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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S1/2015 *SPECIAL*

SERIOUS INCIDENT

Aircraft Type and Registration:	Saab AB Saab 2000, G-LGNO
No & Type of Engines:	2 x Allison AE 2100A turboprop engines
Year of Manufacture:	1995 (Serial no: 2000-013)
Location	Approximately 7 nm east of Sumburgh Airport, Shetland
Date & Time (UTC):	15 December 2014 at 1910 hrs
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 3 Passengers - 30
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to radome and APU exhaust
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	5,780 hours (of which 143 were on type) Last 90 days - 108 hours Last 24 hours - 5 hours
Information Source:	AAIB Field Investigation

The Investigation

The serious incident, which, occurred at 1910 hrs on 15 December 2014, was notified to the Air Accidents Investigation Branch shortly after 1100 hrs on Tuesday 16 December 2014. Representatives of the manufacturer's flight safety department assisted the AAIB in the investigation.

This Special Bulletin is published to provide details of the initial facts. It includes information gathered from the flight crew, the flight data recorder, and recordings of ATC radar and RTF communications. The investigation is continuing and a final report will be published in due course.

Synopsis

The flight crew decided to discontinue their approach to Runway 27 at Sumburgh Airport because of weather ahead. As it established on a southerly heading the aircraft was struck by lightning. The commander made nose-up pitch inputs but perceived that the aircraft did not respond as expected. After reaching 4,000 ft amsl, the aircraft pitched nose-down to a minimum of 19° and the applicable maximum operating speed (V_{MO}) was exceeded by 80 KIAS with a peak descent rate of 9,500 ft/min. The aircraft started to climb after reaching a minimum height of 1,100 ft amsl. Recorded data showed that the autopilot had remained engaged, and the pilots' nose-up pitch inputs were countered by the autopilot pitch trim function, which made a prolonged nose-down pitch trim input in an attempt to maintain its altitude-tracking function.

History of the flight

The aircraft was serviceable with no relevant deferred defects prior to the flight. Weather forecasts for Sumburgh predicted thunderstorms with rain, snow, and hail, and winds gusting up to 60 kt, during the afternoon and early evening. The aircraft and crew operated one uneventful rotation between Aberdeen and Sumburgh and then departed Aberdeen for the third sector, with the commander as pilot flying. The aircraft was loaded with 3,000 kg of fuel, sufficient for the round trip. The flight plan required 1,828 kg of fuel.

As the aircraft flew towards Sumburgh, the co-pilot obtained ATIS information Tango, which stated that Runway 27 was in use, the wind was from 290° at 34 kt, gusting to 47 kt, visibility was 4,700 m in heavy rain and snow, and the lowest cloud was FEW at 700 ft aal; the QNH was 991 hPa.

The aircraft was vectored towards an ILS approach to Runway 27. As it established on the base leg, the approach controller informed the flight crew that the visibility was now 3,300 m in moderate rain and snow, and that the runway was wet. The aircraft, in clean configuration, descended to 2,000 ft amsl and established on the localiser approximately 9 nm east of the airport. The aircraft's weather radar showed a convective cloud cell, 'painting' red, immediately west of the airport, and the commander decided to discontinue the approach, informed the controller, and turned the aircraft onto a southerly heading. The autopilot remained engaged with heading select and altitude tracking[1] modes selected.

As the aircraft rolled out on the heading, it was struck by lightning, which entered the airframe at the radome and exited at the APU exhaust (in the tail). 'Ball lightning' appeared briefly in the forward cabin immediately before the lightning strike.

Footnote

[1] In altitude tracking mode, the autopilot maintains the appropriate altitude or, if disturbed, endeavours to return the aircraft to it.

The commander informed the co-pilot that he (the commander) had control of the aircraft and began making noseup pitch inputs, which he augmented with nose-up elevator trim inputs using the pitch trim switches on the control yoke. The co-pilot transmitted a MAYDAY to ATC, and the controller offered the flight crew "ALL OPTIONS" for an approach or diversion.

