National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

ERA23LA135

SYSTEMS

Group Chair's Factual Report

August 19, 2024

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A. ACCIDENT

Location:	Windsor Locks, Connecticut
Date:	March 3, 2023
Time:	1600 eastern standard time (EST) 2100 coordinated universal time (UTC)
Airplane:	Bombardier BD-100 (Challenger 300), N300ER

B. SYSTEMS GROUP

Group Chair	Steve Magladry National Transportation Safety Board Washington D.C.
Group Chair	John Flynn National Transportation Safety Board Washington D.C.
Group Member	Todd Gentry Federal Aviation Administration Washington D.C.
Group Member	Michael Tremblay Moog East Aurora, NY
Group Member	Michael Lemay Bombardier Montreal, Canada

C. SUMMARY

On March 3, 2023, about 1600 eastern standard time, a Bombardier BD-100-1A10 (Challenger 300) airplane, N300ER, was involved in an accident while enroute from Dillant/Hopkins Airport (EEN), Keene, New Hampshire to Leesburg Executive Airport (JYO), Leesburg, Virginia. The flight diverted to Bradley International Airport (BDL), Windsor Locks, Connecticut. One passenger was fatally injured. The two airline transport pilots and two other passengers were not injured. The airplane was operated as a personal flight under the provisions of Title 14 Code of Federal Regulations Part 91.

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

On November 1, 2023, flight testing was performed at Bombardier flight test center at the Dwight D. Eisenhower National Airport (ICT), in Wichita, Kansas. The purpose of the flight testing was to perform a rejected takeoff (RTO), with a pitot-static probe cover installed on the RH pitot-static probe, and then observe the airplane systems behavior during a subsequent takeoff and climb. The flight test purposely did not exactly replicate the accident flight. After the flight test, the HSTECU was removed from the airplane and shipped to the manufacturer (Moog) for download.

D. DETAILS OF THE INVESTIGATION

1.0 Autopilot (AP) Description

The Challenger 300 is equipped with a two axis digital fail−passive autopilot. Autopilot servos provide command inputs to the ailerons and elevators. The rudder is controlled by the yaw damper (YD) system and not the autopilot. The flight guidance computers (FGC) hosts both the autopilot function and the yaw damper function. The aileron, elevator and rudder are driven by conventional cable and pulley systems. The coupled FGC provides the flight guidance signals to drive the servos. Both FGCs must be operational for the autopilot to function.

The automatic flight control system (AFCS) consists of dual independent flight directors, a two axis (pitch and roll) autopilot, and automatic pitch trim and yaw damper system. The AFCS operates with the integrated avionics processor system (IAPS). The IAPS collects the data from the avionics systems. The AFCS gives the course, heading, and preselected altitude data to the electronic flight instrument system (EFIS). The AFCS calculates the vertical and lateral flight−guidance commands to keep the aircraft on the correct pitch/roll attitude. The flight directors show the flight−guidance commands on the PFDs. Figure 1 shows the cockpit layout. Figure 2 shows a schematic of the autopilot system.

Figure 1. Photo of the accident airplane cockpit layout. (Courtesy of Aircraft.com.)

