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Sudden Aileron Lock Sends Cargo Turboprop Plummeting to the Ground

Improperly rigged ailerons turn a routine left bank into a fatal maneuver.

Editorial Staff Report

The twin-engine British Aerospace (BAe) HS 748-2B turboprop was cruising at 3,000 feet, bound for Ottawa, Canada, when it veered suddenly to the left, rolled through 460 degrees, pitched down and plunged to the ground. The pilot and copilot of the cargo aircraft were killed. They were the sole occupants of the aircraft.

The Transportation Safety Board of Canada (TSB), in a recently released accident investigation report, said a combination of design characteristics, maintenance oversights, poor communication and human factors caused the crash.

The TSB determined that improper rigging of the aileron control system after maintenance repairs made it susceptible to aerodynamic overbalance and was the primary causal factor for the accident. It also said the design of the HS 748 ailerons requires very precise rigging to avoid overbalancing.

The TSB also concluded that other contributing factors included "ambiguous and incomplete maintenance instructions, a lack of published information for flight crews concerning aileron system performance and possible emergencies and crew scheduling and duty times that may have led to the development of flight crew fatigue." Weather was not a factor in the daylight flight, with reported winds at 16 knots and 25-mile visibility.

Information recovered from the flight data recorder (FDR) indicated that the pilot initiated a roll to the left to look at a landmark. According to the TSB report, the FDR recorded a "full-up deflection of the left aileron and a full-down deflection of the right aileron and the aircraft began a roll to the left at a high rate." (Figure 1)

The report added: "The right aileron remained at the fully-deflected position for a period of three seconds and then, over the next seven seconds, the deflection gradually decreased by about five degrees. During the same 10-second period, the left aileron remained nearly fully deflected for the first eight seconds ... and decreased about five degrees in the next two seconds. By this time the aircraft had rolled through approximately 460 degrees and the aircraft nose had dropped to 30 degrees below the horizon. At this point, the ailerons suddenly returned to about the neutral position and remained there for the last three seconds of flight."

The time from the initial aileron deflection to ground impact was 18 seconds.

The captain, 37, held an airline transport license and had logged 5,500 hours total flying time with 1,700 hours in type. The copilot, 25, also held an airline transport license with a total of 1,750 hours, with 200 hours in type.

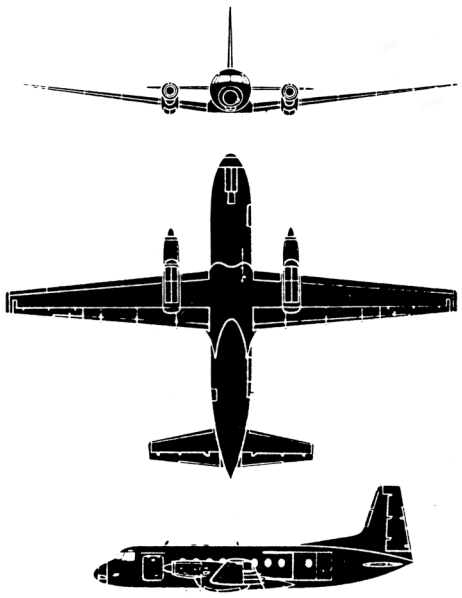
The TSB said a review of company training records indicated that the captain was an average pilot who generally received satisfactory evaluations. The records said the captain's aircraft knowledge was good but that examiners had noted "a tendency to be slow in anticipating

problems."

The captain turned down an offer to become a company training and check pilot because he disliked the physical sensations associated with positive and negative g-forces experienced during some training exercises, the TSB report said.

The copilot was described as a competent pilot with no record of prior accidents or regulatory infractions.

The aircraft was built in 1981 and powered by two Rolls Royce Dart engines. The HS 748 is equipped with conventional dual controls and adjustable trim tabs. The aileron system is a classic manually operated reversible design. HS 748 aircraft do not use rigging pins for control surface rigging. Proper aileron rigging is achieved by aileron angle measurements and painted alignment marks on the control cable quadrants and bell-cranks.



BAe HS 748 Series 2B

Designed in 1959 and first flown a year later in the United Kingdom, this short- to medium-range turboprop airliner was sold worldwide to civilian and military operators. The Series 2B was introduced in 1979 with improved Dart engines. The series was marketed in the United States under the name Intercity 748. The prototype and initial models were produced by Hawker Siddeley.

The operator bought the aircraft in the United States five months before the accident. Considerable maintenance was performed before the aircraft was delivered because it had been in storage for two years before it was purchased.

During maintenance, the left aileron from another HS 748 was installed inadvertently on the crash aircraft when ailerons from two 748s were stored in the same area. "When the error was discovered, the operator decided to have maintenance entries raised, indicating that the left ailerons were changed on both aircraft," the TSB report said. (It was later determined that the substituted left aileron had a different tab adjustment than the original ... which would have produced lower aileron system forces for a left roll.)