The aircraft climbed, but the commander perceived that his increasingly aggressive control column inputs did not appear to be having the expected effect. The co-pilot also applied nose-up pitch inputs and pitch trim inputs, but similarly perceived that the aircraft was not responding as expected. Pitch and roll mis-trim indications were presented on the primary flight displays (PFDs) in the form of a 'P' and an 'R' for the respective condition. Both pilots considered the possibility that they had lost control of the aircraft, perhaps because of a failure of the fly-by-wire elevator controls following the lightning strike.

The commander instructed the co-pilot to select the elevator emergency trim switch on the flight deck overhead panel. This was done, but had no effect, as the system had not detected the failure condition necessary to arm the switch.

As the aircraft reached 4,000 ft amsl, the pitch attitude tended towards nose-down and a descent began. Invalid data from one of the air data computers then caused the autopilot to disengage. The pitch trim was, by this time, almost fully nose-down, and the aircraft continued to pitch nose-down and descend; full aft control column inputs were made. The peak rate of descent was 9,500 feet per minute at 1,600 ft amsl, pitch attitude reached 19° nose down, and the highest recorded speed was 330 KIAS[2].

The pilots maintained nose-up pitch inputs and the aircraft began pitching nose-up. Nearing the minimum height achieved of 1,100 ft amsl, the ground proximity warning system fitted to the aircraft generated 'SINK RATE' and 'PULL UP' warnings. The commander applied full power, and the aircraft began climbing. He was still under the impression that elevator control response was not normal, and instructed the co-pilot to select the pitch control disconnect. The co-pilot queried this instruction, because the pitch control did not appear to be jammed, and the commander selected the disconnect himself. This disconnected the two elevator control systems from each other; each control column remained connected to its respective (on-side) elevator.

The climb continued and the aircraft diverted to Aberdeen. The flight crew ascertained that the aircraft responded to pitch inputs made on either or both control columns. The diversion and landing were uneventful.

Footnote

[2] The aircraft's V_{MO} varies with altitude and the maximum value is 276 KIAS at 21,400 ft; V_{MO} below 4,000 ft amsl is 250 KIAS.

Description of the aircraft

The Saab 2000 is a twin-engined turboprop aircraft designed to carry up to 53 passengers. The aircraft type was certified in 1994 and 63 have been built. It has a fly-by-wire elevator and rudder control system and a conventional mechanical system for roll control. It has a fixed horizontal stabiliser and no elevator trim tabs. Pitch trim consists of elevator movement without associated control column movement.

Autopilot system

The aircraft is fitted with a Rockwell Collins FCC-4003 autopilot system. This system controls the aircraft in pitch by mechanically moving the control column via an electric servo, and by sending pitch trim signals to the digital control system to move the elevator to offload the servo and allow the column to centralise in trimmed flight. When the autopilot is engaged the letters 'AP' are displayed on the PFDs and the autopilot engage lever is in the ENGAGED position.

The autopilot can be disengaged in the following ways:

- pressing the disengage button on either control yoke
- moving the autopilot lever on the centre pedestal to DISENGAGED
- moving the standby trim switches on the centre pedestal
- pushing the power lever go-around palm switches

The autopilot will disengage if it receives invalid system input data. Autopilot disengagement is accompanied by an audible 'cavalry charge' alert, which continues until an autopilot disengage button is depressed.

The pitch trim switches on the control yoke are inhibited when the autopilot is engaged and moving these switches will not cause the autopilot to disengage. If the pilot tries to move the control column while the autopilot is engaged the pilot can overpower the autopilot servo, but the autopilot remains engaged and opposing elevator trim may result. For example, if altitude tracking mode is engaged and the pilot pulls the column aft, the pilot will feel a higher force than if the mode were not engaged, and the autopilot will trim nose-down to regain the selected altitude. This will also result in a 'P' being displayed on the PFD and, if the pilot's inputs are maintained continuously for at least 10 seconds, a PITCH TRIM caution message will appear on the EICAS[3] with an associated flashing amber Master Caution light and a single aural chime, but the autopilot will remain engaged.

Footnote

[3] EICAS = Engine Indicating and Crew Alerting System.

