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Swiss Transportation Safety Investigation Board STSB

Final Report No. 2297 by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident involving the Saab 2000 commercial aircraft, registration HB-IZW,

on 28 November 2013

at FL 110 over Muzzano/TI, east of Lugano regional aerodrome

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Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass der Totalausfall des *beta feedback transducer* (BFT) zur Messung des Propellerblattwinkels aufgrund eines losen Steckanschlusses zu einem Kontrollverlust des rechten Triebwerkes führte, sodass dieses durch die Besatzung stillgelegt werden musste.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Art 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident/incident prevention, due consideration shall be given to this circumstance.

The final version of this report is the original in the German language.

All information, unless otherwise indicated, relates to the time of the serious incident.

All times in this report, unless otherwise indicated, are stated in local time (LT). At the time of the incident, Central European Time (CET) applied as local time in Switzerland. The relation between LT, CET and coordinated universal time (UTC) is:
LT = CET = UTC + 1 hour.

Contents

Synopsis

Narrative

Owner	Nordic Aviation Capital A/S, Stratusvej 12, 7190 Billund, Denmark
Operator	Darwin Airline SA, via alla Campagna 2A, 6900 Lugano, Switzerland
Manufacturer	Saab Aircraft AB, Åkerbogatan 45, 581 88 Linköping, Sweden
Aircraft type	Saab 2000
Country of registration	Switzerland
Registration	HB-IZW
Location	At FL 110 over Muzzano/TI
Date and time	28 November 2013, 06:40 UTC

Investigation

The serious incident occurred on 28 November 2013 at 06:40 UTC. The notification arrived approximately one hour later. The investigation was opened on 29 November 2013 by the then Swiss Accident Investigation Board. The latter informed the following states of the serious incident: the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland (UK), the United States of America and Italy. These states appointed an accredited representative, who cooperated with the investigation.

The following was basis for the investigation:

- On-site evidence preservation
- Recordings of the radio communication
- Data from the flight data recorder
- Interviews

The present final report is published by the Swiss Transportation Safety Investigation Board (STSB).

Summary

On the morning of 28 November 2013, the airliner Saab 2000, registration HB-IZW, took off at approximately 06:34 UTC from Lugano regional aerodrome (LSZA) under flight plan number SWR 73KU for the scheduled flight LX 2903 to Zurich (LSZH). When the aircraft was climbing towards the alps at approximately flight level FL 110, the right engine ceased providing power. The crew then shut down the engine, discontinued the onward flight to Zurich and landed at 07:13 UTC on runway 35R at Milan-Malpensa airport (LIMC). The passengers exited the aircraft normally using the onboard stairs, on the airport apron.

The three crew members and the 25 passengers were uninjured. The aircraft was not damaged.

There was no other damage.

Causes

The serious incident is attributable to the fact that the total failure of the beta feedback transducer (BFT) for measuring the propeller blade angle led to a loss of control of the right engine due to a loose connector, so the engine had to be shut down by the crew.

Safety recommendations

With this final report no safety recommendations and no safety advises were issued.

1 Factual information

1.1 Pre-history and history of the flight

1.1.1 General

For the following description of the pre-history and history of the flight, the recordings of the radio communications, the flight data recorder, radar data and the statements of the crew members were used. Throughout the flight the commander was pilot flying (PF) and the copilot was pilot monitoring (PM).

The flight was conducted under instrument flight rules. It was a scheduled flight.

1.1.2 Pre-history

The copilot was the first of the three-person crew to arrive in the preparation room at Lugano regional aerodrome. Once he had printed out all necessary operating documents, he called the operations centre to request the latest weather information for the upcoming double rotation from Lugano to Zurich and back.

After the arrival of the other crew members, the crew made their way to the aircraft approximately half an hour before the scheduled time of departure and began the preparatory work. After the commander had completed the walk-around inspection, he joined the copilot, who had prepared the cockpit. Together they went through the technical status of the Saab 2000, registration HB-IZW. In addition to minor details concerning the auxiliary power unit (APU) it was found that this unit could sometimes only be started at the second attempt. Using the on-board radio, the crew contacted a mechanic. The latter confirmed that there were difficulties when starting the APU. After various unsuccessful attempts by the pilots to start it, the mechanic who had in the meantime arrived at HB-IZW attempted to start the APU, which he succeeded in doing at the first attempt. After consulting his copilot, the commander decided to accept the aircraft in this state. It was also decided to keep the APU to run during the entire flight.

Once the remaining preparations and the planned aircraft de-icing procedure had been completed, ground operations was ordered to bring the passengers to the aircraft. The flight attendant then closed the doors and began with the assistance of the 25 passengers.

At 06:26:45 UTC, SWR 73KU received clearance to start the engines. When the subsequent checklists had been completed, the copilot requested the taxi clearance. This was given immediately. When the aircraft had arrived at holding point November, SWR 73KU received clearance to taxi to the beginning of the runway and to line up on runway 19.

1.1.3 History of the flight

When take-off clearance was issued at 06:33:38 UTC, the commander moved the thrust levers to take-off power and the aircraft began to roll. At 06:36 UTC, HB-IZW lifted off and climbed in southerly direction to follow standard instrument departure route SID CANNE 1U towards Zurich. When the aircraft had reached approximately 2500 ft QNH[1], the PF instructed the PM to retract the flaps. The PM then set the engines to climb power by pressing the CLB button on the power management unit (PMU). Shortly afterwards, the air traffic controller (ATCO) at Lugano instructed SWR 73KU to contact the Milan Radar air traffic control centre on 126.75 MHz, which was done without delay. The Milan Radar ATCO issued a climb clearance to FL 180. HB-IZW accelerated as planned to approximately 170 knots (knots

[1] pressure reduced to mean sea level using the standard atmosphere of the international civil aviation organization

indicated airspeed - KIAS). Then, at 06:37:21 UTC, the autopilot was engaged. The planned left turn towards waypoint CANNE then followed. Shortly after the crew had switched the altimeters to standard pressure, the commander asked the copilot whether he too had noticed a brief "yawing". The latter said that he had not. After passing FL 100, an aural indication was given to the cabin attendant, to inform her that she could now take care of the passengers.

Just as the copilot was busy reading off the take-off time from the flight management system, the crew noticed that HB-IZW distinctly yawed twice to the right and back. According to the observations of the crew, the amber master warning light illuminated together with an aural tone plus the indications R ENG FAULT and R GEN FAULT, which appeared on part of the central screens in the cockpit. Furthermore, at 06:39 UTC, the caution R PROP CTL FAULT was logged.

At this time HB-IZW was climbing at FL 110 over the municipality of Muzzano/TI, east of Lugano regional aerodrome. The commander asked the copilot to acknowledge the indication by pressing the warning light and to analyse the situation by means of PPAA[2] in accordance with company guidelines. It was determined that power from the left engine was normal, that the aircraft was still climbing and that the flaps and landing gear were retracted. The turbine rotation speed of the right engine was reducing and the rotation speed of the right propeller indicated approximately 1100 rpm instead of 950 rpm.

