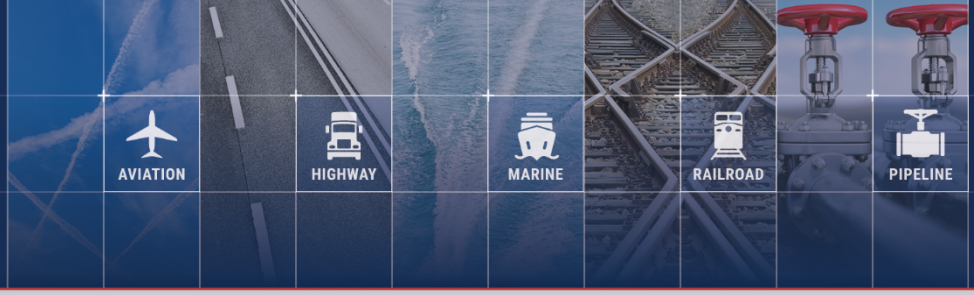


Aviation Investigation Final Report

Location:	Windsor Locks, Connecticut	**Accident Number:**	ERA23LA135
Date & Time:	March 3, 2023, 16:00 Local	**Registration:**	N300ER
Aircraft:	BOMBARDIER INC BD-100-1A10	**Aircraft Damage:**	Minor
Defining Event:	Loss of control in flight	**Injuries:**	1 Fatal, 4 None
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The flight crew flew the passengers to their destination the day before the accident, and were conducting the return flight the following day. During the exterior preflight inspection, the second-in-command (SIC) was interrupted by line personnel delivering ice to the airplane and inadvertently failed to remove the right side pitot probe cover. The flight crew completed the remainder of their preflight activities, boarded the passengers, and taxied for takeoff.

During takeoff, the SIC observed an anomaly with his right side primary flight display (PFD) airspeed indicator and he called for the pilot-in-command (PIC) to abort the takeoff. The PIC aborted the takeoff and taxied the airplane off the runway onto a taxiway. The SIC suspected that he may have forgotten to remove the pitot probe cover, and while stopped on the taxiway with the right engine running, he exited the airplane and removed the cover.

Data recovered from the airplane's flight data recorder (FDR) indicated that the crew aborted the takeoff 16 seconds after thrust application, and the airplane reached a maximum speed of 104 knots (kts) as indicated by the left PFD airspeed indicator. The right PFD airspeed indicator data was consistent with the pitot probe remaining covered.

While on the taxiway, the PIC began troubleshooting a Crew Alerting System (CAS) cyan (blue) "RUDDER LIMITER FAULT" advisory message. He also noticed that the flight director was stuck in a pitch mode. He conducted multiple avionics stall tests, which had cleared the message on past flights; however, he was unable to clear the advisory message. The SIC initially indicated that he would call maintenance control; however, after a short discussion with the PIC, both flight crew members agreed to continue the flight with the advisory message posted. The flight crew did not consult the airplane's "Go/No-Go" guide, but if they had, they would have found

that the Rudder Limiter Fault advisory message was a “No-Go” item, and that the Minimum Equipment List provided no relief to depart with that message displayed.

During the subsequent takeoff, the SIC noticed that the airplane’s V-speeds were no longer referenced (“bugged”) on the airspeed indicator, and he called the speeds from memory. When the airplane passed through about 400 ft radio altitude, an amber (yellow) caution “MACH TRIM FAIL” CAS message posted. The PIC turned the airplane on course and shortly after takeoff, turned on the autopilot (AP), after which the CAS immediately displayed an additional amber “AP STAB TRIM FAIL” caution message. During the climb to cruise altitude, the pilot disconnected the autopilot via his use of the horizontal pitch trim control wheel button. Following his trim adjustments and the resulting disconnect of the autopilot, he subsequently reengaged the autopilot two additional times. With each disengagement and reengagement, all AP-related caution messages would clear, and then reappear upon autopilot reengagement. Furthermore, during the second and third engagements, an additional “AP HOLDING NOSE DOWN” caution message was displayed as airspeed increased in the climb.

According to the cockpit voice recorder (CVR), the SIC asked if the autopilot was failing to off, or if the PIC was disengaging the autopilot. The PIC informed the SIC that he disengaged the autopilot, but during the subsequent disengagements and reengagements, he never announced to the SIC that he was turning the autopilot on or off. The SIC advised the captain to not use the autopilot during the climb, to which the PIC agreed.

Shortly after receiving the amber CAS caution messages, the PIC called for the SIC to “get the checklist,” but did not call for a specific checklist by name. The flight crew then became fixated on reprogramming the V-speeds into the Flight Management System (FMS), as the SIC believed that the caution messages may have been related to a configuration problem with the V-speeds and FMS since they had cleared following the aborted takeoff.

About 8 minutes after the PIC called for the checklist, the SIC located the quick reference card (QRC) and the “PRI STAB TRIM FAIL” [Primary Stabilizer Trim Failure] checklist. The SIC reported in a postaccident interview that he selected this checklist because it was the only trim failure checklist on the QRC, and it seemed to address the root cause of the problem. Although there were multiple CAS messages displayed, he did not consider using any other checklist.

The SIC reported that he visually showed the PIC the checklist, and they agreed to execute the checklist. The first action item was to move the stabilizer trim switch (“STAB TRIM”), located on the center console, from “PRI” (Primary) to “OFF.” The SIC read the checklist item aloud and subsequently moved the switch to off.

Flight data recorder (FDR) information indicated that, as soon as the switch position was moved, the autopilot disconnected, and the airplane, which had been in a 3° nose-up attitude, rapidly pitched up to 11° in one second. The normal acceleration then rapidly rose to 4g. The PIC then pushed the control column forward with at least 90 lbs of force, the airplane pitched down to a near nose-level attitude, and the normal acceleration was reduced to -2.3g. The

control column was subsequently pulled back through neutral, and the airplane rapidly pitched up to over 20° nose-up and more than 4g of normal acceleration. The FDR then stopped recording as the inertial g switch was triggered by the loading. As a result, the full extent of the pitch event was not recorded. The airplane's maneuvering load factor limitation was +2.6g.

The PIC reported that, immediately before the pitch oscillations, his left hand was on the flight controls and his right hand was guarding the right side of the flight controls. He reported that he did not anticipate the airplane pitching up so rapidly, but he did expect the autopilot to disconnect upon turning the stabilizer trim switch off.

Shortly after the in-flight upset, the flight crew were alerted to a passenger that had been seriously injured. The SIC exited the flight deck to check on the passenger and to provide medical attention. He subsequently informed the PIC that there was a medical emergency and that they needed to land. About 17 minutes after the in-flight upset, the flight landed at the diversion airport. Later that day, the passenger succumbed to her injuries sustained during the in-flight upset.

Postaccident download of the horizontal stabilizer trim electronic control unit (HSTECU) non-volatile memory found that, during the aborted takeoff, the speed mismatch between Air Data Computer 1 (ADC1) and ADC2 exceeded 20 kts for more than 5 seconds (due to the covered right pitot probe).

This scenario resulted in key faults being recorded in the HSTECU. A review of the logic for these fault messages showed that the HSTECU latched an "ADC1/ADC2 Miscompare," indicating an airspeed data mismatch between ADC1 and ADC2, resulting in the HSTECU posting the Rudder Limiter Fault advisory message. In addition, a "Confirmed Mach Valid" latched to FALSE, which resulted in the Mach Trim Failure message, and the HSTECU inhibiting the autopilot trim function of the stabilizer. The manual stab trim operated at a reduced rate of movement, but was functional.

The series of faults introduced into the HSTECU following the aborted takeoff resulted in the crew receiving the "AP STAB TRIM FAIL" CAS caution message upon autopilot engagement, due to the HSTECU inhibiting the autopilot trim function of the stabilizer. With the autopilot engaged and the trim function inhibited, the autopilot subsequently alerted the flight crew to "AP HOLDING NOSE DOWN," which was meant to alert the crew that the autopilot was on, but that the airplane was out of trim and the autopilot was holding additional load on the flight controls.

