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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S2/2022 *SPECIAL*

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 from 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:	Still under assessment
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

Introduction

At 1733 hours on 14 August 2022, the AAIB was informed that a Bombardier Challenger 604, registration D-AAAY, had an uncommanded flap extension, above the maximum flaps-extended speed. The event occurred at 1640 hours on 10 August 2022, while the aircraft was in the climb after departing Farnborough Airport. The aircraft returned to Farnborough where it landed without further incident.

On 15 August 2022, the AAIB commenced a safety investigation in accordance with Retained Regulation (EU) 996/2010 and the UK Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018. In accordance with established international arrangements, the National Transportation Safety Board (US), Transportation Safety Board (TSB) of Canada and the German Federal Bureau of Aircraft Accident Investigation appointed Accredited Representatives to the investigation. The TSB was assisted by Advisers from Transport Canada and the aircraft manufacturer.

This Special Bulletin contains preliminary information from the investigation. One Safety Recommendation has been made and four Safety Actions have been taken by the regulator and aircraft manufacturer.

History of the flight

On the day of the occurrence, the crew arrived at Farnborough Airport at 1300 hrs to operate a private charter flight to Málaga – Costa Del Sol Airport, Spain. There were three crew and seven passengers on board. The aircraft took off at 1618 hrs from Runway 06 using flap 20, after which the crew selected flap 0 to fully retract the flaps. 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 message on the EICAS[1] display primary page. The co-pilot, who was the PF, reported that the aircraft pitched nose-up slightly and started to decelerate. The EICAS primary page also displays flap position information which indicated to the crew that the flaps were extending (Figure 1)[2]. The crew reported that the flap overspeed audio warning did not operate as they expected. The flap control lever was still in the flap 0 position selected by the crew after take-off.

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 VFE of 189 KIAS for flap 45. They reported that it required nearly full power to maintain this condition. The autopilot was re-engaged. The cabin crewmember 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 lb over the maximum landing weight of 38,000 lb and planned to increase the landing reference speed (V_{REF}) accordingly.

Footnote

[1] The function of the EICAS is to display the engine instruments and to provide visual and aural crew-alert messages and real-time interpretation of aircraft system operation.

[2] The maximum speeds at which the flaps may be extended (VFE) are: flaps to 20 degrees - 231 KIAS; flaps to 30 degrees - 197 KIAS; flaps to 45 degrees - 189 KIAS.