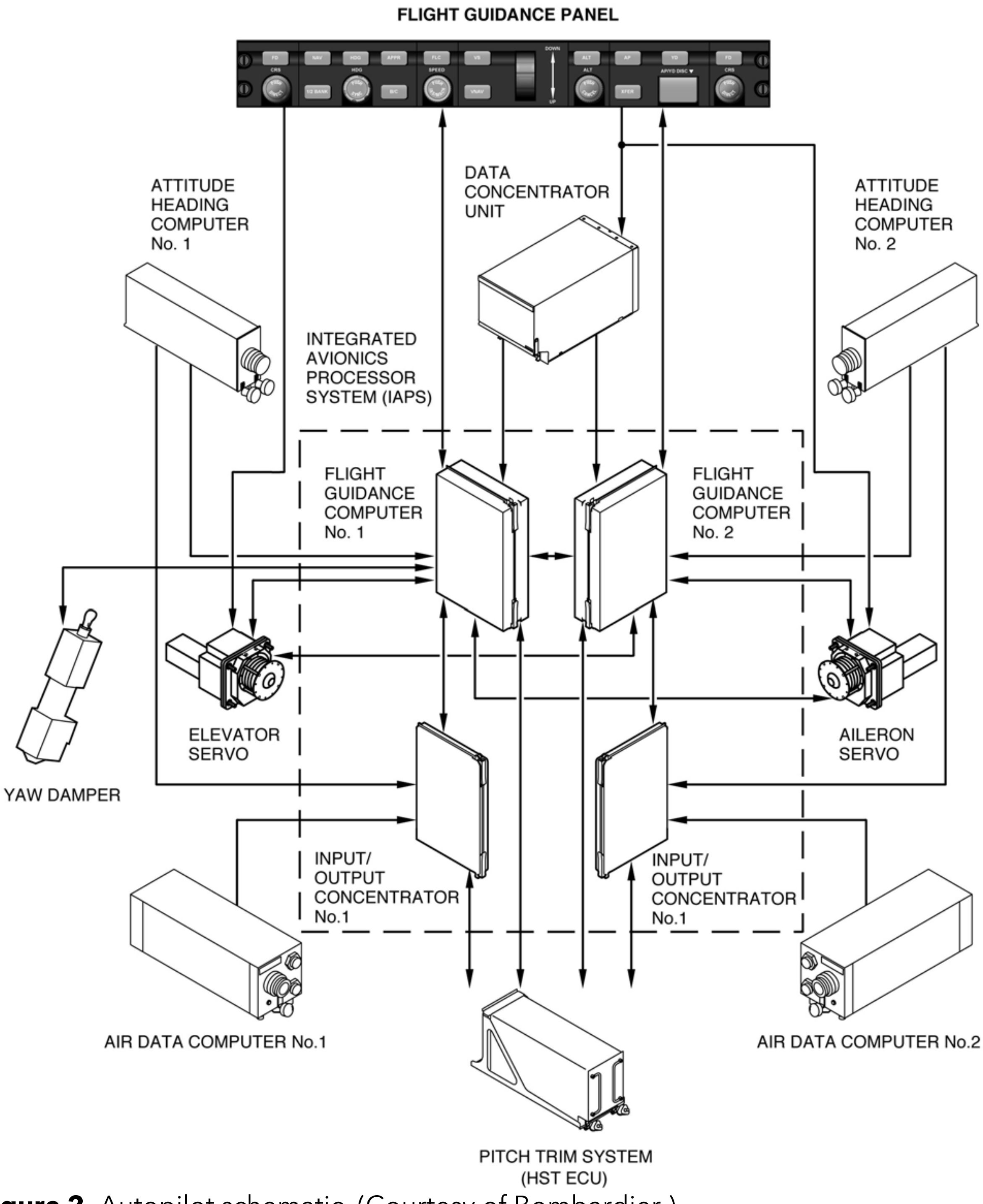

Figure 2. Autopilot schematic. (Courtesy of Bombardier.)

1.1 Components and Operation

1.1.1 Autopilot Engagement

The autopilot is engaged by pressing the AP switch located on the flight guidance panel (FGP) (see Figure 3). When the autopilot is engaged, both channels of the autopilot are coupled to the onside FGC. Autopilot engagement is indicated on the PFD by a green AP indication. Pressing the AP switch on the FGP when the autopilot is engaged will cause the autopilot to disengage.

Figure 3. Flight guidance panel. (Courtesy of Bombardier.)

1.1.2 Autopilot Servo Motors

When the autopilot is engaged, the controlling FGC will direct pitch and roll commands to the aileron and elevator servos. When a change in roll or pitch attitude is required, the FGC signals the aileron servo or elevator servo to bias the control cables to move the associated control surface.

The aileron servo is located on the control cable run for the right aileron. Since the left and right ailerons are normally interconnected, the servo is capable of moving both ailerons. The elevator servo is located in the left elevator cable run. The servo moves both elevators when the elevators are interconnected.

When an out–of–trim condition is sensed in the pitch axis, the FGC signals the horizontal stabilizer trim control unit to reposition the horizontal stabilizer to the proper trim position.

1.1.3 Out-Of-Trim Indications

The FGC continuously monitors the two axes of the autopilot when it is engaged. If a control surface is detected to be significantly out of trim, an engine indication and crew alert system (EICAS) caution message is displayed. The amber EICAS message identifies whether it is the aileron or elevator that is affected, and in which direction the control surface is out of trim.

1.1.4 Master Disconnect Switch

The master disconnect switches are installed on the outboard horn of each control wheel. When the switches are pressed with the autopilot engaged, the PFD red flashing AP indication appears and the autopilot audio warning sounds for approximately 1.5 seconds. If a system fault causes the autopilot to disengage, pressing either master disconnect switches will cancel the red flashing AP message and silence the aural warning.