According to the airplane manufacturer, the "MACH TRIM FAIL" caution message was inhibited by the airplane's avionics system and was not displayed to the flight crew on the CAS until the airplane was in the air (weight off wheels) and above 400 ft radio altitude.

Flight testing of the accident scenario conducted after the accident, in a like make and model airplane, confirmed that the series of CAS messages likely presented in-flight were "MACH TRIM FAIL" (at 400 ft radio altitude), "AP STAB TRIM FAIL" (upon autopilot engagement), and

“AP HOLDING NOSE DOWN” (upon speed deviation from where the AP was engaged). The testing confirmed that the AP-related CAS messages would clear and then reappear upon autopilot engagement and airspeed changes.

The data indicated that there was no HSTECU malfunction other than the faults related to the ADC1 and ADC2 airspeed discrepancy during the initial takeoff. Additionally, there were no faults that would have produced a “PRI STAB TRIM FAIL” CAS message.

Both the AP STAB TRIM FAIL and the AP HOLDING NOSE DOWN QRH checklists provided warnings about the airplane’s out-of-trim condition when those messages were displayed and also warned that abrupt changes in control forces may be experienced when disconnecting the autopilot. The checklists required the flight controls to be held firmly and provided a caution to minimize changes to airspeed and configuration to minimize the out-of-trim state. It is likely that the accident would have been prevented had the pilots completed one of the AP-related checklists; however, the SIC and PIC agreed to complete the PRI STAB TRIM FAIL checklist, despite the CAS not displaying this message.

The crew displayed inadequate crew resource management on a number of occasions, beginning with their actions following the aborted takeoff, when they failed to recognize the “RUDDER LIMITER FAULT” message as a No-Go item. Had the flight crew called their maintenance control as required, they would have been instructed to power down the airplane, which likely would have cleared the HSTECU faults latched during the takeoff as a result of the airspeed discrepancies between ADC1 and ADC2 due to the right pitot probe still being covered.

Then, despite the SIC questioning the decision to continue the climb to cruise after receiving the cascading CAS messages, the PIC continued the flight as planned. Additionally, the PIC failed to communicate with the SIC regarding his continued use of the autopilot during the climb even after receiving a warning from the SIC to not use the autopilot and agreeing with the SIC’s comments. The PIC’s continued use of the autopilot likely contributed to the SIC’s difficulty in selecting the correct checklist, given that the AP-related caution messages would disappear each time the autopilot was disconnected, but would reappear once reengaged.

The PIC did not call for a specific checklist to address the CAS messages, and when the SIC showed the checklist to the PIC for agreement before they completed it, neither identified the chosen PRI STAB TRIM FAIL checklist as incorrect. According to the CVR transcript, shortly after regaining airplane control, both crew members acknowledged that the autopilot should not have been used during the climb.

The fatally injured passenger’s seatbelt was not fastened at the time of the in-flight upset. The PIC reported that the seatbelt sign was on for the entire flight, and that his regular practice was to never turn it off. The in-flight upset occurred near 23,000 ft, about 9 minutes into the flight. It is likely that the passengers had no expectation for the seatbelt sign to be turned off at any time during the flight, given that they regularly flew with this flight crew. As a result, the passengers had to use their own judgement regarding whether it was safe to get up and move about the cabin.

Had the flight crew chosen the correct QRH checklist, they would have been warned of the possible abrupt change in control force upon autopilot disengagement and could have ensured that the passengers were seated with seatbelts fastened before completing the non-normal procedure. Then, even if an in-flight upset occurred, serious injury likely could have been avoided entirely by each passenger simply being seated with their seatbelt fastened. There were no other serious injuries reported from any other occupant on board.

The sequence of events that ultimately led to the accident originated with the flight crew's failure to remove the right pitot probe cover before takeoff and their subsequent decision to depart with a No-Go CAS message. Although the message was advisory and not cautionary in nature, the airplane was indirectly alerting the flight crew to additional faults that had been introduced into the airplane's systems following the aborted takeoff. The crew's continuation of the flight with an unairworthy airplane directly contributed to the subsequent series of CAS messages, which the crew mis-diagnosed during the climb, resulting in the in-flight upset and loss of airplane control.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The flight crew's failure to remove the right side pitot probe cover before flight, their decision to depart with a No-Go advisory message following an aborted takeoff, and their selection of the incorrect non-normal checklist in flight, which resulted in an in-flight upset that exceeded the maneuvering load factor limitations of the airplane and resulted in fatal injuries to a passenger whose seatbelt was not fastened. Contributing to the severity of the in-flight upset were the pilot-in-command's (PIC) decision to continue the climb and use the autopilot while troubleshooting the non-normal situation, and the PIC's pilot-induced oscillations following the autopilot disconnecting from the out-of-trim condition. Also contributing to the accident was the crew's inadequate crew resource management.

Findings

Personnel issues	Preflight inspection - Flight crew
Personnel issues	Understanding/comprehension - Flight crew
Personnel issues	Decision making/judgment - Flight crew
Personnel issues	Aircraft control - Pilot
Aircraft	Autopilot system - Incorrect use/operation

Factual Information

History of Flight

Prior to flight	Aircraft inspection event
Takeoff-rejected takeoff	Flight instrument malf/fail
Enroute-climb to cruise	Sys/Comp malf/fail (non-power)
Enroute-climb to cruise	Loss of control in flight (Defining event)
Enroute-climb to cruise	Cabin safety event

On March 3, 2023, about 1600 eastern standard time, a Bombardier BD-100-1A10 (Challenger 300) airplane, N300ER, was involved in an accident near Windsor Locks, Connecticut. One passenger was fatally injured. The two airline transport pilots and two other passengers were not injured. The airplane incurred minor damage. The airplane was operated as a Title 14 *Code of Federal Regulations (CFR)* Part 91 personal flight.

The flight crew reported that they completed a flight from Leesburg Executive Airport (JYO), Leesburg, Virginia, to Dillant/Hopkins Airport (EEN), Keene, New Hampshire, with the accident passengers the day before the accident. The accident flight was the return flight to JYO and the first flight of the day.

The SIC conducted an exterior preflight inspection of the airplane. His inspection was interrupted when he stopped to assist an employee of the fixed base operator who had brought ice to the airplane. After assisting the lineman, he resumed the preflight inspection where he thought he had stopped; however, he inadvertently left the non-streamer pitot cover on the right pitot probe. The PIC also did not observe the pitot probe cover and reported that the SIC had completed the exterior preflight checklist. The passengers arrived about 1500 boarded the airplane, and the pilots conducted an uneventful engine start and taxi.

During the takeoff roll on runway 2, the SIC reported that the airplane accelerated normally; however, he observed that the right primary flight display (PFD) airspeed indicator failed to show an acceleration above 40 knots (kts), while the left airspeed indicator showed a normal acceleration. The crew rejected the takeoff, and the PIC slowed the airplane without issue and exited the runway onto a taxiway.

According to data recovered from the flight data recorder (FDR), the takeoff was initiated at 1526:11 and was subsequently aborted about 16 seconds later. The airplane reached a maximum speed of 104 kts, as indicated by the left PFD; however, the data for the right PFD airspeed indicator was consistent with the probe remaining covered.

Following the rejected takeoff and exit from runway 2, the left engine was shut down on the taxiway, and the SIC opened the main cabin door and walked to the front of the airplane, where

he subsequently observed that the red pitot probe cover remained installed on the right side pitot probe. The SIC removed the cover, did not see any damage to the probe, and returned to the cockpit.

While the SIC was retrieving the pitot probe cover, the PIC observed a Crew Alerting System (CAS) cyan advisory "RUDDER LIMITER FAULT" message. The PIC reported that he attempted two avionics stall tests (STALL/ RUD LIM test) to clear the message, as he had received this advisory message on previous flights in environments where the airplane was cold soaked; however, the tests did not clear the annunciation.