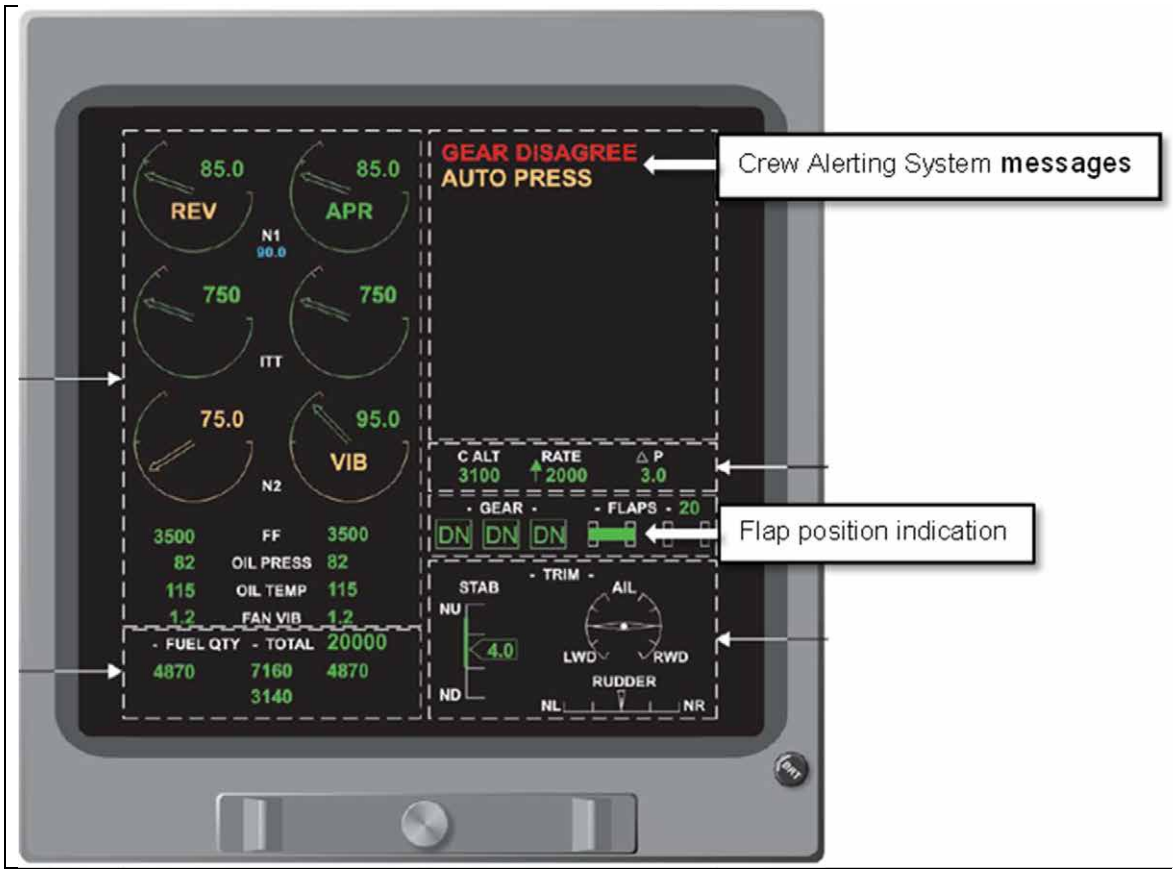

Figure 1

Illustration of EICAS primary page information

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 to match the observed flap position. The aircraft landed without further incident at 1651 hrs, at an airspeed of 135 KIAS.

Recorded information

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, and the position of the flap control lever in the cockpit and the right-wing flaps. The CVR recording of the incident flight had been overwritten during 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

The flaps prior to takeoff had extended normally to 20° at a rate of about 2.4°/sec, but during their retraction after takeoff had moved at half their 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 whilst the flap control lever remained in the flap 0 position (Figure 2, Point A). The rate at which the flaps extended was about 1.1°/sec, which was about half the normal extension speed. The autopilot remained engaged, and the aircraft's speed started to progressively reduce whilst also pitching down from 4° nose up. Shortly after, a flap failure message 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 VFE. This coincided with the flight crew disconnecting the autopilot and reducing engine thrust from 91% to 47% N1 (Figure 2, 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 VFE (Figure 2, Point C).