1.1.5 Autopilot And Yaw Damper Disconnect Lever

Pressing the AP/YD DISC lever down disengages the autopilot and yaw damper simultaneously. With the autopilot engaged and the disconnect switch pressed down, a flashing red AP message appears on the PFD and the autopilot audio warning sounds for approximately 1.5 seconds. A red line is visible on the top edge of the switch when the switch has been moved to the disengage position.

1.1.6 Autopilot Disengagement

When the autopilot is manually disengaged, the AP symbols on each PFD flash red and an aural warning sounds for approximately 1.5 seconds. The autopilot can be manually disengaged by: 1) pressing either master disconnect switch on the control wheels; 2) activating the stab trim switches on the control wheels, 3) pressing the AP push button on the FGP; 4) selecting the AP/YD DISC on the FGP; 5) pressing either TO/GA switch; 6) pressing the YD push button.

If a system fault causes the autopilot to automatically disengage, the pilot must press the control wheel master disconnect switch to cancel the red flashing AP message and silence the aural warning. If the autopilot warning sounds because the TO/GA switch is selected, a second press of the TO/GA switch clears the warnings. The autopilot automatically disengages upon stall warning.

1.1.7 Autopilot Takeoff Configuration Warning

If a takeoff is attempted with the autopilot on, the takeoff configuration warning system presents an EICAS warning message and sounds a voice alert. The warning sounds when the thrust lever is advanced for takeoff.

1.1.8 Yaw Damper

The yaw damper provides automatic turn coordination and yaw oscillation damping. The yaw damper actuator is a mechanically limited linear actuator. Yaw damping improves the aircraft’s stability by damping out oscillations in yaw. These oscillations, if not corrected, lead to the phenomenon known as Dutch roll. The turn coordination function helps the aircraft into and out of turns. The FGCs provide signals to operate the yaw damper actuators. The AP/YD DISC switch or the YD button will disengage the yaw damper. When a yaw damper channel fails or disconnects, the amber YAW DAMPER FAIL (caution) crew alert system (CAS) message is displayed.

1.1.9 EICAS Messages

The auto flight control system messages are shown on the EICAS. In Table 1 below, the AFCS messages and inhibits are listed. The list is from the Flight Crew Operating Manual (FCOM). A brief explanation of each message is provided. Each warning message is accompanied by a triple chime and each caution message is accompanied by a single chime. The advisory and status messages do not have aural alerts.

Table 1. Autopilot EICAS messages.

Message	Level	Inhibits	Meaning
CONFIG AILERON TRIM CONFIG AUTOPILOT CONFIG FLAPS CONFIG RUDDER TRIM CONFIG STAB TRIM CONFIG SPOILERS	Warning	–	The aircraft is on the ground and the takeoff parameters (autopilot, flaps, spoilers, and trims in any axis) are not properly configured for takeoff. Illumination of the respective red CAS will be accompanied by the takeoff "CONFIGURATION" voice warning (continuous).
AFCS MESSAGES FAIL	Caution	Takeoff (TO)	Monitoring and indication of the autopilot modes may be unreliable
AP HOLDING LWD AP HOLDING RWD AP HOLDING NOSE DOWN AP HOLDING NOSE UP	Caution	TO	The autopilot is holding control force in the direction indicated.
AP STAB TRIM FAIL	Caution	TO	The autopilot is unable to make a trim correction to the horizontal stabilizer.
FD MODE CHANGE	Caution	TO	An indirect mode change has occurred within the flight director. An example of an indirect mode change would be NAV or APPR mode changing to ROLL with a navigation source or frequency change.
YAW DAMPER FAIL	Caution	TO/land	The yaw damper has failed.
FD 1 FAIL FD 2 FAIL	Advisory	TO/land	The respective flight director has failed accompanied by an FD flag on the PFD.
YAW DAMPER OFF	Status	–	The yaw damper is selected OFF.

2.0 HSTECU Description

The Challenger 300 aircraft fly-by-wire pitch trim system incorporates a moveable horizontal stabilizer. The position of the aircraft moveable horizontal stabilizer surface is controlled by a horizontal stabilizer trim actuator (HSTA), which in turn is controlled by the HSTECU (see Figure 4). The aircraft pitch trim system also contains a rudder travel limiter (RTL).

