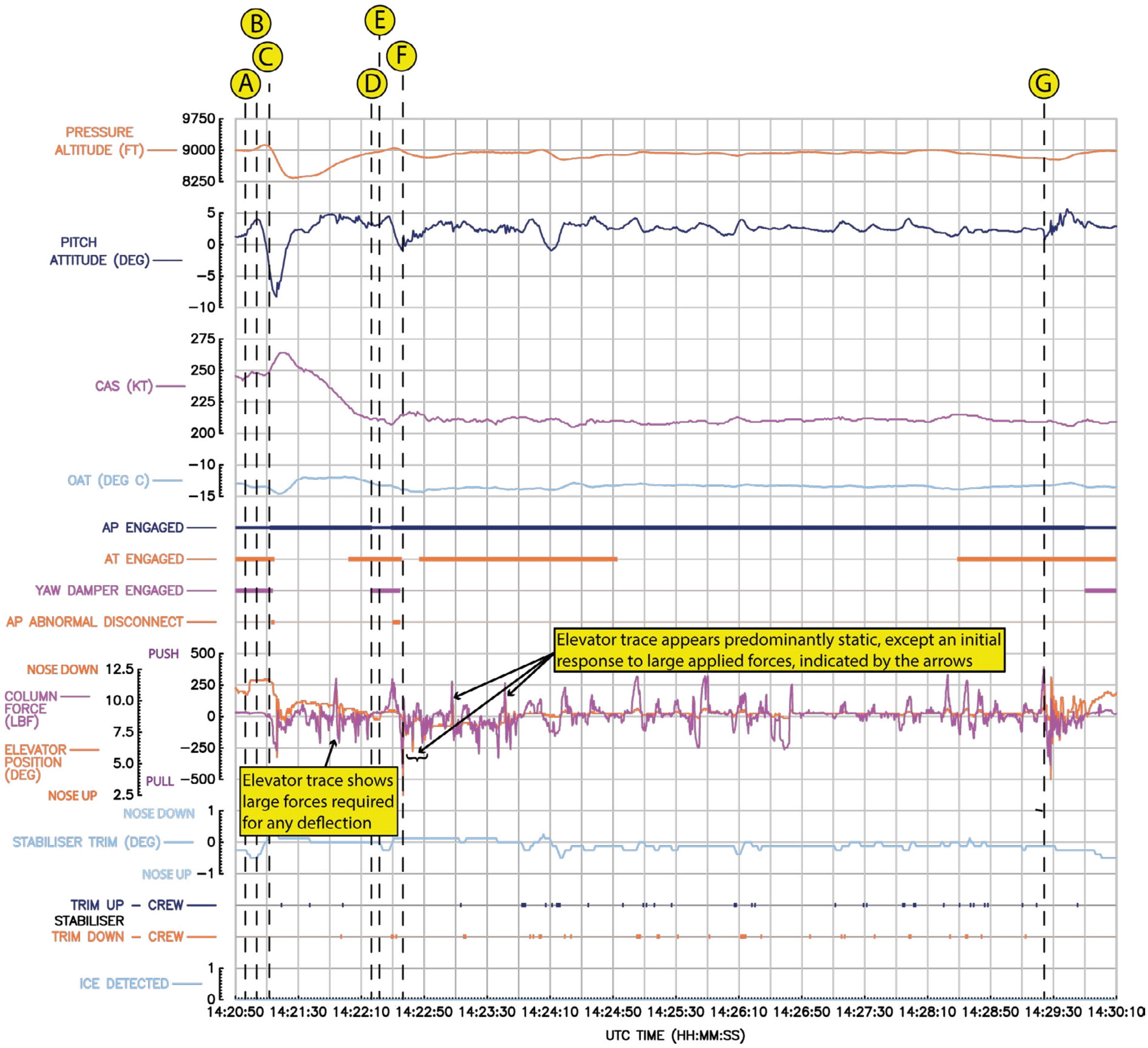


Figure 3

FDR data for the cruise portion of the incident flight

A plot of elevator position against column position[3] (Figure 4) shows data from the event flight in colour, and from 74 other flights recorded on the FDR in grey. The data shows that during the event flight, several clusters of points have a markedly flatter slope indicating where the movement of the elevator was severely restricted. Whilst the elevator's movement was restricted, the control column was still able to move over a substantial range of travel, although high control forces (indicated by the orange/red shading) were experienced during these periods.

Footnote

[3] Both elevator and control column position were recorded by the FDR at a sample rate of 8 Hz. The elevator position is measured by a transducer at the top of the aircraft's tail, the column position by a transducer at the base of the column.

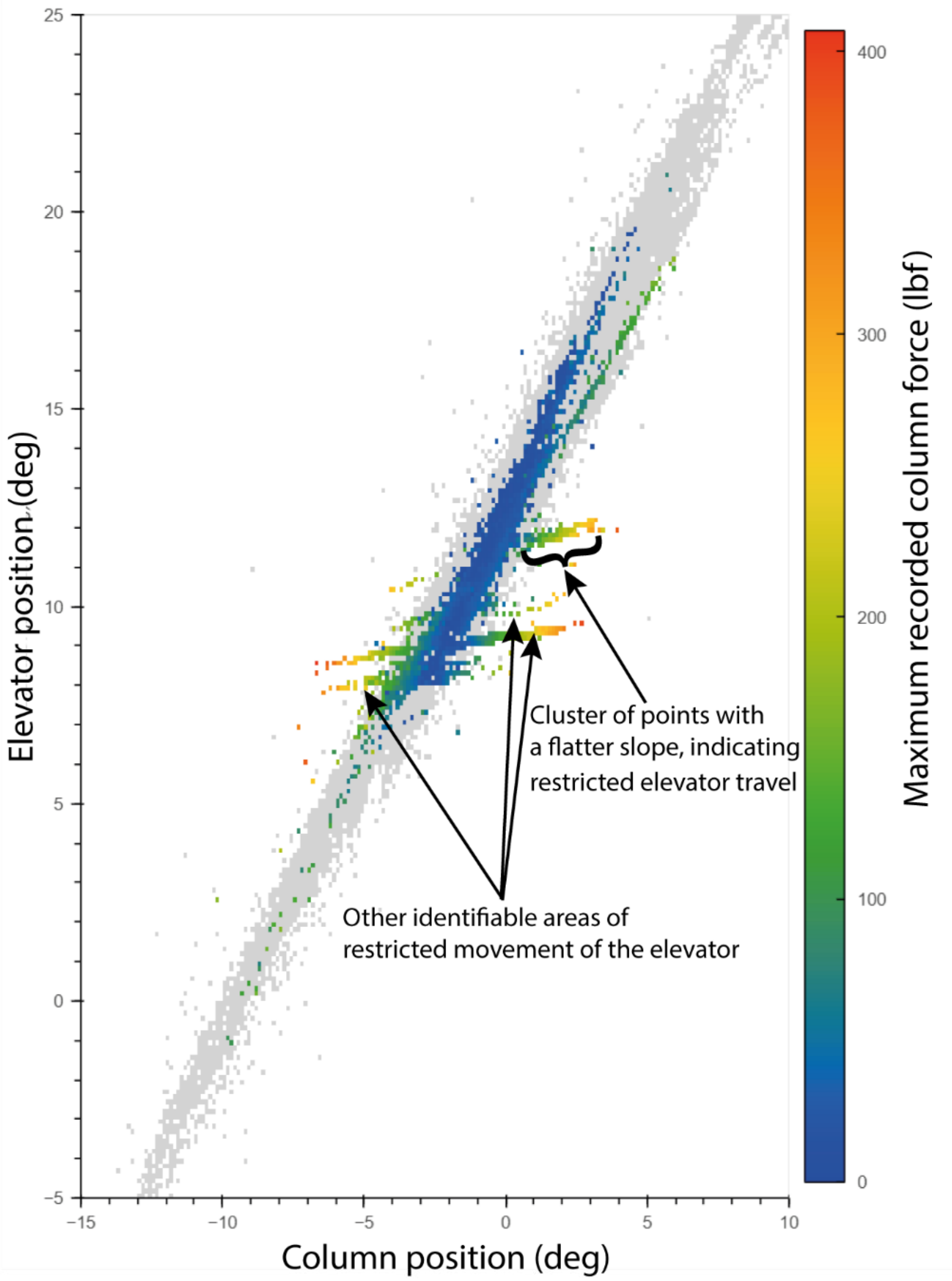


Figure 4

Elevator position vs column position data for the event flight

On board aircraft condition monitoring systems

The Pilatus PC-24 is fitted with an Aircraft Condition Monitoring Function (ACMF), which is an integral part of the Central Maintenance Computer (CMC), that analyses data on the aircraft's databuses and logs data when certain trigger conditions are met. The CMC also has a Fault History Database (FHDB) function that stores faults.