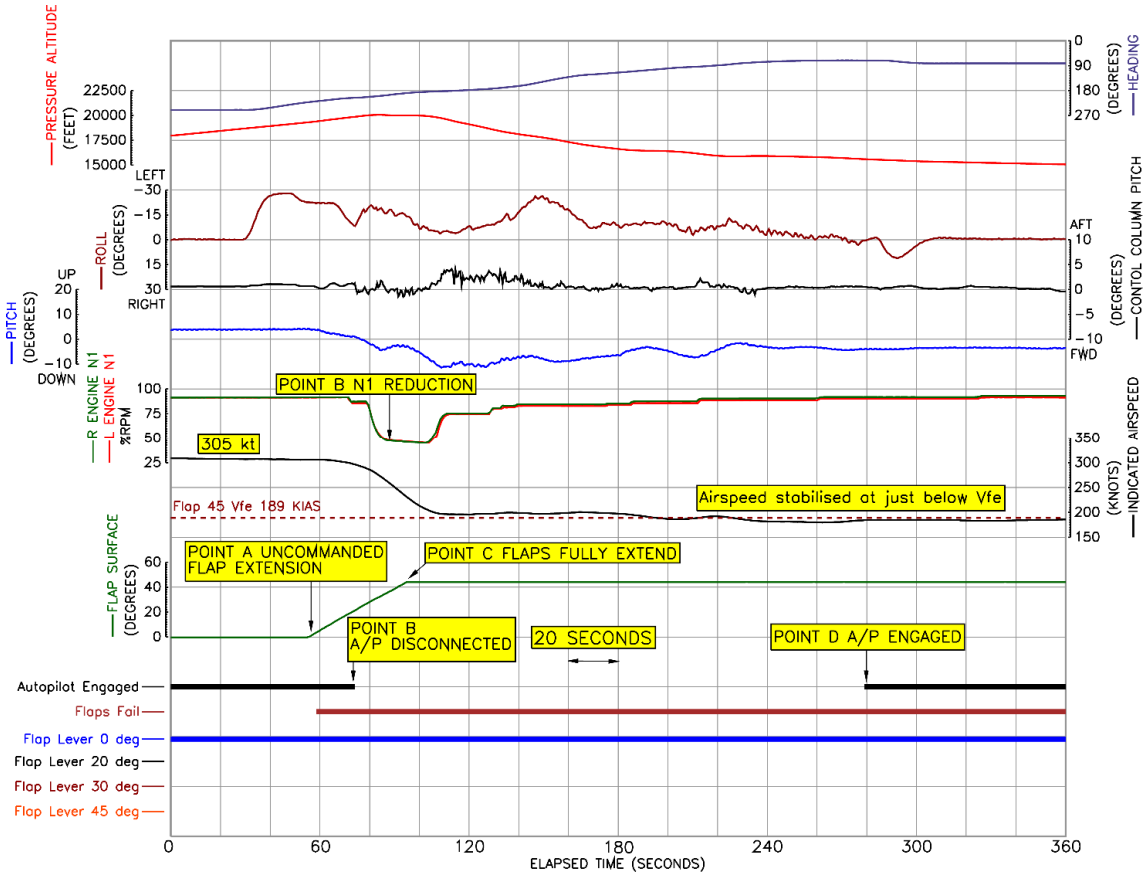

Figure 2

FDR data of uncommanded flap extension

The aircraft's speed continued to progressively reduce over the next 10 seconds, and as it approached 200 KIAS the crew started to progressively increase engine thrust. This coincided with the aircraft also starting to descend, having briefly climbed to FL200. The crew subsequently stabilised the aircraft's speed at about 183 KIAS with engine thrust set at 92% N1. The autopilot was then engaged (Figure 2, Point D), and the aircraft subsequently 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 having been stabilised at just below 189 KIAS with the flaps at 45°. During this period, the maximum flap overspeed was about 103 KIAS.

During the 64 previous flights recorded on the FDR, flap extension had occurred at normal speed, but retraction was at half normal speed. The oldest flight on the FDR was on 4 July 2022.

Aircraft description

General

The CL600-2B16 Challenger 604 is a swept-wing aircraft with a T-tail and is powered by two turbofan engines mounted one either side on the rear fuselage. The aircraft type 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. D-AAAY was configured to carry up to 12 passengers and is operated by two pilots and one cabin crew.

Flap system

Two double-slotted flap panels (inboard and outboard) are externally hinged on the trailing edge of each wing. A flap lever, located on the cockpit centre pedestal, sends an electric signal to the Flap Control Unit (FCU) to initiate flap movement. When the FCU commands a change in flap position, the flap brakes are released, and two 200V 3-phase AC-powered motors mounted on a flap gearbox are energized 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 setting is reached, measured by a flap position potentiometer on the PDU, the motors are de-energized, and the flap brakes 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 3.