The cockpit voice recorder (CVR) captured the flight crew discussing the Rudder Limiter Fault message and that the flight director was in pitch mode. After the SIC observed the Rudder Limiter Fault CAS message, he stated, "I'll call 'em," and the PIC responded with, "who you calling?" The SIC stated, "do you want to take off with a rudder limiter fault?" The PIC responded with "it's advisory only." Their discussions continued briefly and eventually both agreed to continue the flight with the advisory message displayed.

The crew again taxied for takeoff, entered runway 2, and began the takeoff roll. According to the PIC, the flight director command bars on the attitude pitch indicator would not appear after pressing the takeoff button, but he elected to continue with the takeoff. According to the SIC, about 80 kts, he noticed that there were no V-speed bugs displayed on the airspeed indicator, but he remembered from their previous takeoff attempt that the V1 (decision) speed was 116 kts. The SIC announced "V1" about 116 knots, followed by "rotate." The airplane became airborne at 1535:27.

The PIC reported that the autopilot was engaged during the initial climb and the turn onto course, and the crew continued a climb to 6,000 ft mean sea level (msl).

During the climb, the flight crew observed multiple CAS caution messages. The crew recalled messages of "MACH TRIM FAIL," "AP STAB TRIM FAIL" [Autopilot Stabilizer Trim Failure], and "AP HOLDING NOSE DOWN." Neither crewmember could recall exactly what order the CAS messages were presented throughout the climb, or whether other messages were displayed.

About 1536:11, the flight was cleared by air traffic control to climb to FL230 (23,000 ft msl).

According to the CVR, at 1536:28, the SIC asked the PIC if he wanted a lower altitude, and the PIC responded with, "no … get the checklist." The SIC subsequently attempted to re-input the V-speeds into the flight management system (FMS) and stated, "I think it's a configuration issue from the beginning." At 1536:52, the sound of a cavalry charge, consistent with an autopilot disconnect, was heard. The SIC questioned the PIC whether the autopilot had failed or whether the PIC disconnected it, to which the PIC stated, "I did that."

According to the FDR, following the initial disconnect at 15:36:52, the autopilot was reengaged two additional times during the climb. With each engagement, the CAS displayed multiple caution messages. During the postaccident interview, the PIC could not recall engaging and reengaging the autopilot multiple times. Coincident with each autopilot disconnect was the manual adjustment of the horizontal stabilizer trim.

According to the CVR, at 1537:58, the SIC stated, “I’d just leave the autopilot off,” and the PIC responded with, “all right,” and “get the checklist going.” The SIC subsequently continued to mention the V-speed selections and questioned the captain on how to program the FMS. For about 4 additional minutes, the crew continued to discuss FMS programming and V-speeds, and at 1542:49, the SIC stated that, “okay there we go … they took those” to which the PIC responded, “aright… run the checklist.”

The SIC, via an electronic flight bag (EFB), located the quick reference card and the PRI STAB TRIM FAIL [Primary Stabilizer Trim Failure] checklist. The SIC reported in a postaccident interview that he selected the PRI STAB TRIM FAIL checklist because, “…it’s the only trim fail checklist in the quick reference [card] and it seemed to be the root cause of our problem.”

The SIC reported that he visually showed the PIC the checklist on the EFB, and they agreed to execute the checklist. The first action on the checklist was to move the stabilizer trim switch (STAB TRIM), located on the center console, from “PRI” (Primary) to “OFF.” The SIC read the checklist item aloud and subsequently moved the switch to the off position.

As soon as the switch position was moved, the autopilot disconnected, and with the autopilot no longer holding nose-down force on the elevator control surface, the elevator rapidly moved to neutral. Subsequently, the airplane rapidly pitched up, the PIC input nose-down column force, and the airplane pitched back down. The airplane pitched up again and the stall protection system activated. The PIC described during postaccident interviews that, “I did not expect it to pitch as rapidly as it did in either direction.” The PIC also reported that, immediately before the pitch oscillations, his left hand was on the flight controls and his right hand was guarding the right side of the flight controls.

The PIC reported that, preceding the rapid pitch event, the autopilot was on, and he expected that once the stabilizer trim switch was turned off, the autopilot would disconnect, which it did. The SIC reported that he believed the autopilot was off as they were completing the checklist.

During the oscillations, the CVR recorded that, at 1544:08, the SIC announced, “stab trim off” and the autopilot disconnect sound was immediately heard. Sounds consistent with items moving in the flight deck were heard and about four seconds after the upset began, the PIC stated, “turn it on… turn it on!” and an electronic voice announced “stall” multiple times. At 1544:26, after control of the airplane had been regained, the SIC stated, “we shouldn’t have had the autopilot on” and the PIC responded with, “yeah.”

Moments after the in-flight upset, the flight crew were alerted by one of the passengers that another passenger had been seriously injured. The SIC exited the flight deck to check on the passenger and to provide medical attention. He subsequently returned to his seat and informed the PIC that there was a medical emergency and that they needed to land.

The PIC reported that he had no problem manually flying the airplane after the in-flight upset, nor did he experience any abnormalities trimming the airplane using the manual pitch trim switch, located on the control wheel, at any point during the flight.

The flight crew informed air traffic control of the medical emergency and began a diversion to Bradley International Airport (BDL), Windsor Locks, Connecticut. The PIC did not reengage the autopilot for the remainder of the flight and landed about 17 minutes after the in-flight upset. After landing, the airplane taxied to the ramp, where an ambulance was waiting. Paramedics entered the airplane and subsequently transported the injured passenger to a nearby hospital, where she succumbed to her injuries later in the day.

Flight Data Recorder and Non-Volatile Memory Information

Takeoff and Climb

According to data recovered from the airplane's FDR, no significant difference in airspeed between the left and right PFD airspeed indicators was observed in the data following the SIC's removal of the pitot probe cover. Throughout the initial climb, multiple pilot-commanded pitch trim inputs and corresponding movements from the horizontal stabilizer were observed outside of the time the autopilot was engaged.

During the climb, the FDR data showed that the autopilot had been engaged and disengaged three separate instances. With each autopilot engagement, an immediate master caution was annunciated (Note: the FDR did not record specific CAS caution messages. Refer to the Flight Testing section for additional information).

The autopilot disconnected in the first two instances after the pilot pitch trim rocker switch was activated and small pitch oscillations were observed after the disengagement. The autopilot was reengaged for the final time at 6,230 ft msl and remained on until reaching 22,780 ft msl. The airplane's airspeed increased from 238 kts to 274 kts in this segment of the climb.

In-Flight Upset

The FDR recorded that, immediately preceding the in-flight upset, the autopilot was disengaged, which resulted in the autopilot releasing the holding force on the flight controls. The timing of this FDR parameter was consistent with the flight crew's report that the stabilizer trim switch was moved from Primary ("PRI") to "OFF."

A National Transportation Safety Board Performance Study utilized FDR and ADS-B data to evaluate the airplane's performance and configuration during the in-flight upset.

The study found that before the autopilot disengagement, the autopilot was holding an elevator deflection of 5.3° airplane nose-down to balance the airplane's pitching moments and acceleration due to the nose-up horizontal stabilizer position. Following the autopilot disengagement, the elevators rapidly moved to neutral, and the airplane, which had been in a 3° nose-up pitch attitude, rapidly increased pitch to 11° nose-up in one second, and the normal acceleration increased to 4g. The control column was subsequently pushed forward by the PIC with at least 90 lbs of force, the airplane pitched down to a near nose-level attitude, and the normal acceleration was reduced to -2.3g. The control column was then pulled back through neutral, and the airplane again rapidly pitched to over 20° nose up and more than 4g of normal

acceleration. The FDR then stopped recording, as the inertial g switch was triggered by the loading. As a result, the full extent of the pitch event was not recorded. Figure 1 provides an overview of the airplane pitch, column position, and elevator deflection, versus time and normal acceleration for the event. The dots on each respective line trace each sample of the FDR channel.

