

Eleazar Nepomuceno
Aviation Accident Investigator
AS-WPR

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Subject: WPR22LA284, Manufacturer Reference Information Excerpt of AP
STAB TRIM FAIL and Autopilot

Contact: Bombardier Air Safety Investigation Office

According to the airplane manufacturer:

The purpose of the AP STAB TRIM FAIL Caution message is to advise flight crew[s] that the autopilot is no longer able to command horizontal stabilizer trim. In isolation, this has no effect on autopilot engagement, i.e. the message itself does not cause the autopilot to disengage. Inability to command horizontal trim or an out-of-trim condition will not result in autopilot disengagement; in such cases, the autopilot continues to control pitch using only the elevator. The autopilot is designed to remain engaged for all but a few specific failure conditions; when the autopilot disengages due to one of these failure conditions, it is referred to as abnormal automatic disengagement. There are also a number of pilot actions which will cause the autopilot to disengage: use of the master disconnect switches on the control wheels, the AP or YD button on the Flight Guidance Panel (FGP), the AP/YD disconnect bar on the FGP, use of the Takeoff/Go-around (TOGA) switches, use of manual trim, or setting the pitch trim select switch to SEC or OFF. When the autopilot disengages due to one of these pilot actions, it is referred to as normal disengagement. When the autopilot is disengaged with the aircraft in an out-of-trim condition, the elevator is released and free to move until the flight crew take manual control via the control columns; this can result in pitch oscillations driven by the aerodynamic forces from the horizontal stabilizer and lack of counter-balancing aerodynamic forces from the now-released elevator moving back to a neutral position. The pitch oscillations are a natural result of an out-of-trim aircraft and an unrestrained elevator. Maintaining a solid grip on the

control column so as to prevent the elevator from moving back to neutral when it is released by the autopilot, reduces or can even prevent pitch oscillations upon autopilot disengagement. With the autopilot engaged and unable to command trim, and depending on changes to airspeed, altitude and aircraft configuration (flaps position, etc.) the aircraft can enter an out-of-trim condition. Regardless of how out-of-trim the aircraft becomes, the autopilot will remain engaged and continue to attempt to maintain desired pitch attitude with the elevator. If the out-of-trim condition exceeds a pre-defined threshold, as determined via a voltage feedback loop between the elevator servo and autopilot, an AP HOLDING NOSE DOWN or AP HOLDING NOSE UP Caution message will post on the CAS. The purpose of these messages is to advise the flight crew that the autopilot is using significant elevator deflection to maintain desired pitch, i.e. that the aircraft is flying in an out-of-trim condition.

When the autopilot is disengaged with the aircraft in an out-of-trim condition, the elevator is released and free to move until the flight crew take manual control via the control columns; this can result in pitch oscillations driven by the aerodynamic forces from the horizontal stabilizer and lack of counter-balancing aerodynamic forces from the now-released elevator moving back to a neutral position. The pitch oscillations are a natural result of an out-of-trim aircraft and an inadequately restrained elevator. Maintaining a solid grip on the control column to prevent the elevator from moving back to neutral when it is released by the autopilot prevents or reduces pitch oscillations upon autopilot disengagement. During the certification flight test program for the Challenger 300, Bombardier demonstrated that the autopilot can be safely disengaged when the AP HOLDING NOSE DOWN or AP HOLDING NOSE UP Caution messages are posted, with no resulting pitch oscillations and minimal control column forces. However, if disengagement of the autopilot is delayed beyond the posting of these messages, and the aircraft continues to become more out-of-trim, pitch oscillations upon eventual autopilot disengagement can be significant. There are multiple conditions which can lead to the inability of the autopilot to command trim and cause an AP STAB TRIM FAIL Caution message to post. One such example is seen in NTSB investigation reference ERA23LA135. Another source of inability of the autopilot to command trim is the software in the autopilot itself. The autopilot system is comprised of two Flight Guidance Computers (FGC). Each FGC has two independent processors (Main and I/O) and each processor hosts a set of monitors. At the system level, there are a total of four independent sets of monitors. Each monitor from each set can disable the autopilot pitch trim function. Each monitor receives as input the filtered elevator servo motor voltage (an indication of force being held by the servo) and horizontal stabilizer movement rate feedback from the

Horizontal Stabilizer Electronic Trim Control Unit (HSTECU). These monitors check for the following conditions when the autopilot is engaged and latch a fault (except where noted otherwise):

- wrong direction monitor; horizontal stabilizer trim rate is opposing servo force (this monitor also covers the uncommanded trim/trim runaway);
- no trim monitor; servo force is present and horizontal stabilizer trim motion is not above the running threshold;
- post-engagement built-in test; ensures that each FGC's analog discrete can disable autopilot trim;
- HSTECU availability monitor; can also disable autopilot pitch trim (but does not latch).

Triggering of any of the monitors will result in the disabling of the autopilot pitch trim function and the posting of the AP STAB TRIM FAIL Caution message on the CAS. The monitors are cleared when the autopilot is disengaged. When a monitor trips, the enable analog discrete and the ARINC 429 trim arm signals from the FGC to the HSTECU are removed. When this occurs, the HSTECU ignores autopilot trim commands. The autopilot trim command generation is independent from the trim arm. As such, non-zero command values continue to be sent after a monitor trips.