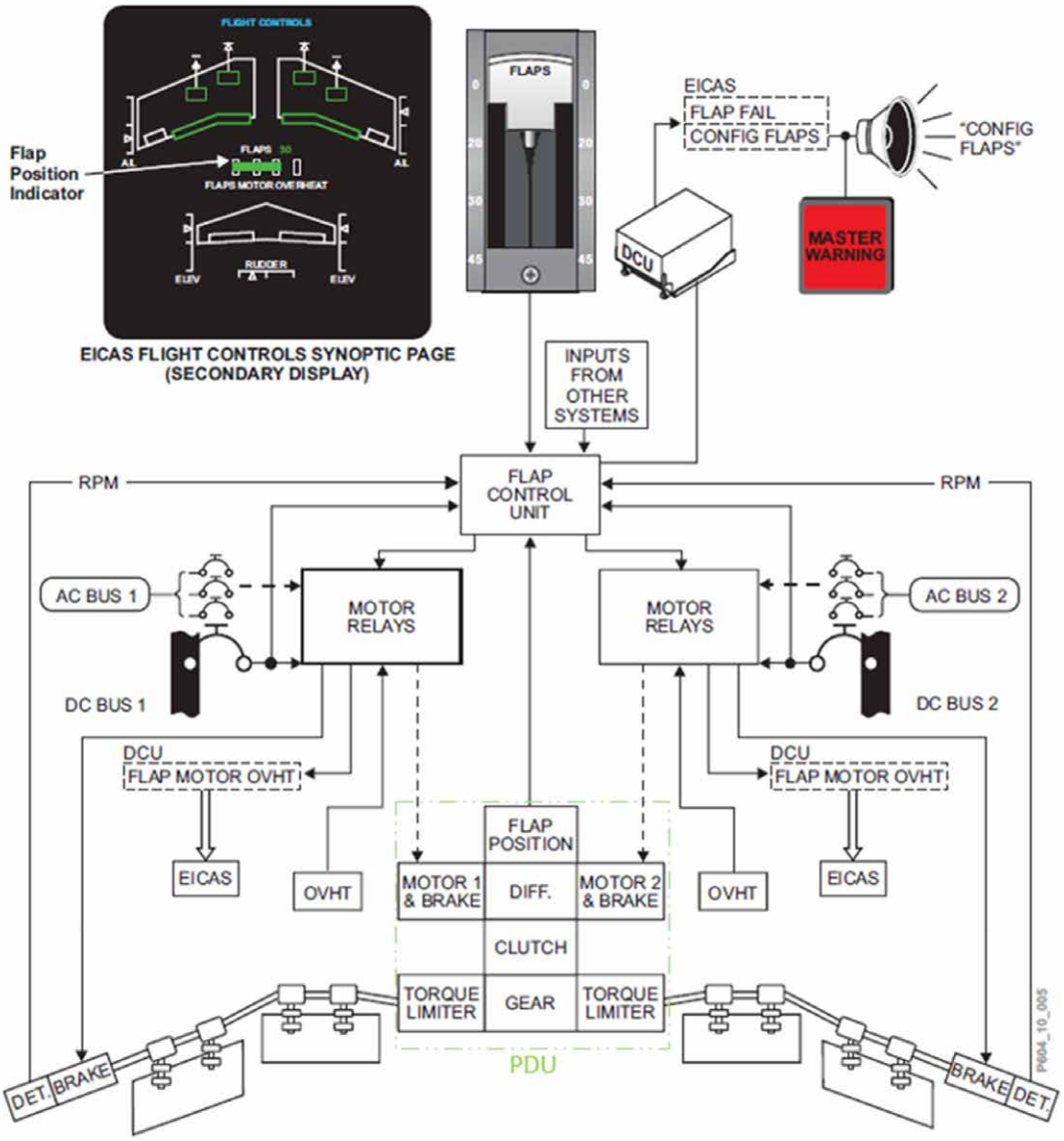

Figure 3

Schematic diagram of flap system

The flaps may be set to one of four positions: 0, 20, 30, and 45 degrees. 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 in view only if the flaps are extended, or if the landing gear is not up and locked.

When both motors are operational, the flaps operate 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 flaps, but the system will operate at half speed due to the gearbox arrangement in the PDU. If a motor fails due to overheat, a 'FLAPS MOTOR OVHT' status EICAS 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 a flap uncommanded movement, a 'FLAPS FAIL' caution message will be displayed on EICAS.

Uncommanded flap movement protection

The FCU has an uncommanded movement protection system. If an uncommanded movement of the flaps occur and the actual flap position exceeds the commanded position by greater than three degrees, the system is activated to arrest further flap movement. Activation of the uncommanded motion monitor powers both the extend and retract commands to the motor relays to activate the protection. This engages the wing tip brakes, by de-energizing them, and removes power from both flap drive motors, arresting the movement, and a 'FLAP FAIL' EICAS message is displayed.