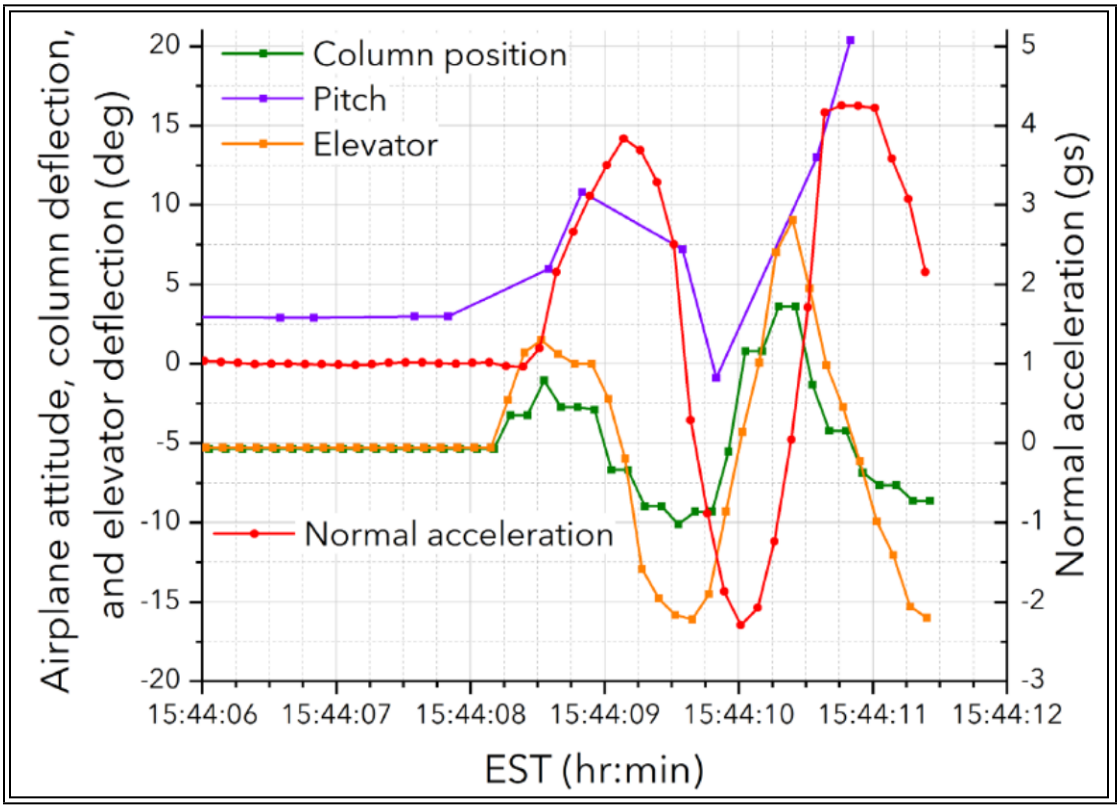


Figure 1: Airplane pitch, column position, and elevator deflection versus time and normal acceleration for event. The dots on each trace show each sample of the FDR channel.

The ADS-B data recorded that the airplane continued to climb to 26,100 ft until 1544:30 while losing 50 kts of groundspeed. The airplane then began to descend and gained over 100 kts of groundspeed in the next two minutes before slowing and descending toward BDL.

The FDR and CVR were equipped with inertial g switches. The CVR continued to record for an additional 10 minutes after the in-flight upset, as it was equipped with a back-up power supply; however, the CVR also stopped recording data prior to landing at BDL.

Horizontal Stabilizer Trim Electronic Control Unit (HSTECU) Information

The horizontal stabilizer trim electronic control unit (HSTECU) was removed from the airplane and shipped to the manufacturer (Moog). On March 16, 2023, the NTSB Systems Group and representatives of Moog convened to download the HSTECU non-volatile memory (NVM) and to test the unit.

Review of the FDR data revealed that, during the rejected takeoff, the mismatch between Air Data Computer 1 (ADC1) and ADC2 speeds were above 20 knots for more than 5 seconds.

This scenario caused several key faults to be recorded in the HSTECU. A review of the logic for these fault messages showed the HSTECU latched an "ADC1/ADC2 Miscompare," indicating an airspeed data mismatch between ADC1 and ADC2, and resulting in the HSTECU posting a "RUDDER LIMITER FAULT" advisory message in the flight deck.

In addition, “Confirmed Mach Valid” latched to FALSE, which resulted in:

- “MACH TRIM FAIL” caution message in the flight deck
- Loss of Mach Trim
- HSTECU inhibit of autopilot trim function of the stabilizer
- Manual trim operating at a reduced rate of 0.2 deg/s

The series of faults introduced into the HSTECU following the rejected takeoff resulted in the crew receiving the CAS caution message of “AP STAB TRIM FAIL” upon autopilot engagement, due to the HSTECU inhibiting the autopilot trim function of the stabilizer. With the autopilot engaged and the trim function inhibited, the autopilot subsequently alerted the flight crew to “AP HOLDING NOSE DOWN” upon acceleration, which was meant to alert the crew to the out-of-trim condition.

A review of the “MACH TRIM FAIL” caution message revealed that it was inhibited (not displayed) by the airplane’s avionics system while on the ground. The system was designed to not display the message to the flight crew on the CAS until the airplane was in the air (weight off wheels) and above 400 ft radio altitude.

The HSTECU latched faults could have been cleared if the unit, via the circuit breaker or the entire airplane, was powered down and then back on before takeoff.

The data found no evidence of a system malfunction with the HSTECU other than that related to the ADC1 and ADC2 issue as a result of the rejected takeoff. Additionally, there were no faults that would have produced a CAS message of “PRI STAB TRIM FAIL.”

Passenger Seating Configuration

Figure 2 shows the reported seating location for each passenger; the fatally injured passenger was No. 3. The cockpit is to the left in the figure, with the lavatory and aft section of the airplane to the right, annotated as “LAV.”

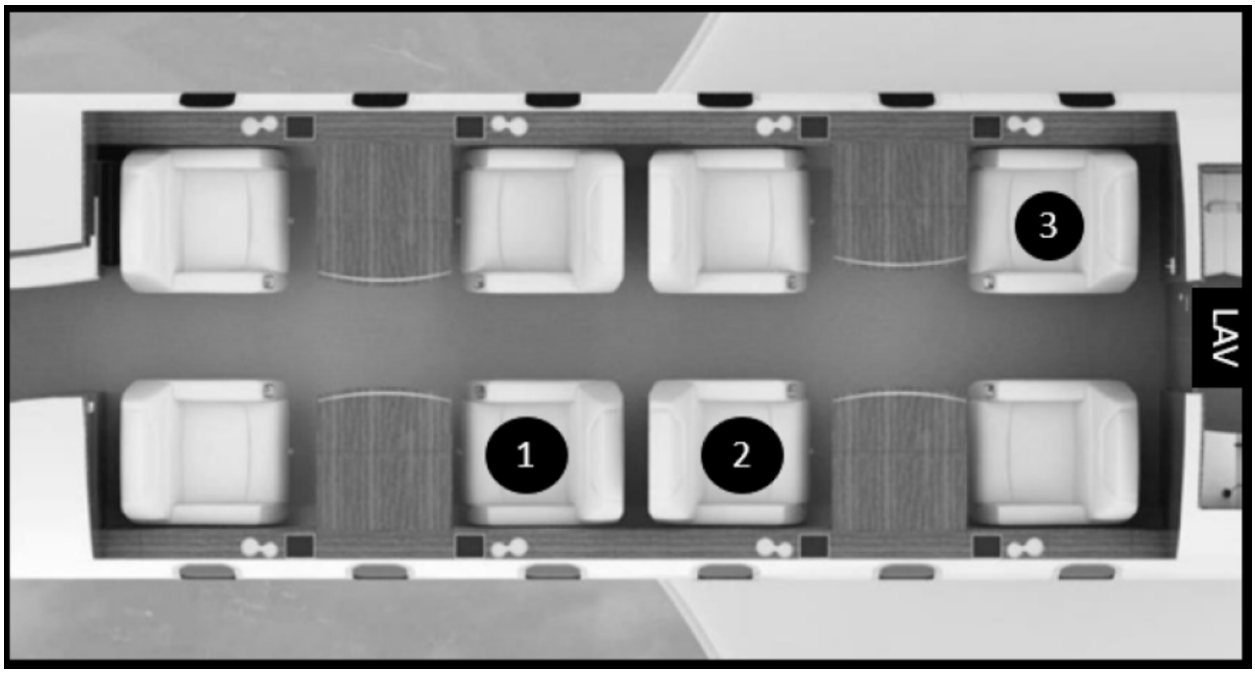


Figure 2: Seating Configuration with passenger seating locations annotated.