The pitch trim system supports eight aircraft functions listed below:

1. Manual trimming of the horizontal stabilizer
   The pilot manually commands movement of the horizontal stabilizer.

2. Autopilot trimming of the horizontal stabilizer
   The HSTECU interfaces with the aircraft flight guidance computer (i.e., autopilot). The autopilot, through the HSTECU, commands the horizontal stabilizer to move when the autopilot elevator servo command force exceeds the autopilot out-of-trim force threshold. The autopilot would move the horizontal stabilizer in a direction to reduce the load on the elevator surface; thereby, reducing the autopilot elevator servo command force.
3. Spoiler Trim compensation
   When the spoilers are extended (deployed) in proportional lift dump (PLD), the HSTECU automatically trims the horizontal stabilizer in the nose down direction to compensate for the pitching moment caused by the spoilers. When the PLD spoilers retract (stow), the HSTECU trims the horizontal stabilizer in the opposite direction.
4. Flap trim compensation
   When the flaps extend (deploy), the HSTECU automatically trims the horizontal stabilizer in the nose up direction to compensate for the pitching movement caused by the flaps. When the flaps retract (stow), the HSTECU trim the horizontal stabilizer in the opposite direction.
5. Mach trim compensation
   At high Mach numbers, the HSTECU computes the commands to the HSTA to move the horizontal stabilizer to compensate for aircraft pitch-down tendencies with increasing Mach.
6. Rudder travel limiting (RTL)
   Limits the maximum deflection of the aircraft rudder surface based on aircraft airspeed.
7. EICAS message logic related to the pitch trim system
   HSTECU transmits pitch trim system data to the CAS.
8. Maintenance and diagnostics related to the pitch trim system.
   The HSTECU interfaces with the aircraft maintenance diagnostics system to provide 1) diagnostic data displays; 2) service messages; 3) system parameter readouts; and 4) aircraft system self-initiated tests.

Figure 4. Photos of the HSTECU. (Courtesy of Moog)

3.0 HSTECU (C47329-012-013, SN 303) Examination

3.1 General

On March 16, 2023, representatives from the NTSB and Bombardier participated virtually in an examination of the HSTECU at the Moog facility in East Aurora, NY. Representatives of Moog visually inspected the unit, downloaded the non-volatile memory (NVM), and performed a functional test of the unit.

The data plate on the unit identified it as the following:

- Part number: C47329-012
- Software version: 013
- Serial number: 303
- Date of manufacture: 05/08

A visual inspection of the shipment was completed. There was no sign of damage to the box the HSTECU was shipped in. The HSTECU was packed in bubble wrap and was not shipped in an anti-static bag. The unit's electrical connector did not have an anti-static protective shipping cover installed.

A visual inspection of the HSTECU was completed and no anomalies were noted. All HSTECU electrical connector pins appeared normal.

3.2 HSTECU Power-up and NVM Download

The HSTECU power-up current was normal at 1.3 Amps. The HSTECU power-up Debug Serial Output Port data showed no anomalies. The HSTECU operational flight program (OFP) cyclic redundancy checks (CRCs) were as expected.[1] The HSTECU command (CMD) NVM and monitor (MON) NVM were downloaded. The relevant data from the NVM downloads can be found in Tables 2 and 3 and is explained in Section D.3.3.1.

Table 2. Extract of the CMD NVM data on the date of the accident.