Examination of the ACMF logs showed that there were no logs stored for the event flight.

The FHDB showed that several faults were recorded during the flight, including multiple messages related to the loss of the AP, which were annunciated to the crew, and faults related to the functioning of the AP that were logged for maintenance purposes. The timings of these messages closely correlated with disengagements of the AP, as recorded on the FDR. In addition, the FHDB shows that at 14:21 hrs an AP HOLD NOSE-DOWN message was logged, indicating the AP servos applied a constant torque to maintain the aircraft's flightpath.

Closed-Circuit TV Recording and bystander's photograph

Closed-Circuit TV (CCTV) recordings from Liverpool showed the weather conditions, particularly the level of precipitation, in the hour prior to departure. It also showed how the pre-departure external checks were carried out by the crew. A screenshot from the recording (Figure 5) taken approximately one hour prior to departure shows rain and large areas of standing water on the apron.

Figure 5

Screenshot from the CCTV recording, an hour prior to departure of D-CMSL

Fleet data

During the investigation the aircraft manufacturer undertook a review of pre-delivery flight test data, gathered from several pre-delivery aircraft, and data taken from their own flight test aircraft to establish whether any previous occurrences of restricted elevator travel could be found. From this data, which covered 107 aircraft, plots of elevator position against column position were produced, and the data from 11 aircraft was selected for further examination.

This data was reviewed by the manufacturer using a web-based tool developed by the AAIB, which allowed the evolution of the data over time to be studied. Following the review, the manufacturer concluded:

> *'In summary, based on the above analysis and all other available information, we are not aware of any PC-24 restricted elevator event except on the incident aircraft.'*

Maintenance history

The aircraft was delivered new to the operator in April 2022 and had accumulated 459 flying hours and 339 flight cycles prior to the event flight; no defects relating to the elevator flying controls had been experienced during this period. The aircraft had last been washed 52 flights before the event flight.

The aircraft had been de-iced only once, 20 flights before the event flight, with 'unthickened' Type 1 de-icing fluid. This fluid is a propylene glycol de-icing fluid and does not contain any thickening agents. De-icing is performed to remove frozen or semi-frozen moisture from the external surfaces of an aircraft prior to flight.

Aircraft examination

Examination by aircraft manufacturer

The aircraft was examined at Birmingham by the manufacturer on 13 December 2022. The examination included visual examination of the elevator control system and the autopilot pitch servo cables[4], elevator and autopilot pitch servo cable tension checks[5], and a functional test of the elevator control system[6]. In addition, an autopilot operational test[7] was carried out.

Visual examination of the elevator control system did not identify any faults with the elevator controls or the autopilot pitch servo cables. The elevator functional tests did not identify any anomalies with the elevator controls.

The tension check on the elevator control cables revealed that the tension regulator rigging gap was 10.0 mm, which was below the required range of 10.8 – 11.8 mm at the ambient temperature of 3°C when this check was carried out. Therefore, the elevator control cable tensions were marginally below the required tension range. The actual cable tension in the elevator cables was not measured or recorded prior to their adjustment.

The elevator control cable turnbuckles were adjusted to increase the tension regulator rigging gap to 11.7 mm. After this adjustment, the tensions in the left and right elevator cables were measured at 332 N and 317 N respectively.

Footnote

4 AMM task PC24-A-E27-30-0000-00A-310A-A.
5 AMM tasks PC24-A-E27-30-0000-00A-369A-A and PC24-A-E27-30-0000-00B-271A-A.
6 AMM task PC24-A-E27-30-0000-00A-340A-A, omitting those sub-tasks requiring the aircraft to be supported on jacks.
7 AMM task PC24-A-E22-10-0000-00A-320A-A, steps 16 to 19.

The tension check on the elevator servo cables recorded a tension of 152 N, which was below the minimum required tension of 250 N (the allowable range being between 250 and 285 N). The elevator servo cable tension was adjusted to 272 N.

The autopilot functional check was carried out with no faults identified.

Following this examination, the aircraft was released back to service and no subsequent occurrences of stiff or jammed elevators were experienced.

Subsequent examination by the AAIB

The aircraft was examined by the AAIB on 28 February 2023, during a scheduled annual maintenance inspection. A detailed visual examination of the elevator controls did not identify any abnormalities or evidence of any foreign object contact or damage. The elevator controls were found to operate smoothly through the full range of control deflection, and no evidence of any de-icing fluid residue was present. All drain holes in the elevators and elevator balance tabs were free from obstruction and there were no witness marks visible on areas where the elevators rotate in close proximity to the horizontal stabiliser. The elevator balance tabs were in good condition, with no obstruction to their hinges or driving pushrods. A functional test of the autopilot was also carried out, with no abnormalities noted.

Manufacturer testing

The aircraft manufacturer conducted functional testing of a PC-24 aircraft with the autopilot pitch servo bridle cable tension initially set at the required tension of 310 N, before being reduced to 110 N and finally 50 N. The tests showed that for all tensions tested, the bridle cable did not slip or reduce the rate of elevator movement commanded by the autopilot. There was also no evidence of any chafing or abnormal contact between the cable and the pitch servo capstan and adjacent structure.

Analysis

Faced with an unexpected and uncommanded pitch down in IMC, the PF reacted instinctively by taking manual control of the aircraft and tried to raise the nose by pulling back on the yoke. On finding that the pitch control was severely restricted the PF followed the first stage of the QRH procedure for a loss of elevator control, which he had previously practised in the simulator. The QRH procedure worked as intended giving the PF sufficient manual flight control authority to regain and maintain the designated cruise level. After the initial severe restriction cleared the crew were able to re-establish automated flight. For additional reassurance the commander reverted to manual flight earlier than normal for an instrument approach and performed an uneventful landing.

Examination of the aircraft immediately after the incident flight and during the following annual maintenance inspection did not identify any evidence of a defect or foreign object damage to the elevator controls that could have restricted movement of the elevator. The cable tension in both the elevator and pitch servo bridle cables measured after the flight was below the Aircraft Maintenance Manual limits. The aircraft manufacturer stated that this is not an uncommon finding and would not restrict the movement of the elevator.

The possibility that the elevator restriction was caused by ice formation on the elevator control system could not be excluded, however it is unlikely that external ice accretion was a factor as both of the aircraft's dual ice detectors did not detect the presence of airframe icing. The manufacturer has stated that no other operator reports of stiff or jammed elevators had been received.

During this investigation the manufacturer reviewed flight data from a number of other PC-24 aircraft and confirmed that no other similar elevator restrictions were observed in the data, or have been reported by other PC-24 operators. However, data from the event flight clearly showed periods when an elevator control restriction was present on D-CMSL. The restrictions were most apparent in the data when it was plotted as a scatter plot against column position as the slope of neighbouring data points was markedly different when a restriction was present.

Conclusion

With the autopilot engaged, the aircraft did not capture the commanded cruise flight level but continued to climb before then pitching down and descending 800 ft below it. The uncommanded descent was halted by the intervention of the PF pulling the control column rearwards, which also caused the autopilot to disengage.

The PF found the elevators very stiff to move, requiring high force inputs on the control yoke for small elevator movements. The use of the QRH jammed elevator control procedure was successful and allowed the crew to maintain control of the aircraft and to descend, during which normal elevator control was regained.