The No. 1 passenger reported that he was seated in the forward area club seating on the left side, facing forward during takeoff. He reported that the No. 2 passenger, also seated on the left side, facing rearward, had his seat reclined.

The No. 1 passenger did not recall any significant turbulence during the climb. He described that the in-flight upset occurred without any warning. He explained that it felt like the airplane was breaking apart and that the event was unlike anything he had ever experienced in his numerous years of flying in airplanes as a passenger.

The No. 1 passenger recalled that he was seated and that his seatbelt was buckled during the in-flight upset. After the event ended, he turned around and got up from his seat to see the No. 2 passenger lying on the ground next to his seat. He then saw the No. 3 passenger lying near the lavatory in the aisle of the airplane at its most rearward cabin area. The No. 1 passenger believed that, at some point during the climb, the No. 3 passenger had gotten up from the seat to use the lavatory.

The No. 1 passenger recalled that there were no passenger announcements made from the flight crew before the upset. He could not recall noticing the seat belt sign.

The PIC reported in an interview that the seatbelt sign was on for the entire flight, and that it is his “normal operation” as the PIC to “never turn it off throughout the flight.” He further reported that he and the SIC frequently flew with this group of passengers.

Pilot Information

Certificate:	Airline transport; Commercial	**Age:**	52,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	December 13, 2022
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	October 11, 2022
Flight Time:	5061 hours (Total, all aircraft), 88 hours (Total, this make and model), 3227 hours (Pilot In Command, all aircraft), 48 hours (Last 90 days, all aircraft), 16 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Commercial	**Age:**	57,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	November 8, 2022
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	October 11, 2022
Flight Time:	8025 hours (Total, all aircraft), 78 hours (Total, this make and model), 4871 hours (Pilot In Command, all aircraft), 48 hours (Last 90 days, all aircraft), 16 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

According to Federal Aviation Administration (FAA) airman records, the PIC held an airline transport pilot certificate and held a PIC type rating in the accident airplane make and model, in addition to other type ratings. Executive Flight Services (EFS) reported that the PIC had accumulated 5,061 total hours of flight experience, and of those, 88 hours were in the accident airplane make and model.

The SIC held an airline transport pilot certificate and held a PIC type rating in the accident airplane make and model, in addition to other type ratings. EFS reported that the SIC had accumulated 8,025 total hours of flight experience, and of those, 78 hours were in the accident airplane make and model.

In October 2022, both pilots completed initial ground and simulator training and earned their PIC type ratings in the Challenger 300.

CAE Training Curriculum

According to the Simulator Instructor (S.I.) #5 “300/350 Instructor Guidance” for the “Initial Type Rating” provided by CAE, “AP STAB TRIM FAIL,” in addition to several other emergency and non-normal procedures, were listed in the topics to be covered outside of the simulator. There were no task items that required “AP STAB TRIM FAIL” or “AP HOLDING NOSE DOWN” to be experienced or examined in the simulator.

According to the PIC’s interview, he stated, “I do not recall doing any training as far as autopilot stab trim fail or autopilot holding nose up or autopilot holding nose down.” The SIC did not recall that either of those CAS messages were presented to him during training.

Simulator Testing

The NTSB conducted simulator testing at CAE in Dallas, Texas, where the accident flight crew received their initial type ratings. The testing attempted to evaluate the accident scenario, to include a rejected takeoff with a failed right side airspeed indicator, followed by a takeoff with known faults on the airplane. The testing determined that the simulator was incapable of producing similar indications to that which the accident flight crew received without a considerable amount of human interaction and abnormal simulator settings not commonly used in training scenarios.

Aircraft and Owner/Operator Information

Aircraft Make:	BOMBARDIER INC	**Registration:**	N300ER
Model/Series:	BD-100-1A10 NO SERIES	**Aircraft Category:**	Airplane
Year of Manufacture:	2013	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	20428
Landing Gear Type:	Retractable - Tricycle	**Seats:**	9
Date/Type of Last Inspection:	February 2, 2023 Continuous airworthiness	**Certified Max Gross Wt.:**	38850 lbs
Time Since Last Inspection:	14 Hrs	**Engines:**	2 Turbo fan
Airframe Total Time:	2321 Hrs at time of accident	**Engine Manufacturer:**	Honeywell
ELT:	C126 installed, not activated	**Engine Model/Series:**	HTF7000
Registered Owner:	Conexon LLC	**Rated Power:**	6944 Lbs thrust
Operator:	Conexon LLC	**Operating Certificate(s) Held:**	None

Owner/Operator

Executive Flight Services (EFS), LLC. held a 14 *CFR* Part 135 air operator certificate and also offered whole aircraft management services. A representative of EFS reported that they managed the accident airplane and employed the flight crew. EFS reported that the flight was operated as a non-revenue 14 *CFR* Part 91 flight by the owner of the airplane, Conexon LLC. According to their website, Conexon was a broadband network design and construction firm based in Kansas City, Missouri.

Airplane

The airplane was a Bombardier BD-100-1A10 Challenger 300. It was powered by two Honeywell HTF7000 engines, each capable of producing 6,944 lbs of thrust.

According to the aircraft maintenance record, on February 2, 2023, the airplane had accumulated 2,307.6 total hours. On October 31, 2022, the airplane was inspected and complied with 14 *CFR* Part 135 inspection requirements, and at that time, had a recorded total time of 2,249.0 hours and 1,229 landing cycles. At the time of the accident, the airplane had accumulated 2,321 total hours.

The airplane was configured with 9 passenger seats and 2 flight crew seats. It did not require a cabin attendant due to the number of seats. The minimum flight crew complement was a pilot and copilot.

Within the limitations section of the Bombardier Challenger 300 Flight Crew Operating Manual (FCOM), the maneuvering load factors with flaps retracted were +2.6 g to -1.0 g.

According to the FCOM, Chapter 1, “General,” the airplane was equipped with an Engine Indication and Crew Alerting System (EICAS). The EICAS system was designed to show system status with specified colors. The “Crew Alerting System” portion of the EICAS displayed indications within the CAS window, which was in the upper right portion of the same display (see Figure 3).