The copilot then announced a fault in the right engine to the commander and stated that the right propeller had not been brought automatically to the feathered position. The commander instructed the copilot to start the checklist for an engine fault. The list included various manipulations which were processed by memory after mutual confirmation. First, with the manual feather push-button depressed, the right power lever was moved to the idle position. Then the condition lever was moved from run to stop. After the propeller speed N_P had reached a value of 100 rpm, the copilot released the manual feather button.

The commander disengaged the autopilot and flew the aircraft manually. The Saab 2000 was climbing at FL 115 with an airspeed of approximately 160 to 170 KIAS.

The overall situation was then analysed. The crew decided to discontinue the planned flight over the alps and, after transmitting a distress call (PAN-PAN), requested to stop the climb at FL 130 and to divert to Milan-Malpensa (LIMC) (see section 0). The Milan ATCO cleared SWR 73KU to perform a left turn towards VHF omnidirectional radio range (VOR) station Saronno. When the autopilot was engaged again at 06:44 UTC, HB-IZW was flying on a southerly heading. The crew then worked through together the checklist for the operating condition R ENG FAULT. An attempt to start the shut-down engine was delayed.

The commander then handed over control of the aircraft and handling of radio communications to the copilot. The commander contacted the flight attendant on the intercom and informed her about the technical problem. She informed the commander that she could not ascertain anything abnormal outside on the engine in question. He also informed her of his intention to divert to Milan-Malpensa airport.

To prepare for the approach in Milan, the crew of SWR 73KU requested to join the holding pattern over VOR Saronno. On the way there, the checklist for preparing for a landing with only one engine was also processed. After all these checklist items had been completed, the passengers were informed about the issue concerning the right engine. The flight crew then discussed whether an attempt to start the right engine could be considered. In view of the available information the crew

[2] PPAA: power performance analysis action

decided to attempt a start in accordance with the checklist. This start had to be interrupted by the commander because the engine was unable to reach a stabilized condition after fuel injection.

When the crew of SWR 73KU reported that they were ready for the approach in Milan, a corresponding clearance with radar vectoring was given. In the meantime, the commander had taken back control of the Saab 2000. The allocation of responsibilities was the same as on take-off from Lugano. For her part, the flight attendant prepared the cabin for landing. SWR 73KU then landed at 07:13 UTC on runway 35R in Milan-Malpensa, without further occurrence.

After HB-IZW had reached its assigned parking position, the left engine was shut down. The passengers disembarked the aircraft normally using the on-board stairs and boarded a bus.

1.1.4 Location of the serious incident

Location	Muzzano/TI, east of Lugano regional aerodrome (LSZA)
Date and time	28 November 2013, 06:40 UTC
Lighting conditions	Dawn
Coordinates	715 300 / 095 000 (Swiss grid 1903) N 45° 59’ 48’’ / E 008° 55’ 37’’ (WGS 84)
Altitude	FL 110

1.2 Injuries to persons

Injuries	Crew members	Passengers	Total number of occupants	Other
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	3	25	28	Not applicable
Total	3	25	28	0

1.3 Damage to aircraft

Apart from the defects described in section 1.12.3, the aircraft was not damaged.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Commander

Person	Swiss citizen, born 1968
Licence	Airline transport pilot licence aeroplane (ATPL (A)) according to the European Aviation Safety Agency (EASA), issued by the Swiss Federal Office of Civil Aviation (FOCA)

Flying experience	Total	8600 hours
	on the type involved in the incident	8600 hours
	during the last 90 days	39:14 hours
	of which on the incident type	52:14 hours

All available information indicates that the commander was rested and healthy when he came on duty. There is no evidence that fatigue played a part at the time of the serious incident.

1.5.1.2 Copilot

Person	German citizen, born 1988
Licence	Commercial pilot licence aeroplane (CPL (A)) according to EASA, issued by the German Federal Office of Aviation

Flying experience	Total	732 hours
	on the type involved in the incident	531 hours
	during the last 90 days	220:03 hours
	of which on the incident type	220:03 hours

All available information indicates that the copilot was rested and healthy when he came on duty. There is no evidence that fatigue played a part at the time of the serious incident.

1.6 Aircraft information

1.6.1 General information

Registration	HB-IZW
Aircraft type	Saab 2000
Characteristics	Two-engined commercial aircraft with turboprop, constructed as a cantilevered low-wing aircraft with retractable landing gear
Manufacturer	Saab Aircraft AB, Åkerbogatan 45, 581 88 Linköping, Sweden
Year of manufacture	1996
Serial number	039
Owner	Nordic Aviation Capital A/S, Stratusvej 12, 7190 Billund, Denmark
Operator	Darwin Airline SA, via alla Campagna 2A, 6900 Lugano, Switzerland
Engine	Rolls Royce (formerly Allison) AE2100A
	Serial number right engine: CAE510146
Propeller	Six-bladed variable-pitch propeller
	Dowty Propellers, R381-6-123-F/5
	Serial number right propeller: DAP0101

Operating hours	Airframe	30,594 h	(TSN[3])
	Right engine	21,653 h 19,443	(TSN) (CSN[4])
	Right propeller	25,296 h	(TSN)
Number of landings	22,057		
Mass and centre of gravity	Both mass and centre of gravity were within the permissible limits according to the aircraft flight manual (AFM).		
Maintenance	The last weekly/62 flight hours check took place on 25 November 2013 at 30,581 hours.		
Technical restrictions	Seven points were entered in the in deferred defect list (DDL). These included the problem with the APU mentioned in section 1.1.2.		
Permitted fuel grade	Kerosene		
Fuel on board	According to the flight plan, the fuel on board at take-off (take off fuel) was 1700 kg. Among other things this included trip fuel of 504 kg. The remaining approximately 1200 kg would have been sufficient for the flight to the alternate aerodrome as well as for a holding procedure of approximately 20 minutes duration, without having to use the final reserve of 354 kg.		
Registration certificate	Issued by the FOCA on 3 April 2013, valid till deletion from the aircraft register.		
Airworthiness certificate	Issued by the FOCA on 9 April 2013, valid till 9 April 2014.		

1.6.2 System description of the engine and its components

1.6.2.1 General

The following information originates from the operations manual B (OM B) for the Saab 2000 aircraft type.

1.6.2.2 General

"The turboprop power plant system consists of two Allison AE 2100A engines, driving six-bladed Dowty Aerospace Propellers (model (c) R 381-6-123-F/5).