The investigation could not identify the cause of the stiff elevators and the aircraft manufacturer is not aware of any similar stiff or jammed elevator events on the PC-24 fleet. The possibility that the elevator restriction was caused by ice formation on the elevator control system could not be excluded.

Published: 25 January 2024.

Accident

Aircraft Type and Registration:	Quik GT450, G-CEVW	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	2007 (Serial no: 8314)	
Date & Time (UTC):	17 May 2023 at 1215 hrs	
Location:	Lundy Island Airfield, Bristol Channel	
Type of Flight:	Private	
Persons on Board:	Crew – 1	Passengers – None
Injuries:	Crew – Minor	Passengers – N/A
Nature of Damage:	Extensive damage to wing and airframe	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	59 years	
Commander's Flying Experience:	134 hours (of which 107 were on type) Last 90 days – 11 hours Last 28 days – 9 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The pilot encountered significant control difficulties soon after takeoff. He was able to manoeuvre to return to Lundy Island but had great difficulty in controlling the aircraft, particularly in pitch. Control was lost close to the ground and the aircraft was extensively damaged in the touchdown. The pilot was taken to hospital by air ambulance but was discharged the same day having sustained only minor injuries.

The loss of a securing bolt had caused the roll bearing to move aft along the wing keel. This altered the trim of the aircraft inducing a significant nose-up pitch that was only marginally controllable.

History of the flight

The aircraft departed Park Hall Farm Airfield, near Nottingham, on the morning of the accident and flew to Lundy Island with a flight time of 2 hours 45 minutes landing at 1040 hrs The pilot stated that there were no issues with the aircraft, a Quik GT450 (Figure 1), during the flight from Nottingham to Lundy Island and that the weather was fine throughout. He refuelled the aircraft with approximately 20 litres of unleaded petrol as this would allow him to avoid a refuelling stop at Porthcawl on the return flight. The aircraft spent approximately 1 hour 35 minutes on the ground before departure for the planned return flight to Park Hall Farm Airfield.

Figure 1
Quik GT450

The aircraft took off from RWY 24 at approximately 1215 hrs and the pilot described that shortly after getting airborne the aircraft pitched up and the airspeed reduced. The pilot pulled the control bar rearwards to try and lower the nose as he was concerned about stalling the aircraft. He described the control forces as being much higher than normal. The pilot decided to return and land on Lundy Island and so commenced a left turn at approximately 300 ft agl. He selected the trim to fully nose down but this had no effect on the attitude or the control loads which the pilot now described as "extreme". The speed remained low with the control response slow and heavy.

The aircraft turned through approximately 270° and flew north along the west coast of Lundy Island until abeam the airfield (Figure 2). The pilot then flew over the airfield and made a left turn to position for an approach to RWY 24. During these manoeuvres the pilot described control forces so high that he had to wedge the control bar under his arms to sustain the load. The pilot made a wide slow left turn to final approach for RWY 24. During the turn the aircraft came very close to the ground and the pilot added power to regain height. He described the final stages of the approach as follows:

> "When I was 'sort of' lined up I pulled the bar in as much as I could and took the power off, and the nose dropped and I gained speed, but the line-up was poor,

to the left, due to the sluggish response to control. I let the bar out a little to flare, and rolled to the right to improve my line-up, although this left me heading off the strip to the right. I was just a few feet up, heading off right, and it felt too fast but I was aware the ground dropped away at the end of the strip, to a cliff edge, and my arms/hands were barely able to keep the bar back in a flying position making going around probably not possible, so I pulled in again just as I left the side of the strip and hit the ground hard, stopping almost immediately."

After the heavy touchdown the pilot heard the engine revving so he turned off the magnetos and electrical master switch and closed the fuel cock before releasing his harness and exiting the aircraft. Lundy Island staff were quickly on scene to assist the pilot and they called the Emergency Services. The pilot was taken to hospital by air ambulance due to concerns for a broken elbow but was discharged after examinations confirmed he had suffered only bruising.

Figure 2
Aircraft track

Accident site

The AAIB did not attend the accident site but was provided with images of the aircraft taken shortly after the accident. The aircraft had come to rest upright, north of the landing strip, but the wing had been destroyed. The nose landing gear had also collapsed.

The aircraft was disassembled and transported by ferry to the mainland by a third party on 22 June 2023.

Figure 3

G-CEVW after the accident (reproduced with permission)

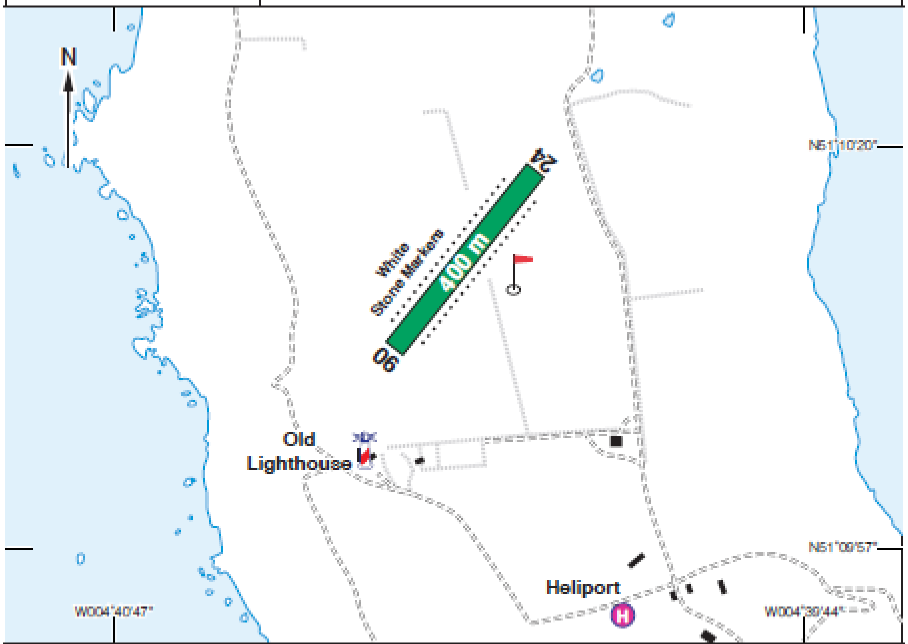
Airfield information

The accident occurred at Lundy Island Airfield. It has a grass runway 400 m long orientated 060/240°. Details are shown at Figure 4.

N51 10.20 W004 40.23	**LUNDY ISLAND**	400ft AMSL

11 nm NW of Hartland Point (North Devon).

SAFETYCOM 135•480



Rwy	Dim(m)	Surface	TORA(m)	LDA(m)	Lighting
06/24	400	Grass	Unlicensed		Nil

Op hrs: PPR essential by telephone. SR-SS.

Landing Fee: £15. National Trust admission £6 per person. **Customs:** Nil.

Hangarage: Nil. **Maintenance:** Nil.

Remarks: Operated by the Lundy Company, Lundy Island, Bristol Channel, Devon EX39 2LY. PPR essential.

Light aircraft accepted at pilots own risk.

Lighthouse near airfield.

Caution: Runway surface rough and farm stock may be in the area.

Accommodation: Please enquire beforehand for availability Tel: 01271 863636.

Fuel: Nil.	**Tel:** 01237 431831 **Fax:** 01237 431832

Robert Pooley © 468 2023

Figure 4

Lundy Island Airfield information

Aircraft information

The P&M Quik GT450 is a two-seat weight shift controlled flexwing microlight with maximum all up weight of 450 kg (Figure 5). The aircraft consists of a wing and trike connected by a front strut and pylon to the hang bracket located on the wing keel tube (Figure 6).

The wing is of tubular aluminium construction with the aerofoil section defined by pre-formed aluminium and pre-formed aluminium/composite ribs and a fabric skin. The skin consists of a Trilam sandwich leading edge, a Kevlar trailing edge and a spanwise Kevlar tape. The remainder of the wing sail fabric is polyester fabric.