057	099	0x0003	19:24:36	03/03/23	FlapMiscomp
058	027	0x0001	20:26:22	03/03/23	Cas1Cas2Miscomp ADC1/ADC2 Miscompare Tier II Figure 30
059	029	0x0000	20:26:22	03/03/23	IsiCas2Miscomp ADC2/ISI Miscompare Tier II Figure 30
060	034	0x0000	20:26:22	03/03/23	MachInvld Confirmed Mach Valid Tier II Figure 33
061	085	0x0000	20:26:22	03/03/23	MachTrimFail
062	058	0x0003	20:28:55	03/03/23	RtlTestInvld RTL Test Command Valid Tier II Figure 44
063	024	0x0003	20:29:07	03/03/23	IsiCasAInvld Local SPC A ISI CAS Valid Tier II Figure 29
064	025	0x0003	20:29:07	03/03/23	IsiCasBInvld Local SPC B ISI CAS Valid Tier II Figure 29
065	026	0x0003	20:29:07	03/03/23	IsiCasInvld ISI CAS Valid Tier II Figure 29
066	031	0x0003	20:29:07	03/03/23	RtlCasInvld RTL CAS Valid Tier II Figure 31
067	056	0x0003	20:29:08	03/03/23	LRtlTestInvld RTL Test Command From L IOC Valid Tier II Figure 44
068	057	0x0003	20:29:08	03/03/23	RRtlTestInvld RTL Test Command From R IOC Valid Tier II Figure 44
069	036	0x0003	20:29:08	03/03/23	RFlapInvld Confirmed R-IOC Flap Position Valid Tier II Figure 34
070	035	0x0003	20:29:08	03/03/23	LFlapInvld Confirmed L-IOC Flap Position Valid Tier II Figure 34
071	037	0x0003	20:29:08	03/03/23	FlapInvld Confirmed Flap Position Valid Tier II Figure 35
072	065	0x0000	20:59:52	03/03/23	Trim3SecWarn Local Trim In Motion Exceeding 3 Seconds Tier II Figure 74

Table 3. Extract of the MON NVM data on the date of the accident.

069	999	0x0000	00:00:00	00/00/00	Power-up Signal
070	022	0x0000	20:26:22	03/03/23	AdcMiscompVldErrID ADC1/ADC2 Miscompare Tier II Figure 30
071	024	0x0000	20:26:22	03/03/23	Adc2IsiMiscompErrID ADC2/ISI Miscompare Tier II Figure 30
072	050	0x0000	20:26:22	03/03/23	MachVldErrID Confirmed Mach Valid Tier II Figure 33
073	019	0x0000	20:29:08	03/03/23	IsiACasErrID Local SPC A ISI CAS Valid Tier II Figure 29.1
074	020	0x0000	20:29:08	03/03/23	IsiBCasErrID Local SPC B ISI CAS Valid Tier II Figure 29.1
075	021	0x0000	20:29:08	03/03/23	IsiErrID ISI CAS Valid Tier II Figure 29.1
076	025	0x0000	20:29:08	03/03/23	LRtlTstCmdErrID RTL Test Command From L IOC Valid Tier II Figure 44
077	026	0x0000	20:29:08	03/03/23	RRtlTstCmdErrID RTL Test Command From R IOC Valid Tier II Figure 44
078	027	0x0000	20:29:08	03/03/23	RtlTstCmdErrID RTL Test Command Valid Tier II Figure 44
079	065	0x0000	20:29:08	03/03/23	RFlapsPosnErrID Confirmed R-IOC Flap Position Valid Tier II Figure 34
080	064	0x0000	20:29:08	03/03/23	LFlapsPosnErrID Confirmed L-IOC Flap Position Valid Tier II Figure 34
081	063	0x0000	20:29:08	03/03/23	FlapsPosnErrID Confirmed Flap Position Valid Tier II Figure 35
082	999	0x0000	00:00:00	00/00/00	Power-up Signal

3.3 Functional Test Procedure (FTP) Performed on the HSTECU

The FTP was conducted by Moog with the existing HSTECU OFP.

[1] The OFP is the software that is in the HSTECU when installed in the aircraft. The CRC is an error-detecting code commonly used to ensure software loaded on a device has not been changed, intentionally, or unintentionally by an electrical failure. The CRC computed number from the software must match the known "good" CRC number and if it does it indicates the software loaded on the device is as expected.

To run the FTP, the HSTECU needed to be electrically rigged to the test stand sensors. This rigging overwrote the existing HSTECU LVDT, RVDT electrical rigging values. The HSTECU rigging values from the aircraft were recorded in the HSTECU CMD and MON NVM downloads.

When initially starting the FTP of the HSTECU, there was an issue with rigging the HSTECU to the FTP test stand sensors. The rigging issue was traced to the HSTECU not being left in the correct state following the MON NVM download conducted just prior to the FTP. Moog's technician had a test equipment communication port issue which left the HSTECU in an incorrect state.

The HSTECU was then reconnected to the MON NVM download equipment to place the HSTECU into the correct state by repeating portions of the NVM download procedures. Then the HSTECU was reinstalled into the FTP test stand, tested per the FTP and it passed all tests. [2]

3.3.1 Review of the Accident Details and NVM

The pilot reported the right-hand air data probe was covered during the initial takeoff roll, and the takeoff was aborted (reference the Operational Factors - Attachment 1 - Flight Crew Interview Transcripts). Upon review of the FDR data (see Flight Data Recorder - Specialist's Factual Report), it was noted that the mismatch between Air Data Computer 1 (ADC1) and ADC2 speeds was above 20 knots for more than 5 seconds. The probe cover was removed, and troubleshooting was performed by the flight crew (not maintenance personnel). Flight crew troubleshooting did not include an HSTECU power cycle before the subsequent takeoff.