"Pilots employed by the operator test flew the aircraft following the maintenance in the United States. A test card was not used and no attempt was made to evaluate aileron rigging by using procedures contained in the HS 748 maintenance manual," the report added.

The HS 748 maintenance manual and a notice to operators (NTO) from the manufacturer detail when test flights are necessary after aileron repairs and what flight test procedures are required.

"However, the description of when these flights are required is ambiguous," the TSB report said. "The maintenance manual states that 'when an aileron is changed or repaired, or if the aileron or aileron tab rigging has been adjusted for any reason, then a flight test should be carried out.'" The NTO relating to aileron maintenance, however, clearly states that checks are "required on the test flight following an aileron change, repair or adjustment."

The TSB noted that operators interviewed after the crash were unclear about the necessity for the flight tests after aileron repairs and believed the tests were recommended, not obligatory, practices.

In addition, the TSB said the maintenance manual "does not contain specific guidance to users to readjust control stops following rigging changes. No specific instructions are contained ... guiding the user back to check control cable tensions." (Evidence suggested that the left aileron control cable loop had less than normal tension).

Flight crews may also have been poorly informed or unaware of the potential for a dangerous control lock situation. Although the NTO carried a notation advising that it be shown to "all pilots and airframe personnel," the operator did not distribute it to all pilots, the TSB report said.

The TSB also said that there no warnings in the flight manual or crew manual "regarding the possibility of aileron aerodynamic overbalance or lock and no information is contained (in either publication) as to the procedures to be followed if aileron lock is encountered."

Moreover, the TSB concluded that there were "differ-

ences of opinion" among operators about whether an NTO was to be considered a "manufacturer's recommendation," which would have the same authority as the maintenance manual.

Aileron overbalance, also known as aileron lock, is a dangerous aerodynamic phenomenon sometimes encountered with offset hinge balanced control surfaces. The condition occurs in some designs when the control surface is deflected to a high angle. "The control surface aerodynamic hinge moment reverses and takes the surface from the pilot's command to an uncommanded higher angle and holds it there. The pilot must ... use considerable strength to force the control surface back towards neutral."

According to the TSB, the flight test after aileron repairs was designed to "heavy" the controls, or "to make it less likely that pilots will apply large aileron control inputs above maneuvering speed (155 knots)." The recorded cruise airspeed immediately before the roll was about 200 knots indicated airspeed (KIAS).

FDR data indicate that the pilot was hand-flying the aircraft and that the pilot initiated the roll to the left after he commented on spotting a new airport to the left of the flight track. A study of the area showed that a newly constructed airport would have been visible to the captain off his left side and slightly behind him.

"Interest shown by the crew in observing local geographical features and airstrips recorded by the cockpit voice recorder (CVR) leads to the conclusion that the captain applied control-wheel force to bank the aircraft to the left," the TSB said. "The limited time for viewing would be an inducement to roll the aircraft quickly."

The TSB ruled out pilot incapacitation, intentional aerobatic roll and aircraft avoidance as precipitating factors. However, the TSB concluded that there was sufficient evidence to indicate that the misrigged aileron caused the aileron control forces to be too light.

"If the pilot deflects the control wheel outside of a rather modest central range of aileron angles, he may, because of the abrupt fall-off in control wheel force, apply more aileron than he intends," the report said. "In effect, the aircraft is biased to roll more readily in one direction than the other. Because of the location of the control stops and their designed limits, an aileron can be rigged high enough to render the stops ineffective in preventing an overbalance position."

According to the report, the pilot had to wrestle with an initial aileron overbalance force of "at least 37 pounds," with the pressure increasing to more than 68 pounds as the roll progressed.

"The fact that the left aileron deflection did not lessen shows that the system overbalance force was greater than the opposite wheel force the captain applied."

The report added: "The forces the captain had to apply exceeded the maximum permissible textbook values and the maximum ... force given by (U.S. Federal Aviation Regulations). To the captain, this amount of negative wheel force would have probably appeared to be an aileron control jam."

When the aircraft was nearly inverted, the report said, the captain applied wheel back pressure ... which caused the aircraft to go from a simple roll to a barrel roll.