Figure 5
P&M Aviation GT450

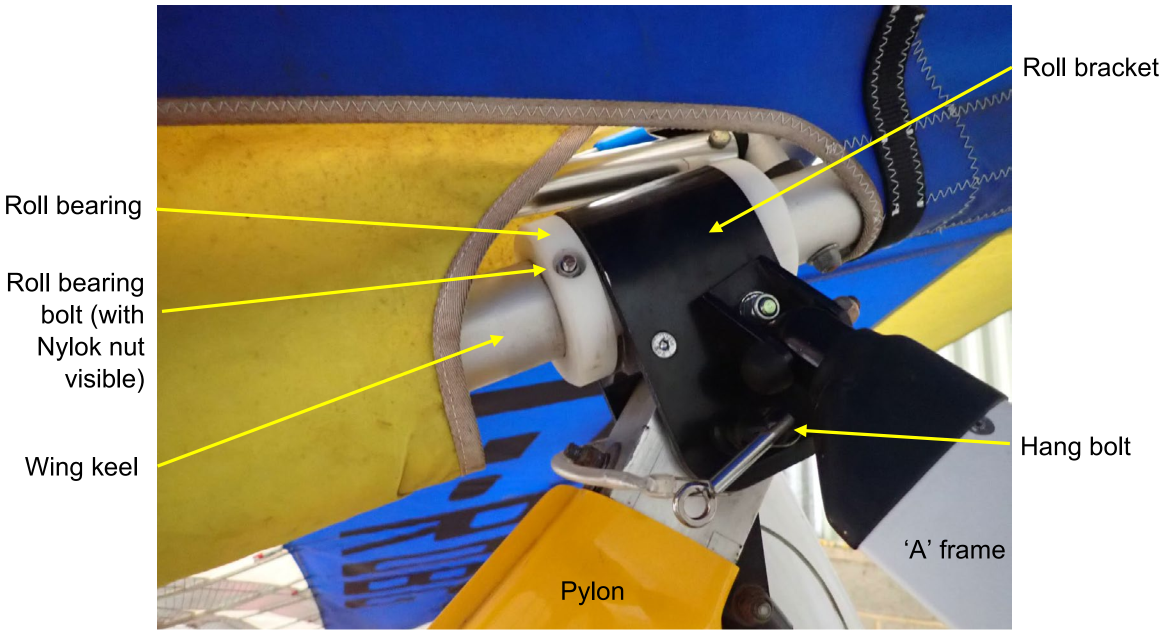


Figure 6
GT450 wing keel and hang bracket viewed from the right

The main structure of the trike is of square section high strength aluminium alloy tube, on which a rigid composite tandem seat is located. The trike has a tricycle landing gear; the nose landing gear of which is steerable. A Rotax 912 engine with a fixed pitch three-bladed propeller is fitted to the rear of the trike.

The pilot controls the microlight through an 'A' frame, which consists of a basebar connected to the wing keel tube by two uprights and a number of wires. Under normal conditions, the pilot controls the pitch of the wing by moving the base bar forward to pitch up or rearward to pitch down. Roll is controlled by moving the basebar to the left to roll right and to the right to roll left. Essentially, the movement of the basebar moves the weight of the trike in the direction of intended travel.

The trike is connected to the hang bracket through the hang bolt, about which the wing pitches. A roll bearing is incorporated in the hang bracket assembly and allows the wing to roll in relation to the trike. The roll bearing consists of a cylindrical nylon inner journal which is fixed to the wing keel tube with a single M6 caphead bolt and Nylok nut. This runs against the roll bracket and spacer block.

The GT450 incorporates an electric trim system. An electric winch, mounted to the pylon and controlled by a pilot operated switch on the throttle box, acts on an arrangement of bungees and cords connected to a bracket on the wing keel. The bracket is approximately 300 mm aft of the roll bearing. With the cord wound in fully the wing is pitched up in the 'slow' configuration and, with the cord wound out, the wing is in the 'fast' configuration.

The aircraft was first registered in September 2007 and had completed 371 hours at the time of the accident. The aircraft's Permit to Fly was valid and had been revalidated by a BMAA inspector on 1 March 2023. The aircraft had flown 8 hours and 30 minutes since the permit revalidation.

In March 2022 the wing was stripped and rebuilt for its 500 hour / 4 year assessment. Once the wing had been re-fitted to the trike, a permit revalidation inspection was completed. During the inspection it was noted that an incorrect nut was fitted in the bottom of the king post. This was rectified and the aircraft's permit was revalidated. No work was recorded as having been completed on the wing or hang bracket after the 2022 permit revalidation.

Aircraft examination

The aircraft components were examined by the AAIB at the third party's storage facility.

The trike's nose landing gear frame had sheared at its bearing. The direction of the failure was in line with its longitudinal axis and associated with the heavy landing on the nose.

The trim mechanism was in the full fast / nose-down position, commensurate with the pilot's recollection.

The wing was destroyed. Most of the wing structure was deformed or fractured. The sail material had ripped in numerous locations, associated with the wing structure damage.

A series of rips and bunched fabric was noted on the keel pocket (Figure 7), indicating that the hang bracket had moved rearward along the wing keel.

Figure 7

Underside of G-CEVW wing material showing rips around the keel beam pocket

Examination of the wing keel confirmed that the roll bearing had migrated rearwards. The M6 cap head bolt, which retained the roll bearing in position, and its associated Nylok nut were missing and were not recovered. Fretting was observed on the bolt head side of the bushing through which the bolt would have passed through the wing keel (Figure 8). The trim cable attachment bracket was deformed and the inner diameter of the roll bearing had worn, indicating that the roll bearing had moved rearwards down the wing keel and struck the trim attachment bracket during flight (Figure 9).

Figure 8

Wing keel bushing showing fretting around bolt hole

Figure 9

Roll bracket bearing showing witness marking from contact with trim bracket

Weight and balance

The aircraft was below the weight limit of 450 kg at the time of the accident. By the nature of the aircraft design, there are no balance limits.

With a rearward movement of the hang-point of approximately 300 mm, it was estimated that a rearward force of approximately 300 N (30.59 kg-force) would need to have been applied to the control bar to remain straight and level.

Analysis

The investigation was not able to positively determine the exact time that the roll bearing bolt separated from its intended location. No work had been conducted on the wing assembly since the Permit to Fly revalidation in March 2022. That Permit to Fly had a further revalidation in March 2023 and the aircraft had flown 8 hours 30 minutes since that examination. It is likely that the roll bearing bolt was present at the date of the revalidation. As there is no other means of restraining the roll bearing position apart from the bolt, the investigation considered it probable that the bolt separated from the aircraft during the takeoff for the accident flight.

The pilot conducted the pre-flight checks as specified in the POH, but the roll bearing bolt was not a specific item in the checklist and he could not be certain if it was present at the time of the walk-around checks. The taxi-out and takeoff roll were entirely normal, but shortly after becoming airborne the aircraft pitched up and the speed reduced. Concerned about a stall the pilot made a control movement to lower the nose. The pilot described the control loads as much higher than normal and he had significant difficulty in controlling the aircraft.

The examination of the aircraft indicated that the trike hang-point had moved aft by 300 mm and this would have induced a significant pitch up tendency in the aircraft. Calculations by the manufacturer estimated that it would require a pull force of approximately 30 kg on the pilot's control bar to overcome the induced pitch-up tendency. This is far more than the usual loads and proved almost unsustainable for the pilot despite the short flight time. At some points the pilot had to hook the control bar behind his elbows to enable him to exert the requisite force and his capacity to accurately control the aircraft was severely diminished. He decided to return immediately to the airfield but even during the short flight had great difficulty in maintaining a safe flightpath. The pilot recognised that his approach to the airfield was not accurately aligned with the runway but felt that due to the high control loads he would not be able to execute a go-around. With the airspeed higher than ideal the pilot was also concerned that endeavouring to better control the landing would cause him to overrun the airfield towards ground that sloped down to a cliff edge. He therefore accepted the poor alignment and the high speed as more survivable. The aircraft touched down heavily and stopped very quickly but the pilot was able to leave it without assistance.

Conclusion

The trike roll bracket slid aft by approximately 300 mm due to the loss of the securing bolt. This induced very large pitch control loads for the pilot which jeopardised safe control of the aircraft. The pilot was able to return to the airfield but control was lost during landing and the aircraft was extensively damaged. The pilot was able to extricate himself from the aircraft and sustained only minor injuries.