This scenario caused these key faults to be recorded in the CMD NVM during the first attempted takeoff (see Table 2):

- "03/03/23, 20:26:22: Cas1Cas2Miscomp ADC1/ADC2 Miscompare Tier II[3] Figure 30"
- "03/03/23, 20:26:22: IsiCas2Miscomp ADC2/ISI Miscompare Tier II Figure 30"
- "03/03/23, 20:26:22: MachInvld Confirmed Mach Valid Tier II Figure 33"
- "03/03/23, 20:26:22: MachTrimFail"

[2] The Acceptance Test Procedure (ATP) was not completed because it would have required dedicated test software to be installed. The group decided to leave the HSTECU in its "as received" state as much as possible, so it was decided NOT to replace the OFP in the HSTECU; hence, only the HSTECU FTP was conducted.
[3] The "Tier II" is Moog's system specification for the Pitch Trim Control System. The Tier II document contains the specification requirements for the HSTECU. The requirements specify the control and monitoring that the pitch trim control system performs.

A review of the logic for these fault messages showed the HSTECU latched (i.e., not cleared unless HSTECU power is cycled) an "ADC1/ADC2 Miscompare" fault indicating an airspeed data mismatch between ADC1 and ADC2 and an "ADC2/ISI Miscompare" fault indicating an airspeed data mismatch between ADC2 and the integrated standby instrument (ISI), causing the HSTECU to post a "RUDDER LIMITER FAULT" advisory message in the flight deck.[4] Also, the "Confirmed Mach Valid" latched to invalid or 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[5]
- Manual trim operating at a reduced rate of 0.2 deg/s

A review of the "MACH TRIM FAIL" caution message logic revealed that the message does not become active until the aircraft is weight-off-wheels. In addition, the message is part of a set of non-critical CAS messages which are not displayed by the aircraft's avionics system until the airplane is above 400 ft above ground level (AGL); this is referred to as takeoff inhibit. Bombardier noted that the takeoff inhibit is so that performance of non-critical checklists, including MACH TRIM FAIL, is delayed until the critical takeoff phase of flight is completed.

There were no faults recorded on the ground or in the air indicating an operational issue with the HSTECU or the primary stabilizer trim system.

Note: Per Operational Factors - Attachment 1 - Flight Crew Interview Transcripts, the flight crew reported that the "RUDDER LIMITER FAULT" advisory message was presented in the flight deck following the aborted takeoff, and they subsequently departed with the advisory message displayed after their troubleshooting efforts failed to clear the message. The "RUDDER LIMITER FAULT" CAS message was listed as a "NO GO" item (which must be cleared prior to takeoff) in the Bombardier Quick Reference Handbook (QRH) (Volume 2) "GO / NO GO GUIDE" under "NON-NORMAL ADVISORY MESSAGES".

3.4 Disposition of the HSTECU (C47329-012-013, SN 303)

An anti-static Aeronautical Radio Incorporated (ARINC) 600 electrical connector cover was installed on the HSTECU. The HSTECU was placed into an anti-

[4] The "RUDDER LIMITER FAULT" advisory message is described in the aircraft manuals as a loss of system redundancy that requires crew awareness and where subsequent action may be needed.
[5] The HSTECU sends a signal to the left and right Flight Guidance Computers (i.e., autopilot) that HSTECU normal trim is not available, and as such, the HSTECU will not respond to autopilot trim commands when the autopilot is engaged. Also, when the pilot engages the autopilot, it would result in an "AP STAB TRIM FAIL" caution message being set by the autopilot. The autopilot will maintain the autopilot elevator servo load and not disengage the autopilot. If the HSTECU primary channel is deselected, the autopilot elevator servo load would immediately disengage resulting in the elevator surface moving to its aerodynamic neutral.

static bag. The HSTECU was repackaged into the shipping container and was returned to the owner via the FAA Bradley Flight Standards District Office.