Engine and propeller parameters are:

- *Controlled and monitored by FADECs (Full Authority Digital Electronic Control) units.*
- *Controlled by PL via FADEC.*
- *Controlled by CL via PMU and FADEC.*
- *Indicated on EICAS."*

[3] TSN: time since new

[4] CSN: cycles since new

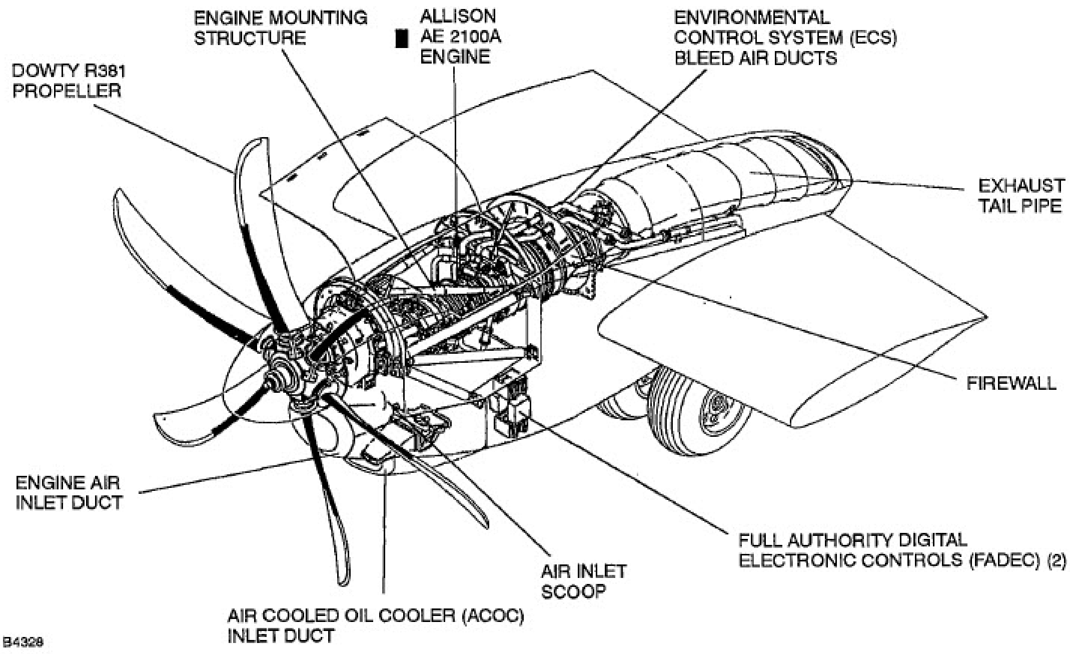

Figure 1: Engine layout on the aircraft's wing

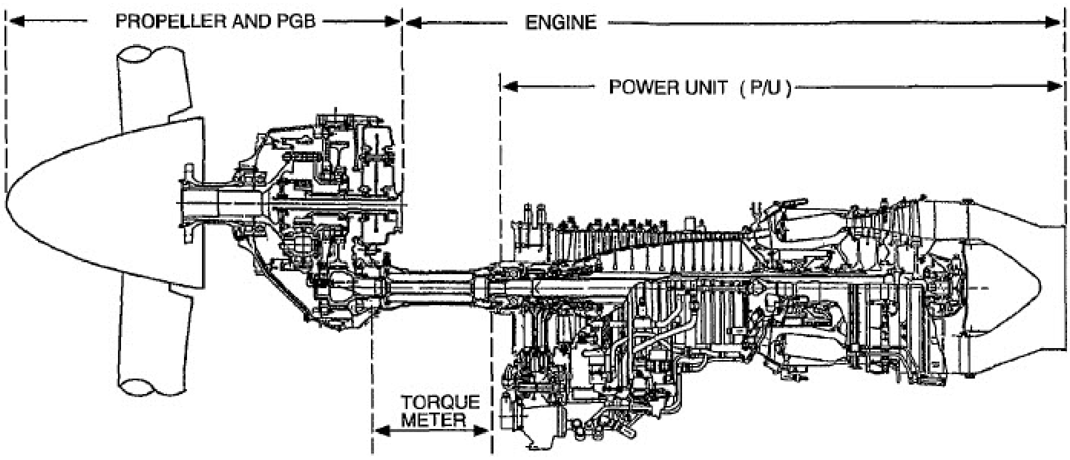

Figure 2: Overview of engine and propeller

1.6.2.3 Engine control

1.6.2.3.1 General

"The control system is a dual channel, fully redundant electronic control system. It is based on two identical, single-channel, Full Authority Digital Electronic Control units (FADECs A and B). The FADECs interface with the engine and propeller systems, the power levers (PL), the condition levers (CL) and the PMU.

The FADECs:

- *Monitor engine and propeller parameters.*
- *Give data & status/cautions/warnings to EICAS.*
- *Control and regulate fuel flow, compressor variable geometry (CVG), ignition and starter, and propeller blade angle ("pitch").*

The FADECs are powered from an engine-driven PMA and from the 28 VDC[5] battery bus (redundant power).

During operation, both FADECs are operating: one is in control, the other is on standby ("Standby FADEC").

Which FADEC is in control - FADEC A or FADEC B - is determined in anyone of the following ways:

- *Automatic change-over at engine start on ground.*
- *Automatic change-over if the controlling FADEC fails.*
- *Manual change-over by pilot (prevented if FADEC failure is detected).*

The FADECs have a continuous Built-In-Test (BIT) and fault accommodation system, which monitors:

- *FADEC hardware and software*
- *Input sensors*
- *Actuators*
- *Data busses*
- *Engine-driven PMA.*

The BIT runs at electric power-up, during operation, and also after engine shutdown. If a fault is detected, the fault accommodation logic will either:

- *Prevent engine start-up.*
- *Use secondary sensor (if primary fails)*
- *Change FADEC*
- *Change to 28 V DC (if PMA fails)*
- *Change to Ng control (if both torque sensors fail)*
- *Use simultaneous operation of ON/OFF actuators by both FADECs*

Each FADEC operates with its own primary dedicated sensors. Cross-communication between the FADECs permits the sharing of sensor data for various performance and fault accommodation purposes. For example, each FADEC senses Ng; if the controlling FADEC determines that its Ng sensor has failed it will use the sensor of the standby FADEC."