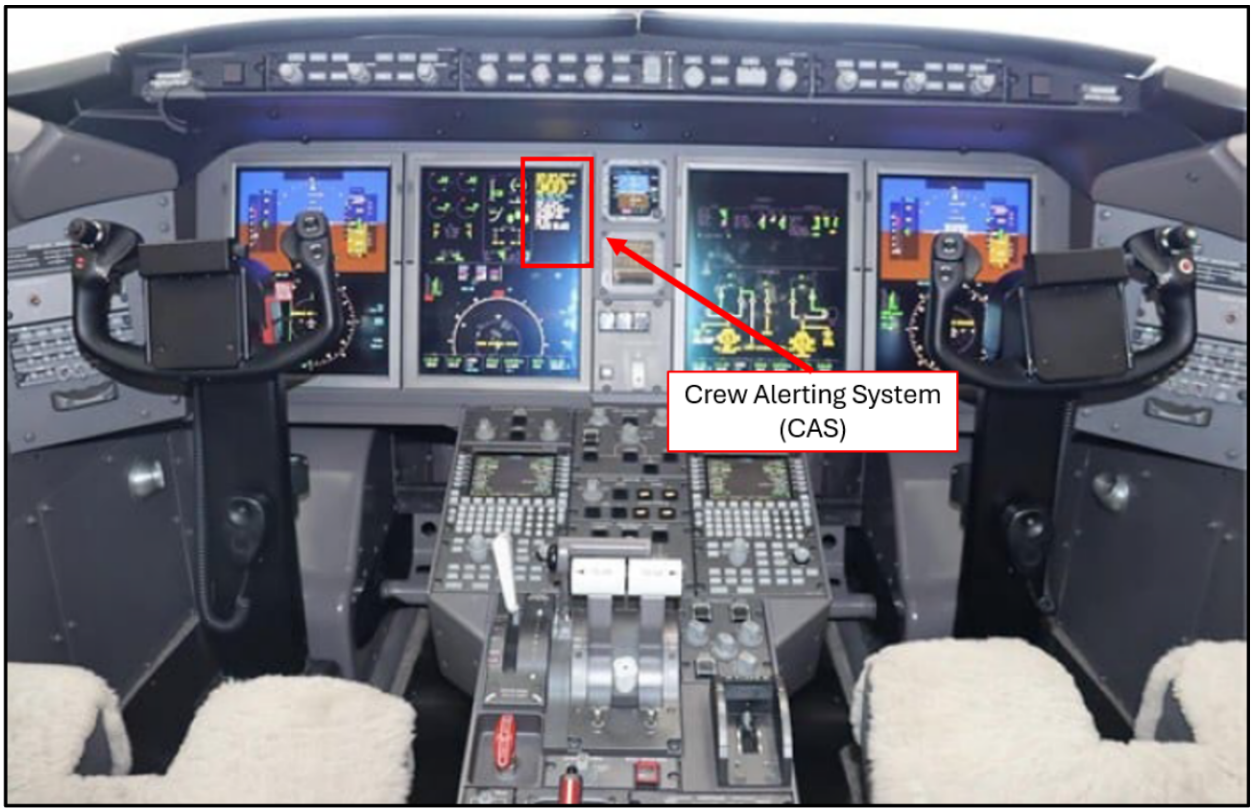


Figure 3: View of the cockpit in the accident airplane with the CAS location annotated (Source of Photo: Aircraft.com)

Final Aircraft Walk-Around Procedure

The EFS General Operations Manual, revision 42, provided, in part, the following guidance about the *"Final Aircraft Walk-Around Procedure"*:

> *Prior to closing the aircraft door with the intent of flight, the PIC shall ensure a final walk-around of the aircraft has been completed on each leg. This procedure will provide a "last chance" to review the exterior of the aircraft to ensure the aircraft is in an airworthy condition and to verify the surroundings of the aircraft.*

Pitot Probe Cover

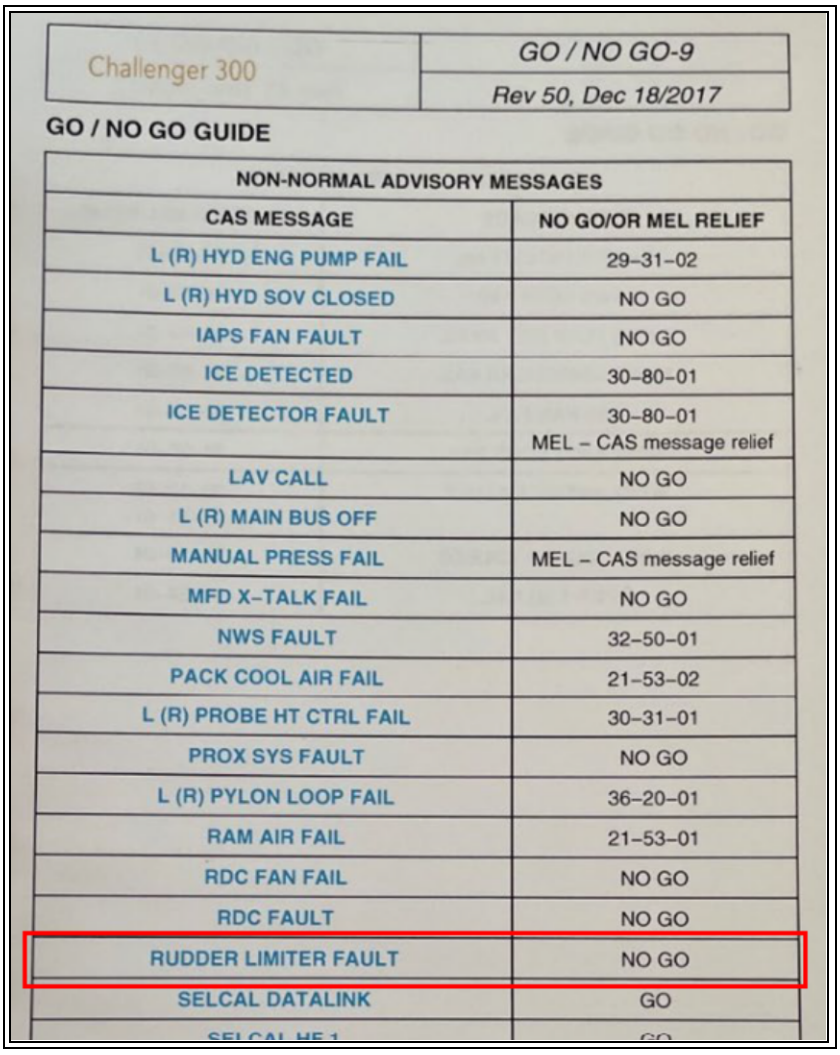
The aircraft was equipped with three pitot probes. Two of the pitot probes were located on the left side and the other was located on the right side, below the pilots' side windows.

Figure 4 contains photographs that were taken postaccident, which show the right pitot probe cover in place as it would have been on the day of the accident, in addition to a closer view of the red-colored cover.

Figure 4: View of the right side forward area of the airplane showing the covered pitot probe.

Rudder Limiter Fault Troubleshooting

The Bombardier Quick Reference handbook (QRH) revision 71, Volume 2, was available to pilots in both electronic form via their EFB and via a paper copy that was stowed in the flight deck. The QRH non-normal advisory message section provided guidance on CAS advisory messages. Depending on the message that was displayed on the CAS, the QRH would provide Minimum Equipment List (MEL) relief, or be listed as a “GO” or “NO GO” item. Review of the list revealed that a “RUDDER LIMITER FAULT” CAS message was a “NO GO” item (see Figure 5.)



Challenger 300	GO / NO GO-9 Rev 50, Dec 18/2017

GO / NO GO GUIDE

NON-NORMAL ADVISORY MESSAGES	
CAS MESSAGE	NO GO/OR MEL RELIEF
L (R) HYD ENG PUMP FAIL	29–31–02
L (R) HYD SOV CLOSED	NO GO
IAPS FAN FAULT	NO GO
ICE DETECTED	30–80–01
ICE DETECTOR FAULT	30–80–01 MEL – CAS message relief
LAV CALL	NO GO
L (R) MAIN BUS OFF	NO GO
MANUAL PRESS FAIL	MEL – CAS message relief
MFD X–TALK FAIL	NO GO
NWS FAULT	32–50–01
PACK COOL AIR FAIL	21–53–02
L (R) PROBE HT CTRL FAIL	30–31–01
PROX SYS FAULT	NO GO
L (R) PYLON LOOP FAIL	36–20–01
RAM AIR FAIL	21–53–01
RDC FAN FAIL	NO GO
RDC FAULT	NO GO
RUDDER LIMITER FAULT	NO GO
SELCAL DATALINK	GO

Figure 5: Go/No Go QRH Guidance [Excerpt] with rudder limiter fault message annotated by red box.