4.0 Bombardier Flight Test and HSTECU (C47329-010-013, SN 086) Examination

On November 1, 2023, flight testing was performed at Bombardier flight test center at the Wichita Dwight D Eisenhower National Airport (ICT), in Wichita, Kansas. The purpose of the flight testing was to perform a rejected takeoff, with a pitot-static probe cover installed on the RH pitot-static probe, and then observe the airplane systems behavior during a subsequent takeoff and climb. The flight test purposely did not allow the airplane to enter a severely out of trim condition as experienced during the accident flight. The HSTECU was removed from the airplane and shipped to the manufacturer (Moog) for download.

4.1 Flight Test HSTECU (C47329-010-013, SN 086) Examination

4.1.1 General

The HSTECU was received at the Moog facility in East Aurora, NY on November 08, 2023. Representatives of Moog visually inspected the unit, downloaded the non-volatile memory (NVM), and performed a functional test of the unit.

The data plate on the unit identified it as the following:
- Part number: C47329-010
- Software version: 013
- Serial number: 086
- Date of manufacture: 07/04

A visual inspection of the unit was completed, and no anomalies were noted. The HSTECU was received with the proper packaging (anti-static bag with electrostatic discharge cover on electrical connector). All HSTECU electrical connector pins appeared normal.

4.1.2 Flight Test HSTECU (C47329-010-013, SN 086) Power-up and NVM Download

The HSTECU power-up current was normal at approximately 1.3 Amps. The HSTECU power-up Debug Serial Output Port data showed no anomalies. The HSTECU OFP CRCs were as expected. The HSTECU CMD NVM and MON NVM were downloaded. The relevant data from the NVM downloads can be found in Tables 4 and 5.

Table 4. Extract of the CMD NVM data on the date of the flight test.

067	027	0x0001	15:40:28	11/1/2023	Cas1Cas2Miscomp ADC1/ADC2 Miscompare Tier II Figure 30
068	034	0x0000	15:40:29	11/1/2023	MachInvld Confirmed Mach Valid Tier II Figure 33
069	085	0x0000	15:40:29	11/1/2023	MachTrimFail
070	029	0x0000	15:40:30	11/1/2023	IsiCas2Miscomp ADC2/ISI Miscompare Tier II Figure 30
071	058	0x0003	15:47:48	11/1/2023	RtlTestInvld RTL Test Command Valid Tier II Figure 44
072	056	0x0003	15:48:00	11/1/2023	LRtlTestInvld RTL Test Command From L IOC Valid Tier II Figure 44
073	057	0x0003	15:48:00	11/1/2023	RRtlTestInvld RTL Test Command From R IOC Valid Tier II Figure 44
074	031	0x0003	15:48:00	11/1/2023	RtlCasInvld RTL CAS Valid Tier II Figure 31
075	035	0x0003	15:48:00	11/1/2023	LFlapInvld Confirmed L-IOC Flap Position Valid Tier II Figure 34
076	036	0x0003	15:48:00	11/1/2023	RFlapInvld Confirmed R-IOC Flap Position Valid Tier II Figure 34
077	037	0x0003	15:48:00	11/1/2023	FlapInvld Confirmed Flap Position Valid Tier II Figure 35
078	065	0x0000	15:58:53	11/1/2023	Trim3SecWarn Local Trim In Motion Exceeding 3 Seconds Tier II Figure 74
079	999	0x0000	00:00:00	00/00/00	Power-up Signal

Table 5. Extract of the MON NVM data on the date of the flight test.