Safety action

Following this accident, the manufacturer issued Service Bulletin (SB) 160 with the text below:

> ***'INTRODUCTION***
>
> *An accident to a GT450 was caused by the 6mm keel roll bearing CG cap head bolt coming out, allowing the roll bearing, hang bracket and control frame top to move back causing a severe pitch up.*
>
> ***ACTION***
>
> *An additional daily inspection check item has been introduced to specifically inspect that the bolt is present and secure before flight.*
>
> *The roll bracket assembly must be inspected to ensure it moves freely on the roll bearing and that the bearing is not loose on the keel. Nylon roll bearings (dark colour) can swell with moisture over the years, causing friction which puts more stress on the CG bolt and keel hole.*

> *Genuine replacement roll bearings are made from Acetal (bright white colour) which is not so affected.*
>
> *If not already fitted, it is strongly recommended to fit the longer bolt, item 13, part no. FCM6-80 with securing M6 T type Nylok nut, item 10, part no. FNM6-NT.'*

The manufacturer also introduced, via SB 160, a clamp that is fitted to the wing keel aft of the roll bearing to prevent its rearward movement in the event of a roll bearing bolt failure or loss.

Published: 18 January 2024.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Serious Incident

Aircraft Type and Registration:	Boeing 737-301, G-JMCU	
No & Type of Engines:	2 CFM 56-3B2 turbofan engines	
Year of Manufacture:	1986 (Serial no: 23513)	
Date & Time (UTC):	6 March 2023 at 2236 hrs	
Location:	Aberdeen Airport	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew – 2	Passengers – None
Injuries:	Crew – None	Passengers – N/A
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	44 years	
Commander's Flying Experience:	7,502 hours (of which 2,569 were on type) Last 90 days – 39 hours Last 28 days – 9 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft departed Aberdeen Airport with FLAP 1 set instead of the planned FLAP 5 used in the takeoff performance calculations. The crew noticed the incorrect flap setting after takeoff, whilst attempting to retract the flaps in the normal sequence. Calculations performed afterwards indicated that on this occasion the aircraft's performance on takeoff was adequate with FLAP 1 set. However, it is not safe to take off without confirming that flap is set correctly, because the aircraft may not achieve the required performance.

History of the flight

The aircraft departed Aberdeen Airport on a cargo flight to East Midlands Airport. The copilot was undergoing differences training for Boeing 737-300 series, having recently completed line training on the Boeing 737 NG. He had previously flown the ATR 72. The commander was PM and the co-pilot was PF.

It was snowing in Aberdeen and the aircraft was de-iced on stand. This required Supplementary Procedures (SP) 16[1] to be actioned by the pilots, which changed the point during the pre-departure preparation when the flaps were set. The taxi route from Stand 9 to Runway 34 was short and included a 90° turn to enter the runway. The weather conditions

Footnote

[1] Boeing 737 Flight Crew Operating Manual - Supplementary Procedures Chapter SP Adverse Weather Section 16.

worsened after pushback, with heavy snow and reduced visibility. The commander stated that he taxied very slowly and was mindful of the threat of a taxiway excursion given the environmental conditions.

During the taxi the remaining checklist items were completed, which included the co-pilot setting takeoff flap. The commander called for 'FLAP 5' to be set and the co-pilot confirmed this was complete. The commander recalled visually checking during line-up that the green light on the flap position indicator was illuminated, which confirmed the flap lever was no longer at zero.

The pilots carried out an engine fan blade ice shedding procedure on the runway before taking off. After departure, the co-pilot called for flaps to be retracted to 'FLAP 1' and the commander realised the lever was already in the flap 1 detent. The pilots maintained the configuration until accelerating to the normal speed for flap retraction to the clean configuration.

During the cruise the pilots carried out performance calculations for a flap 1 takeoff, which revealed that the speeds were similar to those calculated for FLAP 5, and concluded that the error had not had an adverse effect on the safety of the aircraft.

Recorded information

A 25-hour Flight Data Recorder (FDR) and a 2-hour Cockpit Voice Recorder (CVR) were fitted to the aircraft.

Cockpit Voice Recordings

The CVR installed in the aircraft combines all crew channels into a single recorded channel to provide at least 2 hours of cockpit recording, in addition to recording these separately for at least the last 30 minutes of operation.

CVR recordings of the occurrence had been overwritten by recordings of the subsequent flight, though the pilots discussed the event during the cruise on this subsequent flight. The content of the discussion corroborated information provided to the AAIB by the commander.

CVR quality

The recordings on CVR channel 2 had a notably lower volume than the other channels, making some of the audio recorded to this channel unintelligible. The investigation did not determine the reason for this lower volume.

Noise was also present on input channels 1-3 which was not present on the area microphone channel. Spectral analysis determined that this was due to interference from a 400 Hz tone, indicating interference from the aircraft's AC electrical system.

As a result of previous investigations encountering CVRs and FDRs which had not recorded data as expected, the UK Civil Aviation Authority published recommendations for continued airworthiness of CVRs in Chapter 12 of CAP 731[2], intended to ensure appropriate signal levels and intelligibility of CVR recordings. The AAIB notified the operator of the CVR recording quality issues and referred to this guidance. The operator shared these findings with its Continuing Airworthiness Management Organisation (CAMO) and subsequently shared documents with the AAIB indicating that the issues had been rectified.

Flight Data Recordings

The flight parameters recorded by the FDR indicated a normal takeoff from Aberdeen. The takeoff was compared to four previous takeoffs recorded on the FDR which operated under similar conditions from Aberdeen, where FLAP 5 was used for takeoff. The rate of acceleration, pitch attitude during the initial climb, and rate of climb for the FLAP 1 takeoff were similar to the values recorded from the previous FLAP 5 departures.

Aircraft information

Takeoff flap position

The normal *'Before Taxi procedure'*[3] states the commander will call "FLAPS ___" as required for takeoff. In response, the co-pilot should select the flap setting stated by the commander and verify that the LE FLAPS EXT green light is illuminated. The LE FLAPS EXT light is illuminated when the flap position is greater than zero.

SP 16 states:

> *"If taxi route is through ice, snow, slush, or standing water in low temperatures or if precipitation is falling with temperatures below freezing, taxi out with the flaps up. Taxiing with the flaps extended subjects the flaps and flap drives to contamination. Leading edge devices are also susceptible to slush accumulations."*

The co-pilot had recently converted from the ATR 72 aircraft and had not completed any flap 1 departures in the Boeing 737. The ATR 72 has three flap settings, flaps UP, flap 15 and flap 30. The normal selection for takeoff is flap 15 which requires the flap lever to be moved from zero into the first available detent.

The most common takeoff flap selection on the Boeing 737 family is flap 5, requiring the flap lever to be moved into the third detent, which was the configuration on which the performance data had been calculated during this event. On a 737-400 aircraft a flap 1 takeoff is not permitted.

Footnote

2 CAP 731 - *Approval, Operational Serviceability and Readout of Flight Data Recorder Systems and Cockpit Voice Recorders*, available at http://publicapps.caa.co.uk/docs/33/CAP731.PDF [accessed January 2024].