[5] VDC: volt direct current

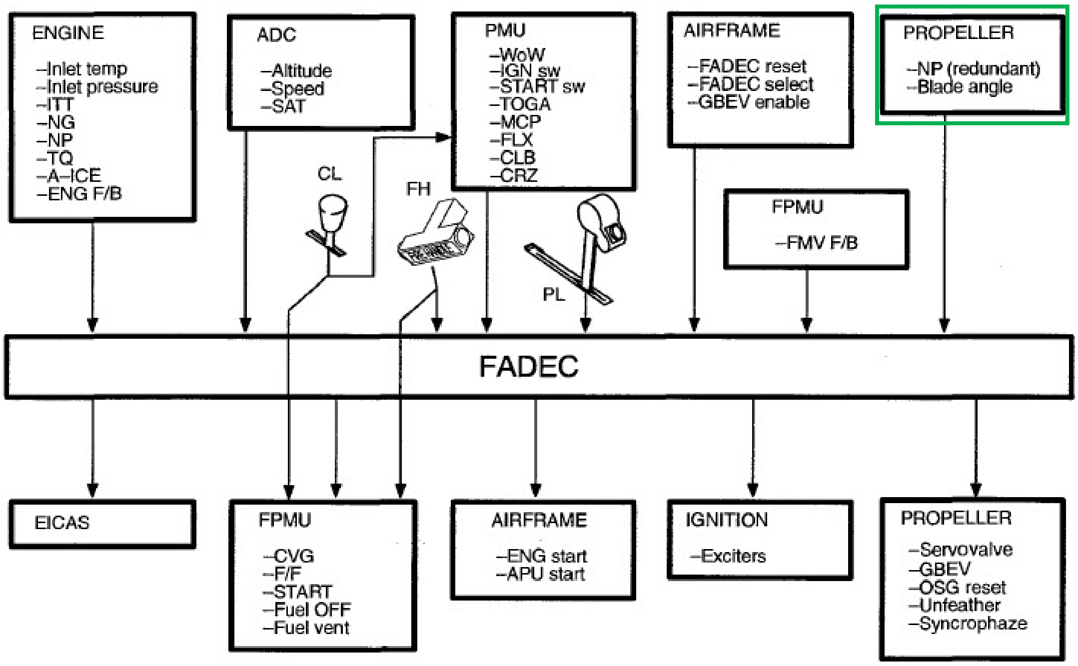

Figure 3: Block diagram of the FADEC. The input parameters for the propeller system are framed in green.

1.6.2.3.2 Functions controlled by FADEC signals

"Propeller speed:

- *Varying propeller pitch and/or fuel flow.*

Thrust control:

- *Sensing PLA, TO (Power) and ADC.*
- *Varying propeller pitch and/or fuel flow.*

[…]

Autofeather:

- *Independent function, if one engine fails, and the other engine operates normally.*
- *Detect loss of TO or NG.*
- *Activation disables autofeather on the other engine.*

Feather:

- *CL signals to FADEC via PMU.*
- *Feathering is also provided by use of the manual feather button which bypasses FADEC to operate the auxiliary feather pump.*

Starting:

- *Automatic sequencing and control of starter, ignition, fuel, CVG, ITT and propeller.*
- *Automatic shutdown if start fails.*

[…]

Overspeed:

- *Protection for propeller, power turbine and gas generator.*

- *Backup/fault accommodation logic to reduce fuel flow if speed exceeds the setting of the prop governor.*
- *Fuel shutoff at hazardous overspeed of propeller, power turbine or gas generator.*

[…]"

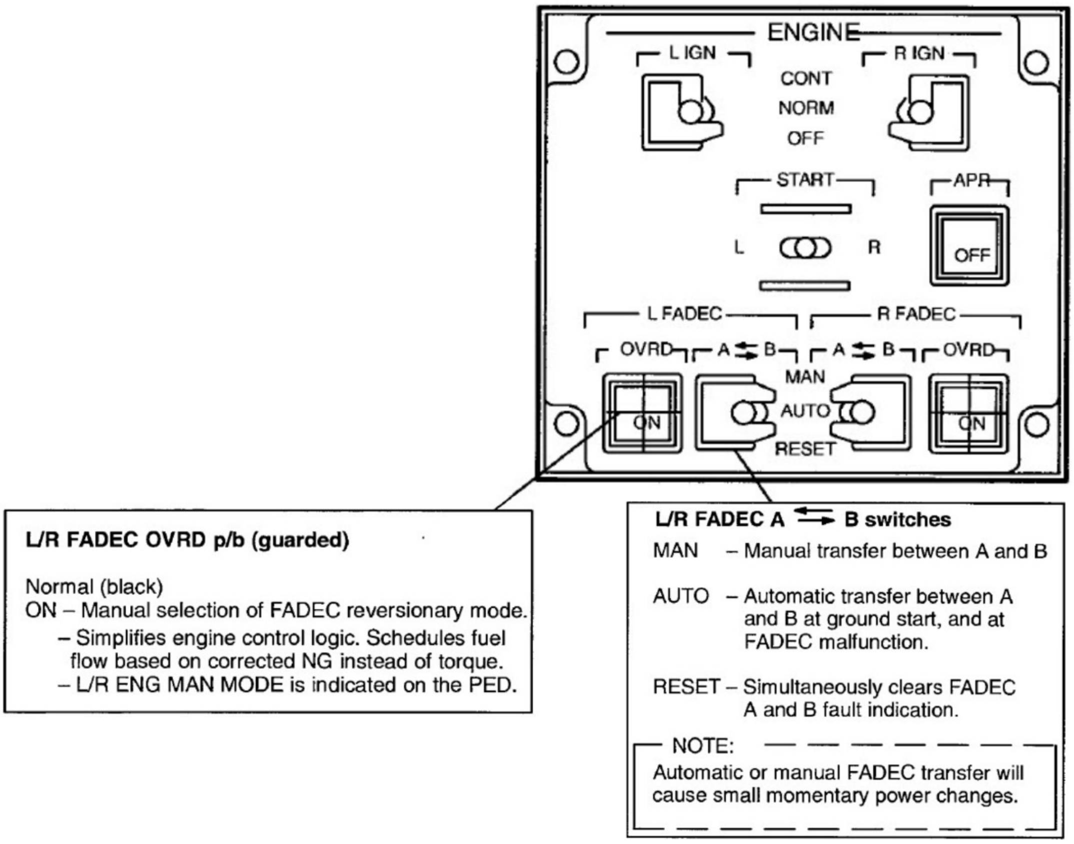

Figure 4: Overview of the FADEC control panel

1.6.2.4 Propeller control system

1.6.2.4.1 General

"The system is a counterweighted two-oil line system, controlled by the propeller control unit (PCU) in response to signals from FADEC. Counterweights on the propeller blades induce a coarse pitch force. High pressure oil, provided by a high pressure oil pump (HPP), driven by the PGB, is utilized to amplify coarse pitch force or modulate blade angle towards fine pitch. The pitch change mechanism is contained in the propeller hub. There is a common oil system for engine lubrication, PGB lubrication and propeller pitch control. Oil is routed through a beta tube which, by forward and rear movements, directs oil on either side of a piston in the pitch change mechanism. The counterweights make the propeller "fail safe towards coarse" in case of loss of oil pressure."

1.6.2.4.2 Propeller control unit

"The PCU consists of control valves, restrictors and a beta feed-back transducer (BFT). The PCU design is such that loss of electrical signals or loss of oil pressure, results in coarse pitch. In case the control mechanically sticks in a low fine position, control will revert to over speed governor (OSG) control, during flight conditions."