Aircraft examination

A detailed inspection of the aircraft revealed minor damage to the radome and APU exhaust which was consistent with a lightning strike. Functional tests of the elevator control system and autopilot system did not reveal any faults. The aircraft has since flown in service without any flight control or autopilot problems.

Analysis

Analysis of the meteorological data showed that the aircraft was struck by triggered lightning which caused only minor damage. Although the pilots' actions suggested that they were under the impression the autopilot had disengaged at the moment of the lightning strike, recorded data showed that it had remained engaged. The pilots' nose-up pitch inputs were countered by the autopilot pitch trim function, which made a prolonged nose-down pitch trim input in an attempt to maintain its altitude tracking function until it disengaged. This accounted for the perception that the control response was not normal.

Safety action

The manufacturer

On 24 February 2015 the aircraft manufacturer published '*Operations Newsletter No.6'*, informing Saab 2000 operators of the circumstances of this serious incident, and clarifying the operation of the autopilot as follows:

'**Autopilot operation**

Autopilot disengage:

Manual control inputs will not cause the autopilot to disengage and the main trim switches are disabled when the autopilot is engaged. Consequently, operation of the main pitch trim switches will not have any effect on aircraft trim nor cause the autopilot to disengage.

Disengaging the autopilot is normally done by pushing the disconnect button on either control wheel.

Manual activation of the following will also cause the autopilot to disengage:

- Autopilot engage/disengage lever
- Go-around button
- The standby pitch trim switches

Autopilot disengage will trigger disengage warning (cavalry charge). The autopilot disengage warning is cleared by a push of the autopilot disconnect button located on the control wheel.

Autopilot mistrim

Conflicting manual control column inputs with the autopilot engaged will cause the autopilot trim to occur in the opposite direction of the control input, causing a mistrim situation. This will result in a 'P' for pitch and/or 'R' for roll appearing on the Primary Flight Display. If the situation is maintained, an AP PITCH MISTRIM or AP ROLL MISTRIM caution message will appear on the EICAS1 with associated flashing amber Master Caution light and a single aural chime. The autopilot will remain engaged.'

The operator

The operator notified the AAIB that it has put in place 'Mitigations to prevent an unsafe condition occurring when a pilot inadvertently applies an override force to the flight controls'. It provided a detailed description of these measures as follows:

Notice to Aircrew (NOTAC)

NOTAC 123/14 was issued to all [the operator's] SAAB 2000 pilots on 23 December 2015 advising to ensure that the autopilot is disconnected in the event of experiencing control abnormalities:

Background

The Saab 2000 autopilot does not disconnect when overpowered or when the control wheel pitch trim switches are operated. If the autopilot is engaged and the autopilot is overpowered it is possible to fly the aircraft and not be aware that the autopilot is engaged. However, in this situation, the autopilot pitch trim will operate to compensate for pilot input and can lead to increased control forces.

Action

In the event that increased control forces are experienced, pilots should ensure that the autopilot is disengaged.

Pilot Briefings

On the 19 December 2014 all SAAB 2000 pilots received a briefing on the incident. These briefings were either face-to-face or via telephone and included the reasons behind the NOTAC.

Operator Conversion Training

Following Type Rating Training all pilots new to the SAAB 2000 undergo 8 hours of simulator conversion training on [the operator's] procedures. All pilots are now exposed to this condition in the simulator and the corrective action required.

Triennial Training

All [the operator's] SAAB 2000 pilots will be exposed to this condition and the corrective actions required in the simulator during recurrent training on a three yearly cycle.

Revision to Autopilot Standard Operating Procedures (SOPs)

The operator has proposed changes to its standard operating procedures (SOP) to improve autopilot engagement state awareness:

> At any time the autopilot disconnects automatically or manually
> Pilot Flying - Presses autopilot disconnect button (Even if disengagement has been automatic) and announces "AUTOPILOT DISCONNECT"
> Pilot Monitoring - Confirms autopilot has disconnected by checking autopilot engagement indication and switches/paddles and announces "AUTOPILOT DISCONNECT"

Further investigation

The AAIB investigation has not identified any technical malfunction which might account for the incident. The investigation continues; exploring crew training, autopilot design requirements, the human-machine interface, including the autopilot system and other human factors of relevance to the incident.

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