The PIC reported that he did not refer to the QRH Go/ No-Go Guide due to his past experience in receiving the advisory message, which he recalled that it was described in the QRH as a "redundancy" and that the advisory "can stay on for up to 10 landing without removing aircraft power." The SIC, when asked about the Go/No-Go guide, stated that, "It's an advisory, we understood it as an advisory and it didn't lead us to looking in the …go/no-go guide." when asked if there were paper manuals in the airplane, including the QRH, the SIC stated "No." A paper QRH was located in the airplane during postaccident examination.

According to the EFS Director of Operations (DO), the operator had a 24/7 maintenance control service available to all aircraft owned or managed by EFS. The DO was asked to explain what the accident crew would have been instructed to do had they called maintenance control regarding the Rudder Limiter Fault message. He reported that the crew would likely have been instructed to shut down both engines, depower the airplane, and start everything back up. The reset procedure was aimed at clearing computer-driven faults and anomalies. If that reset had not cleared the fault message, control would have determined if any MEL relief was available;

if not available, the airplane would have been grounded until maintenance personnel could diagnose the issue.

Autopilot/Flight Director Mode Confirmation

The EFS, General Operations Manual, revision 42, "Autopilot/Flight Director Mode Confirmation" provided, in part, the following guidance on announcing the engagement or disengagement of the autopilot:

> *Knowing the status of the autopilot system is critical to CRM and any changes to the autopilot status must be communicated and confirmed.*
>
> *When in manual flight, all changes to the autopilot are accomplished by the PM including turning it on. The PF may activate it if the PM is unable to due to a high workload. If the PF turns on the autopilot he shall announce "Autopilot On."*

The QRH Volume 2, "INTRO-1" described, in part, the purpose and use of the manual:

> *The QRH Vol. 2 contains procedures that are associated with Non-Normal operations. It serves a tactical purpose providing the crew with rapid access to critical information at time of need, and has been optimized for efficient flight compartment operation. It also contains other pertinent information (visual symbols, system schematics...), aimed at supporting the crew decision making process and understanding of the procedures in relation to the situation being encountered.*

The manual described multiple EICAS message types, including the two noted below:

> ***Caution*** *messages - Are associated with serious system malfunctions that require immediate crew awareness and subsequent action when time and conditions permit.*
> ***Advisory*** *messages - Are associated with a loss of system redundancy that requires crew awareness and where subsequent action may be needed.*

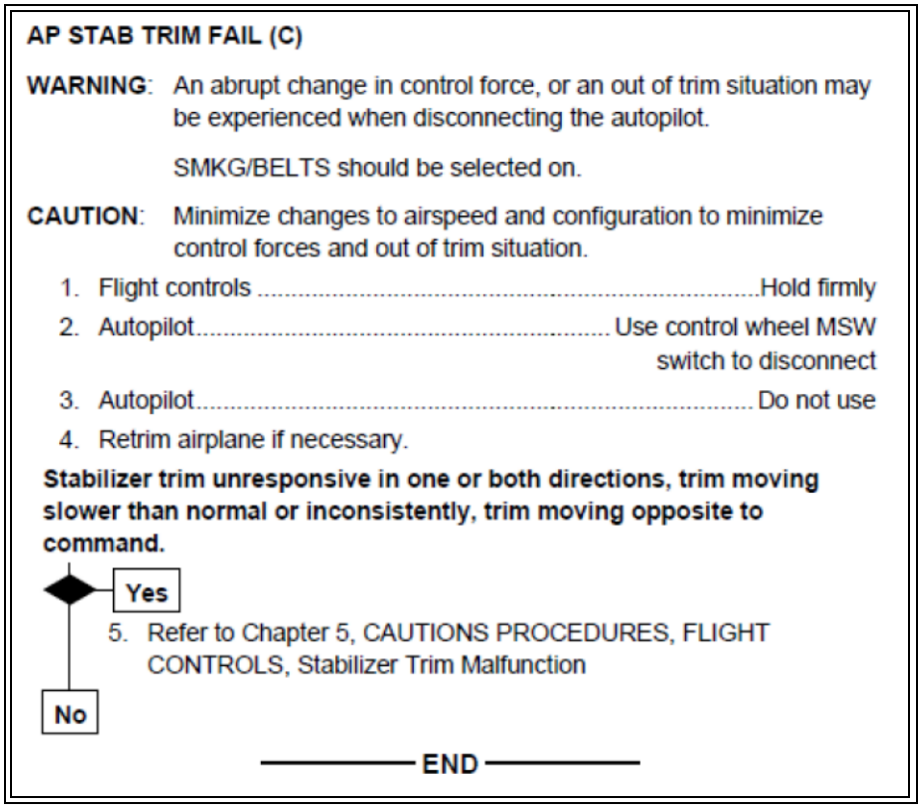
According to the Bombardier QRH, the Quick Reference Card (QRC) was described in part as:

> *Procedures that contain Immediate Action Items, are shown within a box with a red-dashed boarder, and are also provided on the Quick Reference Card (QRC). The QRC can be used by the crew to more efficiently perform the Immediate Action Items without relying solely on memory, thus reducing the possibility of omission or commission errors. The QRC contains only the Immediate Action Items from the QRH, it does not contain the entire procedure.*

The SIC located the PRI STAB TRIM FAIL checklist within the QRC via his EFB. The QRC provided immediate action items on seven items within the flight control portion of the QRH. The "Flight Controls" section, with PRI STAB TRIM FAIL denoted in amber (yellow) contained one action item of, "STAB TRIM ……. OFF." This was the checklist utilized by the flight crew.

The Bombardier Challenger 300 "CSP 100-15- QRH Vol. 2", section 2, "Avionics," provides for the procedure for the "AP STAB TRIM FAIL" message. At the time of the accident, Bombardier

had a temporary revision (TR) in effect for the procedure, which was TR-39-1, dated June 15, 2022 (see Figure 6.) That TR was printed on yellow cardstock and was also located in front of or facing the "AP STAB TRIM FAIL" checklist within the QRH both electronically and in the paper copy, located within the accident airplane, respectively.



AP STAB TRIM FAIL (C)

WARNING: An abrupt change in control force, or an out of trim situation may be experienced when disconnecting the autopilot.

SMKG/BELTS should be selected on.

CAUTION: Minimize changes to airspeed and configuration to minimize control forces and out of trim situation.

1. Flight controls ..... Hold firmly
2. Autopilot ..... Use control wheel MSW switch to disconnect
3. Autopilot ..... Do not use
4. Retrim airplane if necessary.

Stabilizer trim unresponsive in one or both directions, trim moving slower than normal or inconsistently, trim moving opposite to command.