3 Boeing 737 Flight Crew Operating Manual – Normal Procedures – Amplified Procedures.

Takeoff configuration warning

The Flight Crew Operating Manual[4] states:

> *"Takeoff configuration warning is armed when the airplane is on the ground and either or both forward thrust levers are advanced for takeoff. An intermittent warning horn sounds if:*
>
> - *for the 737-300, trailing edge flaps are not in the flaps 1 through 15 takeoff range*
> - *for the 737-400, trailing edge flaps are not in the flaps 5 through 15 takeoff range"*

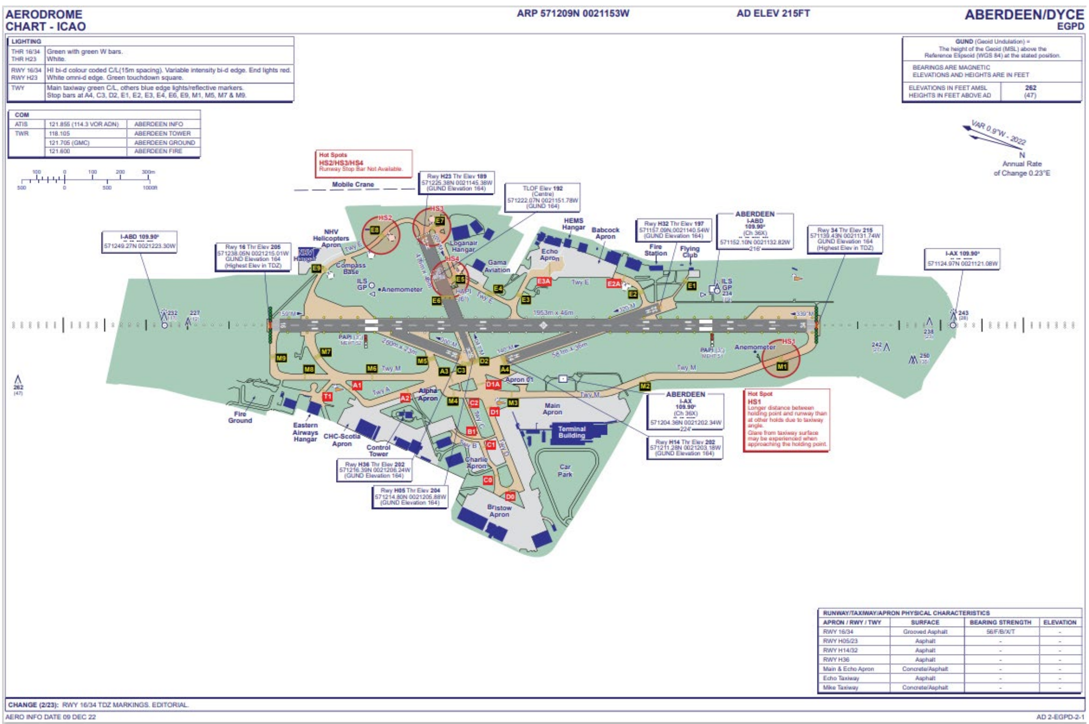
There are seven 737-400 aircraft and three 737-300 aircraft in the operator's fleet.

Meteorology

The weather at Aberdeen Airport at the time of the departure was reported to have been temporary moderate snow showers with a reduction in visibility to 2,000 m. The cloud base was at 1,000 ft and the temperature was 0°C. There was a reported visibility of 800 m during taxi.

Aerodrome information

Aberdeen's Runway 16/34 is the only runway suitable for fixed wing aircraft operations and has a published TORA of 1,953 m.



Footnote

4 Boeing 737 Flight Crew Operating Manual - Warning Systems Chapter 15 System description Section 20.

Personnel

Both pilots held valid licences and their medicals were in date.

Operator response

In response to the event, the operator conducted a review of the 737 *'Before-Takeoff'* checklist. Following this review, a Flight Staff Notice was published to advise crews of the following change to 737 OMB and the *'Before-Takeoff'* checklist in order to mitigate the threat of incorrect flap settings for takeoff:

Boeing 737 Normal Checklist

BEFORE TAKE-OFF (F/O)

Previously:

Flaps……………………… _GREEN LIGHT (Captain)

Amended response:

Flaps………………………. _ PLANNED, _ INDICATED, GREEN LIGHT (Captain)

Analysis

The poor weather conditions introduced several distractions on the fight deck before departure. The application of the SP 16 procedure put the pilots out of their normal sequence for setting takeoff flap. The task of taxiing in reduced visibility on a narrow taxiway would have taken more mental capacity than normal, and was likely exacerbated by the time pressure introduced by the worsening environmental conditions. It is possible the co-pilot reverted to the motor memory of selecting one flap detent, which was correct on the ATR 72 he had recently flown.

The commander visually confirmed the LE FLAP EXT light was illuminated once lined up on the runway, but did not confirm the actual position of the flaps on the indicator. Flap 1 is an allowable takeoff setting for a Boeing 737-300 and would not result in any further annunciations. There was therefore nothing to alert the pilots to the incorrect flap setting other than to check it themselves.

In this event, completing the takeoff with flap 1 did not have any effect on the safe conduct of the flight. In other circumstances where the takeoff performance was limited, such as an increased aircraft weight, reduced runway length or less favourable environmental conditions, there may have been a greater risk to the safety of the aircraft.

Conclusion

An incorrect flap selection was made and not detected before takeoff. A combination of poor weather conditions and time pressure may have influenced the pilot's performance. It is necessary to check the actual flap position set, because the green configuration light indicates only that flap more than zero is set.

Safety actions

In response to this event, the operator amended the 'Before Takeoff' checklist to include the planned and indicating flap setting to be verbalised. They issued a 'Flying Staff Notice' to highlight the potential risk of flap mis-selections. The notice drew particular attention to those recently converted from the ATR of the risk of 'reverting to type' and moving the lever to the first gate (FLAP 1), rather than the second or third as required for FLAP 5 and FLAP 15 departures.

Serious Incident

Aircraft Type and Registration:	Fournier RF4D, G-AWGN
No & Type of Engines:	1 Volkswagen Rectimo 4AR-1200 piston engine
Year of Manufacture:	1968 (Serial no: 4084)
Date & Time (UTC):	23 July 2023 at 1300 hrs
Location:	Stow Maries Great War Aerodrome, Essex
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – None
Injuries:	Crew – None Passengers – N/A
Nature of Damage:	None
Commander's Licence:	Private Pilot's Licence
Commander's Age:	74 years
Commander's Flying Experience:	22,200 hours (of which 1,000 were on type) Last 90 days – 23 hours Last 28 days – 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot of G-AWGN was flying his usual aerobatic display routine for an air display at Stow Maries Great War Aerodrome. During the eighth manoeuvre of the routine the propeller stopped. Unable to restart the engine the pilot positioned the aircraft for an abbreviated circuit and landed off the subsequent glide approach.

Both wingtip smoke generators were still emitting. Whilst the right generator stopped smoking soon after the aircraft had stopped, the left canister began burning with a yellow flame visible. Very shortly after the canister began to flame, the airport fire service arrived and were able to extinguish the flames with a short blast of a powder extinguisher.

The pilot commented that although he regularly practised glide approaches to ensure that he was prepared for an engine failure, he always did this to the runway threshold. During this flight, with the engine actually failed, he also made his glide approach to the threshold, as he had always practised, rather than initially aiming further up the runway.

History of the flight

The pilot of G-AWGN took off at 1253 hrs to commence his display. The aircraft was fitted with two smoke canisters, one on each wingtip. At around 1258 hrs the pilot commenced the eighth manoeuvre of his sequence which consisted of an upwards quarter vertical roll to a canopy-down 'humpty-bump.' As the pilot pulled over the top of the humpty-bump, at around 40 kt and at 850 ft aal, the propeller stopped. This had happened previously to the pilot during a practice flight, and the engine had restarted successfully on the subsequent dive. On this flight, despite diving to 135 kt, the propeller only turned through 90º before stopping completely. At 400 ft aal the pilot decided to use the aircraft energy to position for an abbreviated circuit and glide approach onto the runway at the airfield. The approach and landing were flown onto Runway 20 with the wind from the south or south-west at 10-16 kt. Both smoke canisters were still emitting orange smoke. After landing the pilot turned the aircraft into wind to blow the smoke away from the fuselage. The pilot shut down and vacated the aircraft without injury.

The right smoke canister stopped emitting very shortly after the pilot left the cockpit but the left developed a yellow flame, described by the pilot as being around six inches long. Within a few seconds of the flames appearing the airport fire service arrived and were able to extinguish the flames using a powder extinguisher. Despite the flames, there was no damage to the aircraft.

Results of engine examination

The pilot initially believed that the engine failure had strong similarity to that which occurred to an aircraft with a similar engine when the cause was found to be an increase in the tightness of the centre bearing, which created increasing friction within the engine, especially when it was hot. However, detailed examination of the engine arranged by the pilot, showed that there were a number of causes of the engine issue. The centre bearing was slightly tighter than required but there were also signs of scoring in the pistons. The air filter had been incorrectly cleaned and the aircraft had recently used a taxiway where there was a lot of concrete dust due to the poor quality of the surface. Some of this concrete dust had entered the cylinders and caused the scoring.