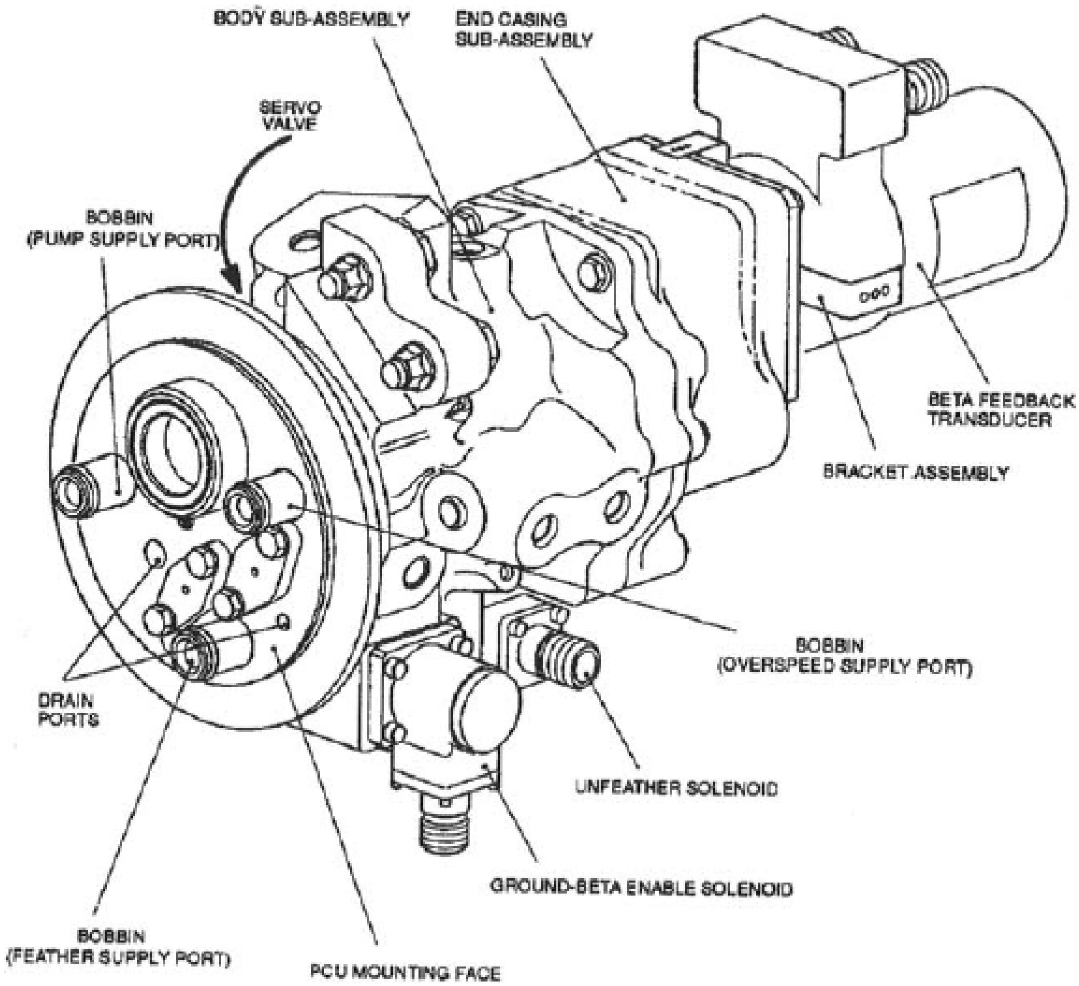

Figure 5: Overview of the PCU together with the fitted BFT

1.6.2.4.3 High pressure pump and overspeed governor

"Normal propeller speed governing is electrically controlled. The OSG is a mechanical feature flyweight design, driven by the HPP. If an overspeed occurs the OSG will drain oil on the "fine pitch side" and allow the counterweights to pull the blades towards coarse.

[…]

Ground Beta Enable Valve (GBEV):

The valve provides facility for:

- *An hydraulic flight fine pitch stop preventing the propeller to go into beta in flight*

[…]

Back-up feather valve:

This valve allows the feathering pump to override the rest of the control system and, when operated by the manual feather button, drives the propeller to feathered position."

1.6.2.4.4 FADEC Propeller control modes

"The FADEC provides propeller speed governing by varying propeller blade angle (pitch/beta) and/or varying engine fuel flow. The propeller pitch is hydromechanically controlled by the PCU in response to signals from the FADEC. The FADEC

controls engine fuel flow by providing signals to the FPMU. These signals are determined as the result of the FADEC correlation of inputs from the aircraft (PLA, CL, PMU, ADC and dedicated inputs from aircraft system sensors and transducers).

There are three control modes: Beta control, constant speed and reverse governing.

1) Beta control:

- *Drives the propeller pitch requested by the PL.*

2) Constant speed:

- *Holds a fixed NP, as demanded by PMU or HI RPM[6] p/b.*
- *Starts when PL above FI (on ground at approx. 40 PU[7], in the air at all times).*
- *Automatic synchrophazing.*

3) Reverse governing:

- *Drives the propeller to negative pitch.*
- *Stationary at max. reverse NP will be approx. 950. At intermediate reverse PL position, with forward speed NP will be approx 950 and then decrease to an intermediate value.*

[…]"

1.6.2.5 Engine and propeller subsystems

1.6.2.5.1 Manual feathering

"The Condition Lever (CL) provides an input to the PMU for selecting propeller feathering. The position of the lever signals the FADEC, which in turn controls the propeller and fuel system.

A manually operated feathering pump is provided:

- *As a backup feathering device, if feathering by use of CL fails.*
- *To ensure full feather position after an engine shut down by CL or after an autofeather activation.*
- *To enable propeller feathering when NP and hence HPP speed, is too low to provide enough oil pressure.*

[…]"

1.6.2.5.2 Autofeather System

"Provided AUTOFEATHER (p/b) is Normal (black) the FADEC automatically directs the propeller towards feather position if an engine failure is detected, and the opposite engine is operating normally."

[…]"

6 HI RPM stands for high revolutions per minutes. If during certain phases of flight an increased propeller speed becomes necessary, the system increases the propeller speed to 1100 RPM after pressing this button.

7 With PU (power units) Saab labels the unit to set the engine power.

1.6.3 Maintenance and repairs

As the result of an engine change, various components, including the PCU with the serial number DAP0161, were removed and then installed to the engine with serial number CAE510146. During this task, this PCU was connected to the wiring harness, including the connectors described in section 1.16.2. This task was certificated on 26 July 2012.

The documentation of the propeller manufacturer unveiled that this PCU was sent in for inspection or overhaul in 2003 for the following reasons: "*Prop gives intermittent control fault, also not possible to unfeather.*"

1.7 Meteorological information

1.7.1 General weather situation

An anticyclone extended from the British Isles to the alps where a secondary centre was present.

1.7.2 Weather at the time and the place of the serious incident

Sky was clear over Southern Switzerland and the Po valley with winds from the northeast above FL 070.

Weather/clouds	Sky clear
Visibility	10 km or more
Wind	360 degrees, 4 kt
Temperature/dew point	-6 °C / -8 °C
Atmospheric pressure QNH	1029 hPa
Hazards	None

1.7.3 Astronomical information

Position of the sun	Azimuth: 118°	Elevation -3°
Lighting conditions	Dawn	

1.7.4 Milan-Malpensa aviation weather report

From 06:50 UTC until the landing the following meteorological aerodrome aviation routine weather report METAR was valid at Milan Malpensa Airport:

METAR LIMC 280650Z 05004KT 330V070 CAVOK M01/M08 Q1030 NOSIG=

In plain text this means:

On November 28th 2013 the following weather conditions were observed at Milan Malpensa Airport shortly before the METAR dissemination at 06:50 UTC:

Wind	From 050 degrees at 4 kt The wind has varied between 330 and 070 degrees.
Meteorological visibility	greater or equal to 10 km
Present weather	sky clear

Cloud	No cloud below 5000 ft or below the highest minimum sector altitude (MSA), whichever is greater. No cumulonimbus (CB) or towering cumulus (TCU) at any altitude. No significant weather phenomenon at or in the vicinity of the airport.
Temperature	-1 °C
Dew point	-8 °C
Atmospheric pressure QNH	1030 hPa, pressure reduced to mean sea level using the ICAO standard atmosphere.
Trend	No significant change is expected to the reported conditions within the next two hours.