"The elevator deflection, happening where it did in the maneuver, quickly created a critical recovery situation. The rate of descent increased quickly and, from such a

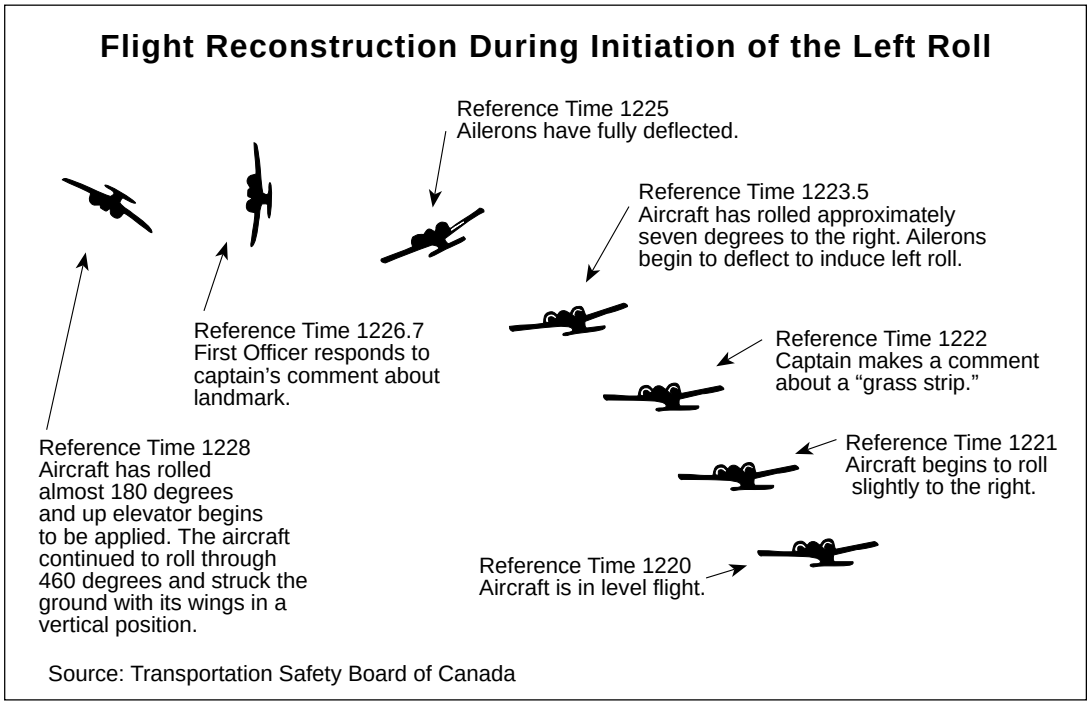


Figure 1

low altitude, only a few seconds were available for any recovery action attempts."

The report speculated that the elevator action was caused subconsciously by the pilot, who disliked the sensations associated with high g-forces. It said he may have also inadvertently applied elevator while grabbing the wheel to hold himself in his seat.

"The roll rate during the maneuver was in the range of that of a jet aerobatic trainer," the report said. "To the uninitiated, such a roll can be confusing and can lead to disorientation."

By the time the overbalance was eliminated, the aircraft was descending rapidly with a 30-degree down attitude and a 90-degree bank. The aircraft struck the ground at 290 KIAS. "Recovery, with only three seconds remaining to impact, was impossible."

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Fatigue also was a likely factor in the accident, the TSB said. At the time of the accident, the crew had been on duty for 16 hours. The captain was averaging about four hours of sleep a day with perhaps a short nap during a layover, the report said. The schedule subjected the crew to night/day work cycles and the time available between each arrival and departure was limited, it said. The schedule the flight crew was assigned at the time of the accident involved a 7 p.m. departure from Ottawa with stops in Montreal and Dayton, Ohio, U.S., before arriving back in Ottawa at 10 a.m. the next day via Montreal. The crew was on its third consecutive duty day.

"There is no reason to expect that these pilots would not have been affected to some extent by fatigue at the time the flight control problem occurred," the report said.

The TSB criticized flight scheduling practices, saying the operator's "planned flight duty time expectation was not realistic."

In addition, the TSB said the scheduling practices "did not conform to the operator's operations manual" and exceeded duty times established by Canadian regulatory authorities. After the accident, the operator began allowing flight crews on the route to stay overnight in Montreal, reducing daily flight times by about two hours and putting them within regulation limitations.

Advisories about potential aileron rigging problems were also sent to all HS 748 operators, and the importance of flight tests after aileron repairs was stressed. In all, 29 Canadian-registered HS 748s were flight tested and four aircraft were found to require aileron rigging adjustments.

"The aileron system used on the HS 748 is more susceptible to overbalance than other designs currently used on aircraft of similar size and speed," the TSB said. "However, this aircraft can be operated quite safely if the ailerons are properly rigged and maintained."

The TSB also noted the importance of flight crew briefing on the potential for aileron lock and training on how to recover from such a situation. "Had the flight crew of the accident aircraft been aware of the potential for aileron aerodynamic overbalance and of the recovery action required, they might have been better prepared to neutralize the ailerons before the aircraft entered an unusual attitude." ♦

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