The issue with the centre bearing was shown to be caused by the fretting of the two crankcase halves.

Other information

Glide approach

The pilot practised glide approaches almost every flight and was therefore very well versed on the actions when his engine failed. He routinely flew these practice approaches to the runway threshold rather than aiming further down the runway initially as is suggested. When the engine failed during his routine, he conducted the approach exactly as he had done in all his practises despite the fact that he did not have the windmilling engine. Aiming at the runway threshold leaves no room for changing conditions or any slight mistakes on the approach. Whilst the approach and landing were successful with no damage to the aircraft or injuries to the pilot, the pilot felt he had reverted to what was familiar despite the actual engine failure condition.

Smoke generators

The smoke generators used on G-AWGN use a chemical reaction to generate the orange-coloured smoke. They are electrically triggered by the pilot at the beginning of his display. They are three-minute devices which you also might find on maritime vessels and with rescue organisations. The chemical reaction is exothermic, meaning that it generates heat although there is no flame or burning involved in the reaction. The pilot reported that whilst he had never landed with one generator still smoking before, others have without issue. The chemical reaction generating the smoke is very difficult to stop once it has started although the flames the pilot saw were rapidly extinguished using a powder extinguisher by the airfield fire service.

Analysis

An inspection of the engine arranged by the pilot showed that there were a number of issues generating increased friction within the engine. The additional internal engine friction caused the propeller to stop rotating in the manoeuvre and prevented it from restarting during the subsequent attempt at windmilling.

The actions of the pilot proved that being in very current practice for engine failures is extremely valuable for ensuring a successful outcome. However, regular rehearsals should use the same techniques that would be used in a real event, for if they do not then there is a risk that a pilot may revert to what is more familiar rather than what is best practice. The pilot in this event changed his regular glide approaches to initially aim one third of the way down the runway rather than at the runway threshold.

Although the smoke generators rely on a chemical reaction rather than flames or burning to produce the smoke, the reaction is exothermic. After landing one of the smoke generators emitted flames but these were rapidly extinguished using a powder extinguisher.

Conclusion

The engine of G-AWGN failed during an aerobatic display due to a combination of internal faults causing increased friction within the engine. The pilot rapidly recovered the aircraft to the runway without damage to it or injury to himself. One smoke generator emitted some flames, but these were rapidly extinguished and there was no damage to the aircraft.

Accident

Aircraft Type and Registration:	JS-MD 3, G-JSMD
No & Type of Engines:	1 M&D Flugzeugbau Gmbh & Co. Kg Md-Tj42 turbojet engine
Year of Manufacture:	2020 (Serial no: 3.MD079)
Date & Time (UTC):	15 June 2023 at 1221 hrs
Location:	Nympsfield Airfield, Gloucestershire
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – None
Injuries:	Crew – 1 (Serious) Passengers – N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Light Aircraft Pilot's Licence (Sailplanes)
Commander's Age:	70 years
Commander's Flying Experience:	2,027 hours (of which 20 were on type) Last 90 days – 46 hours Last 28 days – 21 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and BGA accident report.

Synopsis

During a winch launch, the aircraft was seen to pitch up into a steep climb. The left wing then dropped, and the aircraft lost control and struck the ground. The pilot recalled little after the launch but believed he may have slid backwards in the seat during the launch.

The BGA have highlighted two safety areas around winch launching and ensuring adequate restraints prior to launch.

History of the flight

The pilot reported securing his harness, accepting the cable for a winch launch and selecting negative flap with the intention of moving to positive flap once the aircraft began accelerating. There was a light north-easterly wind and the weather was fine. After the acceleration began, the pilot stated that he believed he slid backwards in his seat before recalling nothing further of the event.

Witnesses described the ground run and the takeoff as normal, but the glider subsequently rotated 'more vigorously' than normal. A steep climb followed during which the left wing was seen to drop, and the aircraft descended while continuing to roll and yaw left before contact with the ground in a steep nose-down attitude. The winch was stopped quickly and the pilot, who had sustained significant injuries, was transferred to hospital by air ambulance.

Discussion

The pilot was an experienced glider pilot and this was his 6th winch launch on this type. The aircraft was within the weight and balance limits, but it was not possible to ascertain the flap position for the takeoff due to the damage sustained in the impact.

As part of their investigation, the BGA engaged with the aircraft manufacturer to investigate the pilot's report of sliding back in his seat. The seating position in this glider is more reclined than others and the manufacturer's chief test pilot performed some winch launch tests under launch similar conditions. He reported that it is possible to slide back in the seat during the launch and, in his test, it was 'only possible to control the aircraft with his fingertips'. Of note was that this did not occur if the pilot restraints were tightly secured.

The BGA's assessment of the accident was that the rapid pitch up at start of the flight led to a stall and subsequent loss of control at a height that was not recoverable.

Safety Action

The BGA have written to all gliding clubs, highlighting the following:

> A reminder to pilots of the hazard of being forced rearwards during acceleration on a winch launch and highlighting the need for the pilot to be adequately restrained during this phase of flight.
>
> A reminder of their 'Safe Launching Initiative' with guidance on their website for both winch launches[1] and aerotows[2].

Footnote

1 Safe Winch Launching - Pilot & Club Info (gliding.co.uk) [accessed December 2023].
2 Safe Aerotowing - Pilot & Club Info (gliding.co.uk) [accessed December 2023].

Accident

Aircraft Type and Registration:	Slingsby Swallow T45, BYJ
No & Type of Engines:	None
Year of Manufacture:	1967 (Serial no:1568)
Date & Time (UTC):	7 November 2023 at 1330 hrs
Location:	Bishop Hill, near Portmoak Airfield, Kinross
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – None
Injuries:	Crew – 1 (Serious) Passengers – N/A
Nature of Damage:	Substantial
Commander's Licence:	Other
Commander's Age:	68 years
Commander's Flying Experience:	114 hours (of which 2 were on type) Last 90 days – 1 hour Last 28 days – 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The glider struck the ground after experiencing turbulence and a high sink rate whilst flying near to the ridge line of Bishop Hill, near the village of Scotlandwell. The pilot sustained serious injuries during the accident. It is likely that, upon encountering turbulent air, the glider's lower than recommended airspeed resulted in it having insufficient energy to safely manoeuvre away from the hill.

History of the flight

The pilot had planned to ridge soar at Bishop Hill, near Scotlandwell, which is about 1 nm north of Portmoak Airfield, Kinross. The reported wind was from 270° at between 8 to 10 kt. At about 1325 hrs the glider was winch launched to a height of about 1,100 ft agl (1,450 ft amsl) from the westerly runway at Portmoak Airfield. The pilot then headed directly towards Bishop Hill, whose summit extends to about 1,400 ft amsl and was the area in which the pilot intended to fly. The pilot advised that the glider's controls were responding normally.

The pilot could see two other gliders and at least one paraglider flying near the ridge line ahead of him. The pilot recalled that as he approached the hill the glider's airspeed was about 45 kt (1.4 V_s[1]). He then made a left turn onto a northerly heading to fly approximately

Footnote

1 V_s stated by the pilot was 32 kt.

parallel to the windward ridge line. The glider momentarily started to climb, but then experienced turbulence with the vario indicating "severe sink". The glider was now below the summit of the hill, at a visually estimated height of 800 ft, and the pilot stated that he had intended to make a left turn, away from the hill. However, his next recollection was of the glider striking the side of the hill and travelling through gorse shrubs before coming to a stop on a south-easterly heading (Figure 1).

The glider's wings and cockpit were damaged. The pilot suffered injuries to his spine and was attended to at the accident site by emergency services and mountain rescue, prior to being airlifted to hospital.

The continuity of the glider's controls was checked shortly after the accident and no anomalies were found.