1.8 Aids to navigation

Not applicable

1.9 Communications

Radio communications between the crew and the air traffic control centres concerned took place correctly and without difficulties.

1.10 Aerodrome information

1.10.1 Lugano regional aerodrome

1.10.1.1 General

The Lugano regional aerodrome is located in the south of Switzerland and is located close to 3 km west of the city of Lugano.

The reference airport elevation of is 915 ft above mean sea level (AMSL) and the reference temperature is specified as 27.0 °C.

1.10.1.2 Runway equipment

The runways at Lugano regional aerodrome have the following dimensions:

Runway designation	Dimensions	Elevation of the runway thresholds
01/19	1350 x 30 m	900/915 ft AMSL

Lugano is classified as a category C aerodrome. Because of the topography surrounding the aerodrome, arrivals and departures under instrument flight rules (IFR) are permissible only for crews which have a corresponding airport qualification.

Runway 01 can be approached with the aid of an instrument guidance system (IGS) and 1240 m are available for landing. The nominal glide path for this approach is 6.65°. Aircraft approaching the airport using this procedure must be certifed for corresponding steep approaches.

The runway 01 IGS procedure also constitutes the starting point up to a defined minimum descent altitude/height (MDA/H) for instrument approaches on runway 19. Subsequently, the published flight paths for circuit approaches for runway 19 must be followed. 1145 m are available here for landing.

1.10.2 Milan-Malpensa airport

1.10.2.1 General

Milan-Malpensa airport is the largest of Milan's three international airports. It is located approximately 44 km south-south-west of Lugano regional aerodrome and is generally chosen as the alternate aerodrome in flight operations.

The reference airport elevation of is 768 ft AMSL and the reference temperature is specified as 27.9 °C.

1.10.2.2 Runway equipment

The runways at Milan-Malpensa airport have the following dimensions:

Runway designation	Dimensions	Elevation of the runway thresholds
17R/35L	3920 x 60 m	764/714 ft AMSL
17L/35R	3920 x 60 m	745/708 ft AMSL

The preferred approach direction is from the south on both runways 35L and 35R. These are both equipped with a category CAT II/CIII instrument landing system (ILS). In rare cases, approaches are made from the north. In this case only runway 17L can be approached; it is equipped with a category CAT I ILS.

1.11 Flight recorders

1.11.1 Flight data recorder

1.11.1.1 General information

Type	Digital flight data recorder (DFDR)
Manufacturer	Allied Signal / Honeywell Inc.
Recording medium	Solid state memory (SSM)
Recording duration	50 hours

1.11.1.2 Results of the analysis

It was possible to read out the data from the flight recorder which was available to the investigation. The analysis unveiled the following results:

- On this flight FADEC channel A was active for both engines. The propeller blade angle in the right engine was measured by the BFT signal from the right connector.
- At 06:39:44 UTC a propeller blade angle of 38° was recorded on the right engine.
- At 06:39:45 UTC a propeller blade angle of -5.4° was recorded on the right engine.
- The propeller blade position sensor falsely indicated a blade angle of -5.4°, although this was always above the normal position for flight idle.
- The overspeed governor (OSG) was not able to prevent the maximum speed of rotation of 104% from being exceeded by 2.5%.

1.11.2 Cockpit voice recorder

1.11.2.1 General information

Type	Cockpit voice recorder *(*CVR)
Manufacturer	Honeywell Inc.
Recording medium	Solid state memory (SSM)
Recording time	30 minutes

1.11.2.2 Results of the analysis

Because of the short recording time, the period relating to the serious incident had already been overwritten again.

1.11.3 EICAS

1.11.3.1 General information

In the engine indicating and crew alerting system (EICAS) all data plus various operational states of most aircraft systems are indicated. Two colour screens are available to the crew for this purpose.

This data is recorded in the DFDR.

1.11.3.2 Results of the analysis

In relation with the serious incident, among other things the amber caution R PROP CTL FAULT was displayed.

In addition, at 06:39 UTC the following relevant maintenance messages were recorded:

- PCU
- BETA FEEDB SENS
- LOSS PROP CTL
- R FADEC (A)
- R FADEC (B)

In this context, a propeller overspeed exceedance R NP OVERSPEED was also recorded for 6.9 seconds.

1.12 Wreckage and impact information

1.12.1 Site of the accident

Not applicable

1.12.2 Impact

Not applicable

1.12.3 Damage found on the right engine

After landing in Milan Malpensa, an oil spill approximately 15 cm in diameter was found under the right engine. No external damage to the engine was visible. The loss of oil was very probably caused by the windmilling of the propeller in flight with the engine shut down. The right propeller was replaced due to the overspeed exceedance.

1.13 Medical and pathological information

Not applicable

1.14 Fire

Fire did not break out.

1.15 Survival aspects

Not applicable

1.16 Tests and research results

1.16.1 Action taken after the landing

For trouble shooting purposes, the pitch control unit (PCU), serial number DAP0161, and the corresponding wiring harness were removed from the right engine of HB-IZW for further investigation.

1.16.2 Investigation of the PCU

1.16.2.1 General

Based on the DFDR data it can be stated that both FADEC channels recorded a fault on the beta feedback transducer (BFT), resulting in the FADEC being unable to measure the right propeller blade angle.

Visual inspection of the BFT unveiled that the left connector was loose and worn out (cf. Figure 6). Damage was found to the four not sufficiently tightened mounting bolts and on the housing. This indicates that unprofessional work had been carried out in this area. A functional test of the BFT was then performed with the connectors removed. This test unveiled that the basic functions of the BFT complied with the specifications.