Maximum flap speeds

Flap setting (degrees)	Maximum airspeed (KIAS)
20	231
30	197
45	189

Overspeed warning for flap extension is provided by a second set of contacts in the flap lever. If the flap lever is set to a flap position other than flap 0, and the aircraft's speed is above the limit speed for that position, an aural 'clacker' warning will sound in the cockpit. There is no warning linked directly to the actual flap position.

Relevant maintenance history

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 movement protection system of the flaps is carried out every 4,800 flying hours on the Challenger 604, 605 and 650 aircraft. At the time of this occurrence the aircraft had flown 8,151 hours and the last check was carried out in December 2018, approximately 1,696 flight hours prior to this occurrence, as part of a functional test of the FCU. The operation of the protection system was satisfactory.

Recent maintenance on the flap operating system

The aircraft 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 position sensor was replaced. 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 normal.

Examination of the aircraft

After the aircraft had landed, engineers from a maintenance company began fault finding the defect reported by the flight crew. The aircraft was left parked with electrical power applied and the aircraft powered up. After approximately two hours, the flaps extended fully without command. The flap selector lever in the cockpit was in the flap 0 position.

The manufacturer was contacted for technical and fault finding advice and provided detailed testing and inspection procedures designed to identify any anomalies with the flap system. This work included detailed wiring and insulation checks as well as functional tests of the flap system. On 15 August 2022, the AAIB commenced its investigation.

In parallel with the fault isolation work, a preliminary structural inspection was carried out. The results were passed to the manufacturer for review in conjunction with the flight data to understand the loads experienced by the aircraft during the occurrence. The results of this review will be used to determine the extent of the remedial actions required.

No 1 retract relay

The testing and inspection identified that the No 1 motor retract relay was not working as expected.

All four of the flap extend / retract relays were taken to a specialist facility and were scanned using a computerised tomography (CT) scanner. Figure 4 is an image of the No 1 motor retract relay from the scan showing a contact anomaly. This anomaly is being investigated further, along with discrepancies in the operation of the relay.

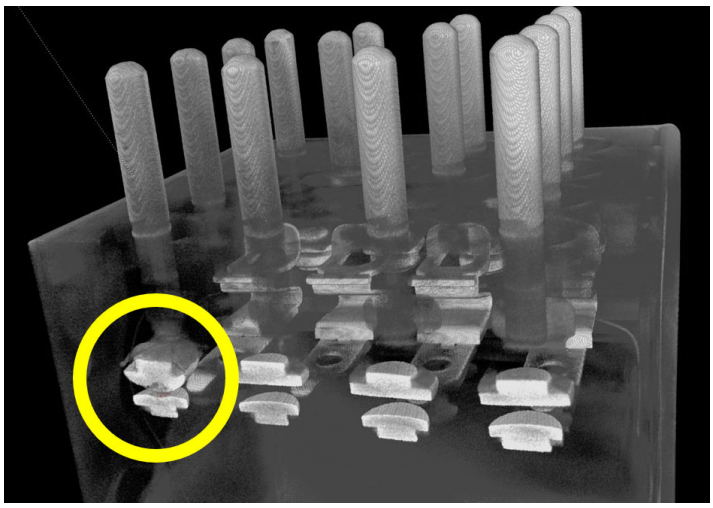

Figure 4

CT scan image of a contact anomaly in No1 motor retract relay

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 considering multiple failures. An uncommanded flap extension in cruise was identified as a potentially catastrophic event[3]. The analysis concluded that two concurrent failures would be required, and the probability of this occurring was calculated as being extremely improbable[4].

Analysis

At least two faults are required for an uncommanded flap movement beyond three degrees of the commanded position. One to cause the flaps to move, and a second to prevent the movement from being arrested.

Uncommanded extension of flaps

The reason for the uncommanded extension of the flaps has not yet been determined and is subject to further investigation.

Uncommanded flap movement protection

When uncommanded flap movement is detected by the protection system, it provides electrical power to the No 1 and No 2 extend and retract relays. This engages the wing tip brakes, by de-energizing them, and removes power from both flap drive motors thereby arresting the movement of the flaps.

The fault with the No 1 retract relay meant the No 1 motor continued to operate and the wing tip brakes did not engage. The No 2 relays worked as expected and the No 2 motor was unpowered. Consequently, the flaps continued to extend uncommanded at half speed, driven by the No 1 motor, until they reached the limit stop.