Guidance information on hill soaring

The BGA provides information[2] and references other recommended publications concerning hill, ridge and mountain soaring. This includes '*Safety in Mountain Flying*'[3] provided by the French gliding association FFVP[4]. The FFVP recommend a minimum airspeed of '*1.45 Vs (stall velocity)*' when hill, ridge and mountain flying. This excess energy enables the glider to fly quickly through areas of strong sink or windshear without stalling.

Figure 1

Accident site (the glider is circled)

Footnote

2 BGA - managing flying risk - Hill, ridge and mountain soaring [accessed 12 December 2023].
3 Mountain Flying Safety [accessed 12 December 2023].
4 Fédération Française de Vol en Planeur [accessed 12 December 2023].

Conclusion

The pilot considered that the reason for the accident was a loss of lift after encountering strong sink whilst flying near to the ridge line at Bishop Hill.

Based on the pilot's recollection, the glider's airspeed as it approached the hill was just less than the 1.45 V_s recommended by the FFVP. However, it is likely that the glider's airspeed was lower than this when it encountered turbulent sinking air, resulting in insufficient energy to safely manoeuvre away from the hill.

This accident highlights the safety risks of ridge soaring. Information on managing these risks is available from the BGA website.

AAIB Record-Only Investigations

This section provides details of accidents and incidents which were not subject to a Field or full Correspondence Investigation.

They are wholly, or largely, based on information provided by the aircraft commander at the time of reporting and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed: November - December 2023

11 Jul 2023 **Virus SW 128** **G-KDKD** Membury Airfield, Berkshire

Upon arriving at the destination airfield, the pilot found the speed of the wind gusts were higher than expected. After two landing attempts, the aircraft's remaining electrical charge was below the manufacturer's threshold for the pilot to safely divert. The fourth landing resulted in several hard bounces, during which the aircraft's nosewheel failed and the propeller was damaged.

17 Aug 2023 **Pipistrel Virus SW 121** **G-OVIR** Damyns Hall Aerodrome, Essex

On final after a post maintenance check flight by two instructors, the aircraft dropped suddenly in gusty conditions and struck the runway. Extensive damage was sustained to the propeller and landing gear and both pilots sustained injuries requiring hospital attention. The cross wind was close to the aircraft limit and the pilot flying was not accustomed to flying from the left seat.

3 Sept 2023 **Europa XS** **G-CDBX** Ronaldsway Airport, Isle of Man

During the landing, the nose gear collapsed.

8 Sept 2023 **Pou Du Ciel - Bifly** **G-POUX** Near Preston, Lancashire

While flying a circuit, the pilot noticed an increase in engine temperature. During the base leg, the engine stopped and would not restart. The pilot elected to land in a field. At touchdown the aircraft's nose gear caught some long grass causing the aircraft to tip over.

15 Sept 2023 **DH82A Tiger Moth** **G-AJVE** Near Tring, Hertfordshire

The aircraft descended too low on approach and struck low tension power cables which crossed the undershoot. The aircraft then suffered a hard landing, which damaged the landing gear and caused the aircraft to bounce. On the second touchdown the damaged landing gear dug into the grass which caused the aircraft to yaw and then invert. Both occupants were uninjured.

21 Sept 2023 **Nicollier HN 700 Menestrel II** **G-CCVW** White Fen Farm Airstrip, Cambridgeshire

Whilst coming into land on a grass strip the engine stopped at approximately 8 feet above the ground and the aircraft landed heavily. The engine stoppage was most likely due to carburettor icing. The aircraft's left wing and engine were damaged.

22 Sept 2023 **Aquila AT01-100A** **G-TSDA** Teesside International Airport

The aircraft engine began running roughly and the pilot could not set the power to idle for landing. The approach speed was higher than normal, the aircraft landed heavily and the nose leg collapsed.

Record-only investigations reviewed: November - December 2023 cont

29 Sept 2023 **Hughes 369E** **G-OBAS** Near Brimpton, Berkshire

At around 1,000 ft agl the engine out light illuminated together with an audible alarm. During the subsequent autorotation the helicopter rolled onto its left side on uneven ground. The engine was still running when the helicopter came to rest and the reason for the power loss was not established. The pilot reported that he may have inadvertently reduced engine power whilst adjusting the collective friction, or the engine governor may have failed.

8 Oct 2023 **Vans RV-12** **G-CJIC** Bolts Head Airfield, Devon

The aircraft was fast on final approach and floated for approximately three-quarters of the length of the runway. It touched down and both pilots applied brakes. The aircraft departed the runway to the left and shortly before coming to rest, the left wingtip struck a fence post.

5 Nov 2023 **Rotorsport Uk MTO Sport 2017** **G-CKYD** Inverness Airport

A student on his fourth solo flight, whilst receiving clearance for takeoff, allowed the rotor speed to drop and applied back stick causing the main rotor to contact the propeller and rudder. The student taxied back to the apron, unaware of debris that had been left on the runway and met the instructor who advised the Tower; this was after another aircraft had landed without incident. The runway was closed temporarily for an inspection and removal of the debris.

5 Nov 2023 **SA341G Gazelle** **N150SF** Near Spalding, Lincolnshire

While departing from a remote landing site near the coast, the helicopter lifted into a low hover. It was then caught by a strong gust of wind causing it to yaw rapidly to the left and drift backwards. The rotor blades struck a flag post causing structural damage to the helicopter, but the pilot managed to land with no injuries to the occupants.

10 Nov 2023 **Maule M-6-235C Super Rocket** **N6130X** Lydd Airport, London Ashford

Directional control was not maintained while landing on asphalt Runway 21. The aircraft departed to the left of the paved surface and pitched forward, suffering damage to the propeller and engine. The reported meteorological conditions included wind from 140° at 6 kt and rain showers. The pilot commented that he may have applied brake pressure inadvertently, causing or exacerbating the runway excursion and pitching motion.

Record-only investigations reviewed: November - December 2023 cont

11 Nov 2023 **Piper PA-28-180** **G-RVNX** Near Ellesmere, Shropshire

The aircraft's propeller spinner detached in flight, but no further damage occurred and the aircraft landed safely. A single 5 cm crack had been observed in the spinner prior during pre-departure checks.

25 Nov 2023 **DH82A Tiger Moth** **G-ADJJ** Eshott Aerodrome, Northumberland

The pilot was looking out to the left of the aircraft during landing. The aircraft drifted to the right after touchdown and, as it was decelerating, it struck a fence that was approximately 6 m to the right side of the runway.

Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

TEN MOST RECENTLY PUBLISHED FORMAL REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

3/2015 Eurocopter (Deutschland) EC135 T2+, G-SPAO
Glasgow City Centre, Scotland
on 29 November 2013.

Published October 2015.

1/2016 AS332 L2 Super Puma, G-WNSB
on approach to Sumburgh Airport
on 23 August 2013.

Published March 2016.

2/2016 Saab 2000, G-LGNO
approximately 7 nm east of Sumburgh Airport, Shetland
on 15 December 2014.

Published September 2016.

1/2017 Hawker Hunter T7, G-BXFI
near Shoreham Airport
on 22 August 2015.

Published March 2017.

1/2018 Sikorsky S-92A, G-WNSR
West Franklin wellhead platform, North Sea
on 28 December 2016.

Published March 2018.

2/2018 Boeing 737-86J, C-FWGH
Belfast International Airport
on 21 July 2017.

Published November 2018.

1/2020 Piper PA-46-310P Malibu, N264DB
22 nm north-north-west of Guernsey
on 21 January 2019.

Published March 2020.

1/2021 Airbus A321-211, G-POWN
London Gatwick Airport
on 26 February 2020.

Published May 2021.

1/2023 Leonardo AW169, G-VSKP
King Power Stadium, Leicester
on 27 October 2018.

Published September 2023.

2/2023 Sikorsky S-92A, G-MCGY
Derriford Hospital, Plymouth, Devon
on 4 March 2022.

Published November 2023.

Unabridged versions of all AAIB Formal Reports, published back to and including 1971, are available in full on the AAIB Website

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot’s Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot’s Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Union Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth’s gravity
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
POH	Pilot’s Operating Handbook
PPL	Private Pilot’s Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TODA	Takeoff Distance Available
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

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