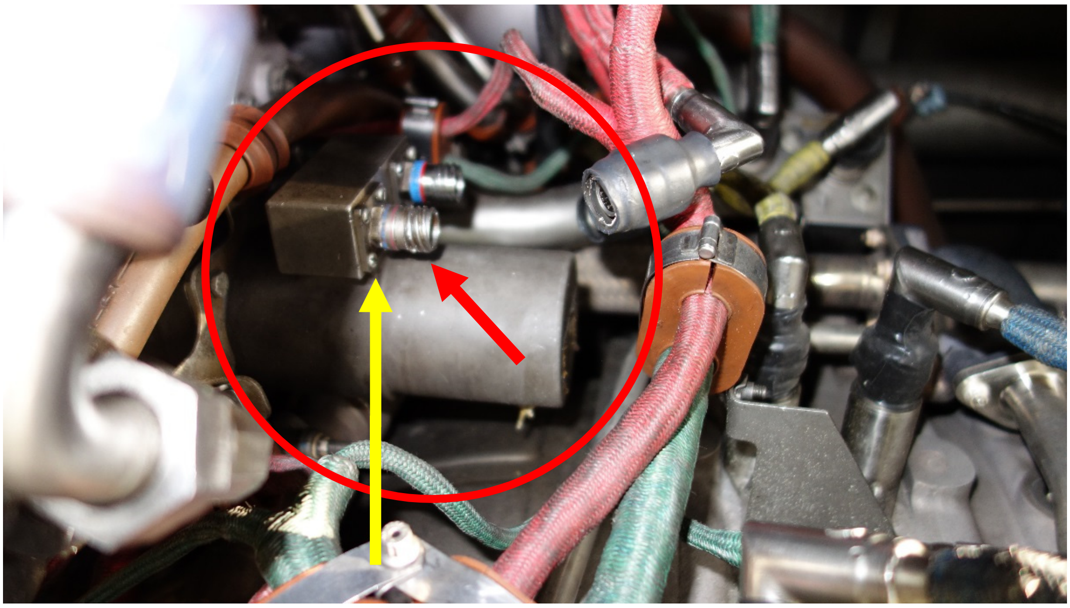

Figure 6: Beta feedback transducer (BFT) mounted on the right engine on HB-IZW (red circle); the red arrow indicates the worn out thread of the left connector. The yellow arrow indicates the not sufficiently tightened mounting bolts.

Inside the left connector the plastic guide of the connector pins was spoiled (cf. Figure 7).

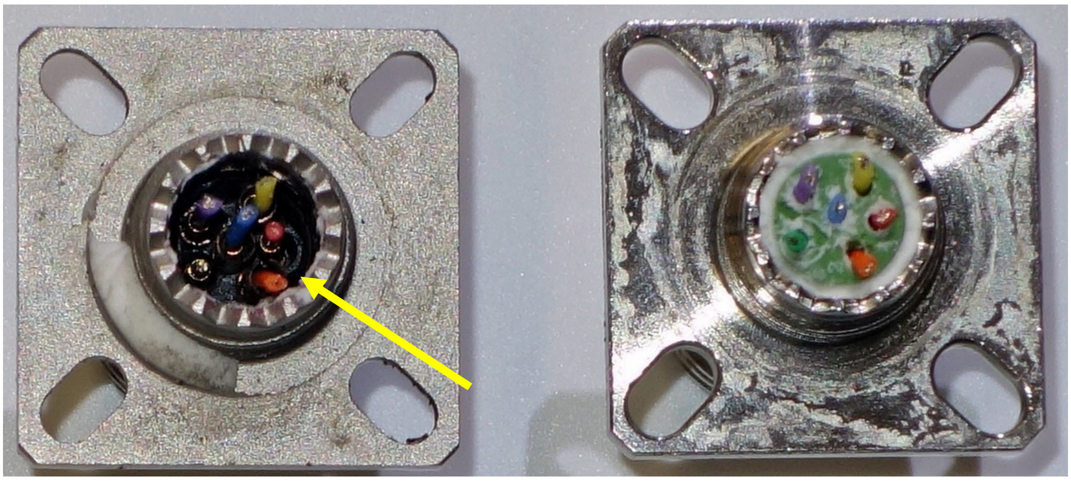

Figure 7: Rear view of the two connectors in disassembled state. The yellow arrow indicates the worn out connection with the area of the spoiled plastic guide. The intact right connector is shown next to it for comparison.

1.16.2.2 Computer tomographic examination

Before disassembly the BFT was examined using computer tomography. It was possible to visualize the areas in the left connector where short-circuits between the connector pins could have occurred.

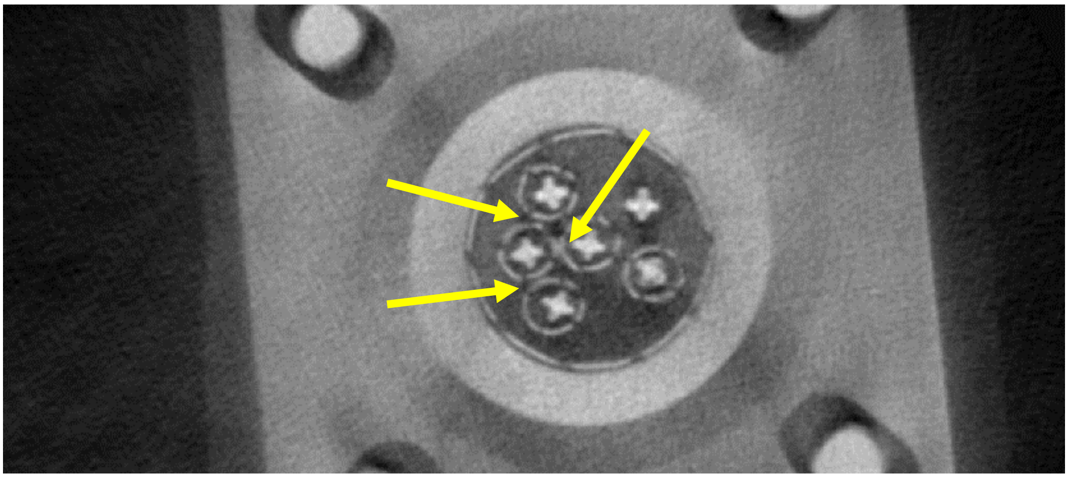

Figure 8: Visualization of the left connector. The yellow arrows indicate the areas in which short-circuits occurred.

1.16.2.3 Electrical measurements

The BFT has two channels, each with three copper winding, each of which having a connector with a cable link to the FADEC. Each channel has a primary, a secondary and a reference winding. The active FADEC channel energizes the primary winding of a BFT channel with alternating current at 1280 Hz. The shaft of the BFT, which is mechanically connected to the propeller, moves in the primary winding and induces currents which are measured in the secondary and the reference winding. With these currents the propeller blade angle is calculated by the FADEC. The other primary winding is not energized at this time. This only happens when the FADEC accesses this channel.

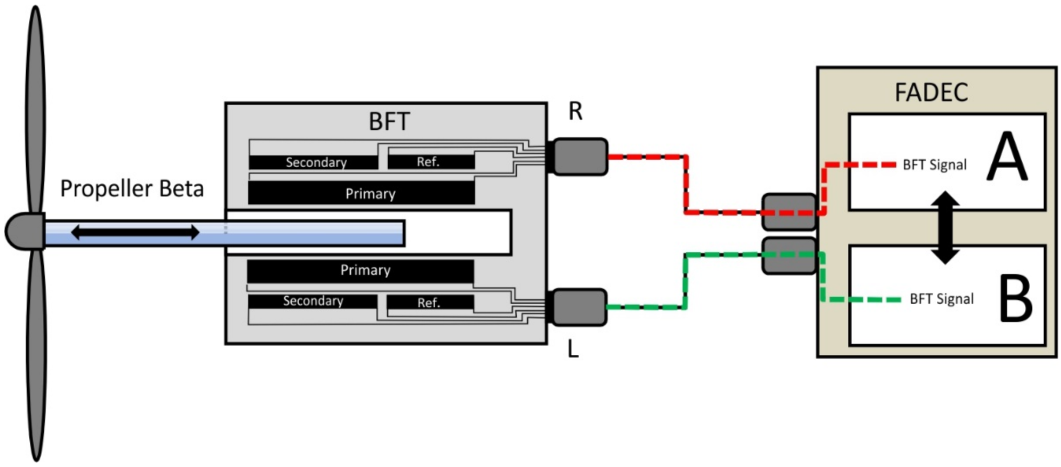

Figure 9: Block diagram illustrating the connections from the FADEC to the BFT sensor. The letters R and L designate the respective connectors.

