Bombardier CL-600-2B16 (604), **D-AAAY**	**In the climb after departing Farnborough Airport, Hampshire**	**10 August 2022**	**Serious Incident**

Investigation Synopsis

In the climb, after departing Farnborough Airport, D-AAAY had an uncommanded1 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 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: S2/20222 on 22 September 2022, and S1/20233 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.

Safety Recommendation 2022-017

Justification

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.

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.

Therefore, the following safety recommendation was 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.

Date Safety Recommendation made: 22 September 2022

LATEST RESPONSE

Response received: 14 February 2023

On January 30th, 2023, Bombardier's Corrective Action Review Board (CARB) mandated that Bombardier revise the Challenger 600 series 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 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.

Safety Recommendation Status **Open**

AAIB Assessment **Adequate**

Action Status **Planned Action Ongoing Update Due** 30 June 2024

Feedback rationale

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. (EU Regulation 996/2010 article 18 refers).

RESPONSE HISTORY

Response received: 14 December 2022

Bombardier is still evaluating the flight crew actions which could be taken in the event of uncommanded unarrested flap operation, and what those actions might be. A final decision will be taken on January 27th, 2023.

AAIB Assessment – Partially Adequate Open

Safety Recommendation 2023-004

Justification

The failure of the relays was caused by damage to the D contacts which switch electrical power to the BDUs. The damage was consistent with arcing between the contacts, which caused metal transfer and the welding of the contacts. As all the contacts in the relay are mounted on a common shaft, the welding of the D contacts would stop the other three sets of contacts from working properly.

Therefore, the following safety recommendation was made:

> **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.

Date Safety Recommendation made: 01 March 2023

LATEST RESPONSE

Response received: 19 April 2024

The relay contact energizing the BDU coils ("D-contact") is degrading before the expected end-of-life. This degradation is caused by low-voltage arcing, which is in turn caused by 14.8V/10A inductive back-EMF from the BDU coils. The relays are rated for an 8A inductive load and a 10A resistive load; however, the relay supplier has since validated by test that the relays can withstand a 15A resistive load. Based on this, Bombardier Engineering has developed an arcing and EMF protection circuit which allows the D-contact to perceive a 10A resistive load instead of the actual 10A inductive load, protecting the relay from premature failure. The circuit has been tested and found to be effective.

For the Challenger 604/605/650 fleet, the proposed terminating corrective action is to carry out a onetime replacement of the currently installed extension/retraction relays in each in-service aircraft with new relays, and at the same time introduce either a Time Limits and Maintenance Checks (TLMC) task to replace the relays every subsequent 3000 flight hours or install the new protection circuit.

For the Challenger 600/601 fleet, it was identified that there is too much variability in JB configurations between aircraft, such that creating standardized engineering to install the new protection circuit would not be feasible. Therefore, the proposed terminating corrective action for these aircraft is to replace the currently installed extension/retraction relays in each in-service aircraft with new relays, and add a task to the TLMC requiring replacement of the relays every subsequent 3000 flight hours.

The above proposed corrective actions are to be presented to CARB for approval no later than June 30th, 2024, at which time an implementation strategy will also be discussed.

Safety Recommendation Status **Open**

AAIB Assessment **Adequate**

Action Status **Planned Action Ongoing Update Due** 31 July 2024

Feedback rationale

The proposed action from Bombardier Aviation meets the intent of the Safety Recommendation. An update is requested, by 31 July 2024, following the decision of the CARB to approve the proposed modification and implementation strategy. (EU Regulation 996/2010 article 18 refers).

RESPONSE HISTORY

Response received: 04 June 2023

Bombardier is 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 – Partially Adequate Open

Safety Recommendation 2023-005

Justification

The relays have a component manufacturer inductive load life of 20,000 operating cycles. During a normal flight there will be four flap extensions and two flap retractions, with each movement energising and deenergising the BDU brake solenoids. This would mean the relays would reach their life after 5,000 flight cycles for the extend relays and 10,000 flight cycles for the retract relays. The three aircraft on which the relays had failed had flown 3,900 (retract), 4,687 (extend) and 4,344 (extend) flight cycles.

The maintenance policy is for the relays to remain fitted to the aircraft until a failure is detected; however, detection can be many flight hours after a failure has occurred. The correct function of these relays is required for the operation of the safety critical, uncommanded flap movement arrest system.

Therefore, the following safety recommendation was made:

> **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.

Date Safety Recommendation made: 01 March 2023

LATEST RESPONSE

Response received: 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.

Safety Recommendation Status **Closed**

AAIB Assessment **Not Adequate**

Action Status **No Planned Actions**

Feedback rationale

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. (EU Regulation 996/2010 article 18 refers).

RESPONSE HISTORY

Response received: 04 June 2023

Bombardier is 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 – Not Adequate Open

Safety Recommendation 2023-006

Justification

The uncommanded, unarrested movement of the flaps is potentially catastrophic and requires two concurrent failures. The original safety case considered this to be extremely improbable. However, this investigation has identified that on at least 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 any one of these relays is a latent failure because it is not annunciated to the operating crew or maintenance staff. The undetected latent failure of these relays suggests that the original safety case for the uncommanded, unarrested flap movement may no longer be valid. This is because the protection offered by the flap brake system is no longer available and a single failure of another part of the system could be sufficient to cause a catastrophic outcome. This possibility is unlikely to satisfy the 'extremely improbable' requirement. At the time of certification, FAR 25.1309 required that the occurrence of any failure condition which would prevent the continued safe flight of the airplane is 'extremely improbable'.

Therefore, the following safety recommendation was made:

> **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.

Date Safety Recommendation made: 01 March 2023

LATEST RESPONSE

Response received: 03 November 2023

Transport Canada Continuing Airworthiness' 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.

Safety Recommendation Status **Closed**

AAIB Assessment **Adequate**

Action Status **Planned Action Completed** 30 June 2023

Feedback rationale

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. (EU Regulation 996/2010 article 18 refers).

RESPONSE HISTORY

Response received: 05 April 2023

Transport Canada Civil Aviation concurs with the intent of the safety recommendation.

On February 24th, 2023, after review of the initial facts related to the un-commanded flap extension which occurred on aircraft D-AAAY, Transport Canada Civil Aviation issued Airworthiness Directive (AD) CF-2023-07 as an interim risk mitigation measure for the CL-600-1A11, CL-600-2A12, and CL-600-2B16 aeroplane models.

Transport Canada Civil Aviation continues 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.

AAIB Assessment – Partially Adequate Open