Yes

5. Refer to Chapter 5, CAUTIONS PROCEDURES, FLIGHT CONTROLS, Stabilizer Trim Malfunction

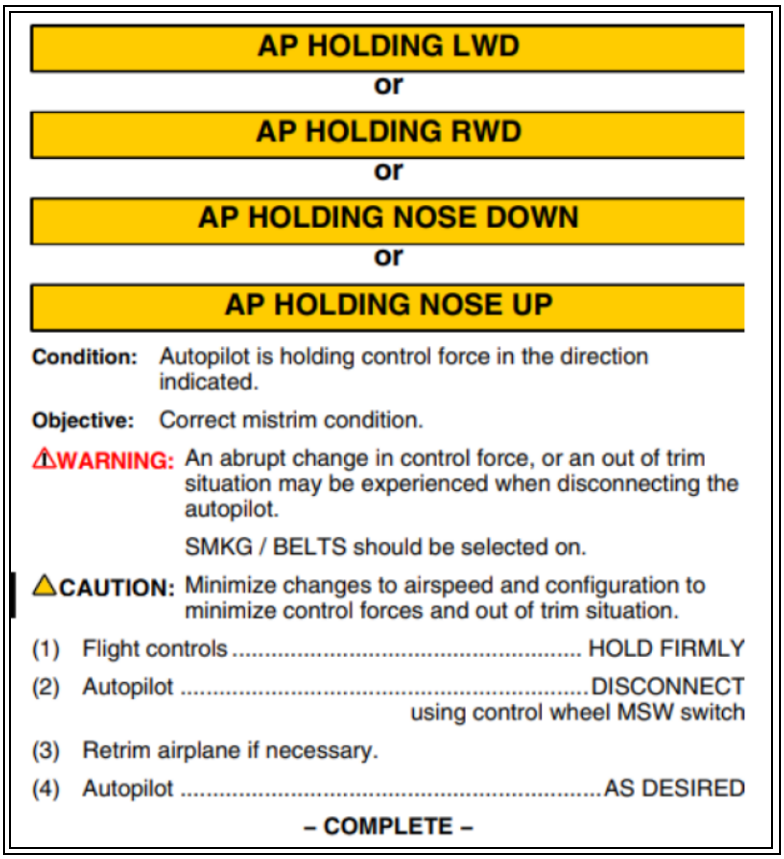
No

END

Figure 6: Temporary revision for AP STAB TRIM FAIL.

The TR included an additional step noted as item 5 within the checklist and reordered items 3 and 4. The TR also included the addition of "Trim Malfunction procedures" and "STAB TRIM FAULT (A) procedures."

Figure 7 below contains an excerpt from the Bombardier Challenger 300 "CSP 100-15- QRH Vol. 2", section 2 "Avionics,"for an "*AP HOLDING LWD" or "AP HOLDING RWD" or "AP HOLDING NOSE DOWN" or "AP HOLDING NOSE UP"* caution message:



AP HOLDING LWD

or

AP HOLDING RWD

or

AP HOLDING NOSE DOWN

or

AP HOLDING NOSE UP

Condition: Autopilot is holding control force in the direction indicated.

Objective: Correct mistrim condition.

⚠WARNING: An abrupt change in control force, or an out of trim situation may be experienced when disconnecting the autopilot.

SMKG / BELTS should be selected on.

⚠CAUTION: Minimize changes to airspeed and configuration to minimize control forces and out of trim situation.

(1) Flight controls ..... HOLD FIRMLY

(2) Autopilot ..... DISCONNECT using control wheel MSW switch

(3) Retrim airplane if necessary.

(4) Autopilot ..... AS DESIRED

– COMPLETE –

Figure 7: Autopilot Holding Left/Right Wing Down and Nose Up/Down Checklist.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	BDL,173 ft msl	**Distance from Accident Site:**	25 Nautical Miles
Observation Time:	15:51 Local	**Direction from Accident Site:**	180°
Lowest Cloud Condition:		**Visibility**	10 miles
Lowest Ceiling:	Broken / 16000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	6 knots /	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	10°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	30.01 inches Hg	**Temperature/Dew Point:**	7°C / -7°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Keene, NH (EEN)	**Type of Flight Plan Filed:**	IFR
Destination:	Leesburg, VA (JYO)	**Type of Clearance:**	IFR
Departure Time:	15:35 Local	**Type of Airspace:**	Class A

Review of weather conditions along the route of flight revealed found no evidence of convective activity, nor any evidence of significant turbulence (reported or forecast).

The flight crew reported that they did not experience any remarkable turbulence during the flight, or during the time immediately surrounding the in-flight upset.

Airport Information

Airport:	Bradley International Airport BDL	**Runway Surface Type:**	Asphalt
Airport Elevation:	173 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	6-24	**IFR Approach:**	ILS;Visual
Runway Length/Width:	9510 ft / 200 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Minor
Passenger Injuries:	1 Fatal, 2 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal, 4 None	**Latitude, Longitude:**	41.938425,-72.688307

The airplane landed without further incident at BDL airport following the in-flight upset event.

The Federal Bureau of Investigations Evidence Response Team sent an agent to the airplane the day of the accident. Photographs showed loose items scattered about the cabin. Some cabin shelving had broken inside of storage cabinets. Above the location of the No. 2 passenger, a part of the curved wood paneling and padded ceiling was cracked and displayed evidence of denting. Additional ceiling dents were located near the last row of seats and aft area of the cabin. Multiple oxygen masks had deployed from the ceiling. There was no evidence of any seat belts breaking free from their attachment points.

An exterior inspection following the accident found no visible damage to any flight control surface or airplane structure. Due to the g loads sustained during the event, the airplane underwent several hidden damage and structural tests following its release from the investigation to determine its future airworthiness.

Medical and Pathological Information

According to the State of Connecticut, Office of the Chief Medical Examiner, the passenger's cause of death was blunt injuries of head, neck, torso, and extremities, and the manner of death was stated as, "Accident (unbelted on plane in flight)."

Tests and Research

Flight Testing

On November 1, 2023, flight testing was performed at Bombardier in Wichita, Kansas. The purpose of the flight testing was to perform a rejected takeoff (RTO) with a cover installed on the right side pitot probe, repeat the actions observed by the flight crew, and then observe the airplane systems' behavior during flight.

The flight test vehicle was compared to the equipment installed on the accident airplane and it was found to be a valid comparison make and model. In addition, the flight test vehicle was flown in a similar weight and balance configuration.

The flight test purposely did not allow the airplane to enter a severely out-of-trim condition as that experienced during the accident flight.

The flight testing found that, following the rejected takeoff, the cyan (blue) advisory CAS message, "RUDDER LIMITER FAULT" posted and persisted for the entire flight, despite multiple ground avionics stall tests (STALL/ RUD LIM test).

During the initial climb, the amber caution message, "MACH TRIM FAIL," annunciated about 400 ft radio altitude and persisted for the remainder of the flight. The autopilot was engaged in the climb, at a similar time compared to the accident flight. Immediately following the autopilot engagement, the caution message "AP STAB TRIM FAIL" annunciated. When the autopilot was disconnected, the "AP STAB TRIM FAIL" message cleared from the CAS. Following the autopilot reengagement, the message immediately re-posted to the CAS.

The autopilot was reengaged at 162 kts and 5,750 ft msl. The flight test vehicle was accelerated at a rate of about one knot per second. Upon reaching 182 kts, the "AP HOLDING NOSE DOWN" caution message posted. When speed was reduced below 182 kts, the "AP HOLDING NOSE DOWN" message cleared. The flight test vehicle flight crew subsequently executed the "AP STAB TRIM FAIL" checklist, which included turning the autopilot off, and returned to land without incident. Figure 8 shows the PFD and CAS displaying the series of caution messages observed with the autopilot on and with the airplane having accelerated into an out of trim condition.

Figure 8: View of the flight test vehicle in-flight with the CAS displaying a series of caution messages and advisory messages.

Following the flight test, the HSTECU was removed from the airplane and shipped to the manufacturer for download. The data showed the same latched faults as those present in the download from the accident airplane. The flight testing confirmed that, given the accident circumstances, there were no conditions identified in the HSTECU, nor displayed in the EICAS, that would have enabled the “PRI STAB TRIM FAIL” message to display.

Administrative Information

Investigator In Charge (IIC):	Gerhardt, Adam
Additional Participating Persons:	Daniel Ferlatte ; Transportation Safety Board of Canada ; Gatineau, OF Michael Lemay; Bombardier; Dorval, OF Paul Hawthorne; Moog Aircraft ; East Aurora, NY Brian Jewell; Executive Flight Services LLC.; Lenexa, KS Jennifer McDuffie; Honeywell Aerospace; Phoenix, AZ Kevin Godbout; FAA/FSDO; Bradley, CT
Original Publish Date:	December 5, 2024
Last Revision Date:	
Investigation Class:	Class 2
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=106816