008	999	0x0000	00:00:00	00/00/00	Power-up Signal
009	999	0x0000	00:00:00	00/00/00	Power-up Signal
010	019	0x0000	12:54:28	11/01/23	IsiACasErrID Local SPC A ISI CAS Valid Tier II Figure 29.1
011	020	0x0000	12:54:28	11/01/23	IsiBCasErrID Local SPC B ISI CAS Valid Tier II Figure 29.1
012	021	0x0000	12:54:28	11/01/23	IsiErrID ISI CAS Valid Tier II Figure 29.1
013	022	0x0000	15:40:28	11/01/23	AdcMiscompVldErrID ADC1/ADC2 Miscompare Tier II Figure 30
014	050	0x0000	15:40:29	11/01/23	MachVldErrID Confirmed Mach Valid Tier II Figure 33
015	024	0x0000	15:40:30	11/01/23	Adc2IsiMiscompErrID ADC2/ISI Miscompare Tier II Figure 30
016	025	0x0000	15:48:00	11/01/23	LRtlTstCmdErrID RTL Test Command From L IOC Valid Tier II Figure 44
017	026	0x0000	15:48:00	11/01/23	RRtlTstCmdErrID RTL Test Command From R IOC Valid Tier II Figure 44
018	027	0x0000	15:48:00	11/01/23	RtlTstCmdErrID RTL Test Command Valid Tier II Figure 44
019	064	0x0000	15:48:00	11/01/23	LFlapsPosnErrID Confirmed L-IOC Flap Position Valid Tier II Figure 34
020	065	0x0000	15:48:00	11/01/23	RFlapsPosnErrID Confirmed R-IOC Flap Position Valid Tier II Figure 34
021	063	0x0000	15:48:00	11/01/23	FlapsPosnErrID Confirmed Flap Position Valid Tier II Figure 35
022	999	0x0000	00:00:00	00/00/00	Power-up Signal
023	999	0x0000	00:00:00	00/00/00	Power-up Signal
024	019	0x0000	17:23:58	11/01/23	IsiACasErrID Local SPC A ISI CAS Valid Tier II Figure 29.1
025	020	0x0000	17:23:58	11/01/23	IsiBCasErrID Local SPC B ISI CAS Valid Tier II Figure 29.1
026	021	0x0000	17:23:58	11/01/23	IsiErrID ISI CAS Valid Tier II Figure 29.1
027	999	0x0000	00:00:00	00/00/00	Power-up Signal
028	999	0x0000	00:00:00	00/00/00	Power-up Signal
029	019	0x0000	17:31:15	11/01/23	IsiACasErrID Local SPC A ISI CAS Valid Tier II Figure 29.1
030	020	0x0000	17:31:15	11/01/23	IsiBCasErrID Local SPC B ISI CAS Valid Tier II Figure 29.1
031	021	0x0000	17:31:15	11/01/23	IsiErrID ISI CAS Valid Tier II Figure 29.1
032	999	0x0000	00:00:00	00/00/00	Power-up Signal
033	999	0x0000	00:00:00	00/00/00	Power-up Signal

The covered pitot tube caused these key faults to be recorded in the CMD NVM during the rejected takeoff (RTO) (see Table 4):

- "11/1/2023, 15:40:28 (UTC): Cas1Cas2Miscomp ADC1/ADC2 Miscompare Tier II Figure 30"
- "11/1/2023, 15:40:29: MachInvld Confirmed Mach Valid Tier II Figure 33"
- "11/1/2023, 15:40:29: MachTrimFail"
- "11/1/2023, 15:40:30: IsiCas2Miscomp ADC2/ISI Miscompare Tier II Figure 30"

A review of the logic for these fault messages showed the HSTECU latched (i.e. not cleared unless HSTECU power is cycled) an "ADC1/ADC2 Miscompare" fault indicating an airspeed data mismatch between ADC1 and ADC2 and an "ADC2/ISI Miscompare" fault indicating an airspeed data mismatch between ADC2 and the ISI, causing the HSTECU to post a "RUDDER LIMITER FAULT" advisory message in the flight deck. Also, the “Confirmed Mach Valid” latched to FALSE which resulted in:

- “MACH TRIM FAIL” caution message
- 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

A review of the “MACH TRIM FAIL” caution message logic revealed that the message does not become active until the aircraft is weight-off-wheels. In addition, the message is part of a set of non-critical CAS messages which are not displayed by the aircraft’s avionics system until the airplane is above 400 ft AGL; this is referred to as takeoff inhibit.

There were no faults recorded on the ground or in the air indicating an operational issue with the HSTECU or the primary stabilizer trim system.

4.1.3 Other Checks Performed on the Flight Test HSTECU (C47329-010-013, SN 086)

The HSTECU was returned to Bombardier for use in their flight test airplane. As part of the Moog return to service testing, Moog accomplished the following (as part of their standard return to service testing:

- Conducted inbound HSTECU “as received” FTP.
  FTP passed and no faults were present.
- Loaded HSTECU embedded ATP software into HSTECU.
  HSTECU ATP software was loaded. This software was required to conduct the HSTECU ATP.
- Conducted inbound HSTECU ATP.
  ATP passed and no faults were present.
- Loaded HSTECU Flight code.
- Checked software CRCs
  HSTECU software CRCs were as expected. Pass.
- Conducted outbound FTP.
  FTP passed and no faults were present.

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