Failure of the No 1 retract relay meant that the uncommanded movement protection system was disabled and only an uncommanded extend signal was required to extend the flaps. The safety case for an uncommanded flap movement was calculated assuming two concurrent failures, but this event shows that it is possible for one failure to exist undetected for some time, thereby increasing the risk of this potentially catastrophic event occurring. The following Safety Action is being taken by Transport Canada and the aircraft manufacturer to review the safety case for the Challenger 600 series of aircraft:

Safety Action

Transport Canada have advised that they and Bombardier are reviewing the safety case for the flap operating system of the Challenger 600 series of aircraft to ensure that the safety risk probability of an uncommanded flap movement is correct.

Footnote

[3] Catastrophic – Aircraft destroyed and/or multiple deaths. (ICAO Doc 5863, Safety Management Manual).
[4] Extremely improbable – Almost inconceivable that the event will occur. (ICAO Doc 5863, Safety Management Manual).

On this occasion the crew, who were actively monitoring the aircraft during climb, quickly noticed the uncommanded flap extension and were able to respond appropriately to control the aircraft and reduce its speed to below the flap limit speed. Even so, the flap overspeed reached up to about 103 kts and the speed was not reduced below the flaps 45 limit speed for some 170 seconds.

Had the aircraft been in the cruise, the crew may not have been able to recognise the uncommanded flap extension so promptly and take corrective action within the time required for the flaps to fully extend.

As the outcome of an uncommanded flap extension could potentially be catastrophic, the aircraft manufacturer has taken the following Safety Action to advise operators of this event:

Safety Action

By 20 October 2022, Bombardier will advise operators of the Challenger 600 series of aircraft, through an Advisory Wire, of the circumstances of the occurrence to D-AAAY.

To ensure that operators are aware of the actions to take in the event of an uncommanded flap operation, which may occur without warning, the following Safety Recommendation is made:

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.

A failed relay, or the flaps operating at half speed, is not annunciated and it is possible that other aircraft in the fleet may be operating with a similar latent failure that could render the uncommanded flap movement protection system ineffective. Therefore, the following Safety Actions have been taken to advise operators of the instructions available to check the speed of movement of the flaps, and ensure that appropriate mandatory inspections are carried out to ensure the continued safe operation of the fleet:

Safety Action

By 20 October 2022, Bombardier will advise operators, through an Advisory Wire, of the existing maintenance tasks that will identify if the flaps are operating at half speed.

Safety Action

Transport Canada have advised that Bombardier and Transport Canada will determine any appropriate actions to ensure that the protection system on the Challenger 600 series of aircraft will stop an uncommanded flap extension and the system operates as intended. Transport Canada will mandate such actions as necessary for the continued safe operation of the aircraft.

Initial findings

1. Whilst the aircraft was climbing, an uncommanded flap extension occurred which was not arrested by the uncommanded movement protection system.

2. The flap overspeed warning did not sound, as the flap lever remained at the flap 0 position. This warning is triggered by flap lever movement, not the actual flap position.

3. The flap uncommanded movement protection system detected the uncommanded movement and the 'FLAP FAIL' EICAS message was displayed.

4. The flap position indicator showed the flaps extending.

5. Fault finding identified an anomaly with the operation of the electrical contacts inside the No1 retract relay. The result of this anomaly was that as the flaps were only being driven by one of the two motors, they retracted at half-speed.

6. There is no annunciation or warning to indicate the incorrect operation of the relay or to indicate the flaps are operating on one motor at half speed.

7. A further effect of the defective No 1 retract relay was that the uncommanded flap movement protection system did not work on D-AAAY.

8. The flaps on D-AAAY had been retracting at half speed since at least the 4 July 2022. Since this date the aircraft had operated for 154 hours and 64 flights.

Further work

The investigation continues to focus on identifying the cause of the uncommanded flap extend signal.

The four flap extend and retract relays, along with other flap system components removed from the aircraft, will be sent for more detailed examination and testing.

The structural analysis of the event by the manufacturer is continuing and initial inspections and checks for damage to the aircraft are ongoing.

Published: 22 September 2022.