The windings of both BFT channels were electrically tested at room temperature and at an ambient temperature of 80 °C. The results of the tests were as follows:

- The channel of the right connector (R) functioned electrically without any faults.
- The channel of the left connector (L) failed the electrical tests, due to an electrical resistance between connector pins 3 and 6 (primary winding) of 0.4 Ω at room temperature, corresponding to a short circuit. The resistance at room temperature should be 60 Ω.
- Testing on the insulation of the left connector revealed that the resistance between the primary and secondary winding was only 20 kΩ. In addition, the resistance in the left channel, between the primary and the reference winding was also only 20 kΩ. The same measurement on the right connector yielded a value of 100 GΩ, whilst 22 GΩ was measured on the right channel.

The manufacturer of the BFT commented that this was the first occurrence of a short circuit within the BFT that they had experienced. Previous BFT faults had occurred when the crimped joints at the connectors had failed due to corrosion, giving an open-circuit condition.

1.16.2.4 Extended functional check

The PCU was electrically checked on a performance test bench.

For this test a dummy shaft was used in the PCU which can simulate three reference positions. These three positions each triggered a corresponding test signal in the BFT which could be compared with the default values.

The test series with the right connector of the BFT channel could be completed successfully.

During the test with the left connector of the BFT channel, two fuses tripped on the test bench as a result of the short circuit in the primary winding, so the test series was stopped. Consequently no performance tests could be carried out on this channel.

1.16.2.5 Summary

Prior to the serious incident, FADEC channel A was active; it was connected to the right connector of the BFT and its windings. This configuration initially functioned perfectly.

As the DFDR data shows, FADEC channel A registered a problem with measurement of the propeller blade angle. The FADEC then switched to the BFT channel on the left connector. Due to the pre-existing short circuit, a propeller blade angle likewise not be calculated from this signal either. This resulted in the FADEC switching to fault accommodation mode.

In this FADEC fault accommodation mode, the so-called beta control mode is activated, triggering the following processes:

- idle engine;
- drive propeller fine;
- set “loss of propeller control” fault;
- hold ground state (flight or ground);
- stay in beta control until feather requested, then hold feather (drive coarse).

1.16.3 Investigation of the wiring harness

A functional test of the wiring harness did not reveal any malfunction.

The wiring harness passed all electrical and visual checks. No irregularities were found.

1.17 Organisational and management information

1.17.1 Airline operator

1.17.1.1 General

The operator Darwin Airline was founded in 2003. Since the end of July 2004, Darwin Airline possessed an air operator certificate (AOC) from the FOCA and started its scheduled flight operations on 28 July 2004.

In November 2013 the participation of Etihad Airways in the existing Darwin Airline company was announced; it resulted in a change of the company's name into Etihad Regional.

At the time of the serious incident Darwin Airline operated, amongst others, a fleet of seven Saab 2000 aircraft.

1.17.2 Continuing Airworthiness Management Organisation

The continuing airworthiness management organisation (CAMO) was delegated by the operator to an independent company.

Generally a CAMO has various tasks. Among other things it develops maintenance programmes for aircraft and arranges or coordinates in particular the corresponding modification, repair and maintenance tasks which is necessary. The accomplishment of technical inspection on aircraft, provided an appropriate authorisation exists, as well as maintaining the technical aircraft documentation, are also activities performed by the CAMO.

The designated CAMO of the operator was unable to provide any up-to-date information on the status and configuration of the aircraft in good time.

1.18 Additional information

1.18.1 Airline operator

1.18.1.1 General

HB-IZW was operated under Darwin Airline's AOC. All operating standards are based on this operator's regulations.

1.18.1.2 Operational manual

In operational manual B (OM B), the following relevant sections are to be found in the malfunction checklist for the Saab 2000 aircraft:

"***PROP CTL FAULT***

NOTE:
On ground with PL below FLIGHT IDLE, the propeller goes to max reverse or fine pitch. In flight, the propeller goes to 800 rpm or autofeathers.

1. FADEC……………………………….....RESET

Caution still on? ***NO*** ➔ *2. END*

YES

➘

2. Proceed to ENG SHUT DOWN procedure M8

[…]

ENG FAULT

ENGINE SHUT DOWN – Failure / Flameout

NOTE:
If precautionary shut-down is required, cool down the engine for 2 minutes before actual shut-down. If the propeller has autofeathered, retard power lever to flight idle.

1. POWER (affected side)……………....SET 10-20 PU

2. COND LEVER (affected side)………START ➔ FUEL OFF

3. APU…………………………………… START ➔ AVAIL

- *Consider ENG RESTART IN FLIGHT procedures* ***M41***
- *Do not restart engine if it was shut down due to FIRE, Overspeed or suspected Damage. (Check Eng Parameters)*

4. Proceed to OEI OPERATION procedure ***M120***

[…]"

1.19 Useful or effective investigation techniques

Not applicable

2 Analysis

2.1 Technical aspects

Since the engine start, the right hand engine's redundant digital controller for all engine functions (full authority digital engine control - FADEC) was active on channel A. That means that FADEC channel A was measuring the propeller blade angle via the right connector of the beta feedback transducer (BFT) and its windings. In the recordings of the DFDR data, an instant reduction in the propeller blade angle from 38° to -5.4° was recorded at 06:39:45 UTC. Due to the layout of this hydraulic system, this is technically not possible. Therefore a measurement fault within the BFT must be assumed. A possible explanation is that the short circuit in the left connector interfering with the propeller blade angle measurement through the right connector. This resulted the FADEC switching to fault accommodation mode. Subsequently, the FADEC regulated the right engine to idle and generated the amber caution R PROP CTL FAULT.

As the examination of the BFT unveiled, a short circuit in the left connector between connector pins 3 and 6 existed. Inside the left connector, the plastic guide of the connector pins was spoiled. This defect was presumably caused by vibration. This only became possible by the loose mounting bolts of the connector.

Conclusively, it can be asserted that the existing fault could not be compensated by the system design, resulting in a total failure of the BFT in the right engine.

2.2 Human and operational aspects

During the climb the commander noticed a slight yawing movement and immediately notified the copilot about this. When the aircraft had passed FL 100, both pilots noticed that HB-IZW distinctly yawed twice to the right and back again. Shortly afterwards, the amber caution illuminated, accompanied by an aural tone and various annunciations on the engine indicating and crew alerting system (EICAS). After a systems analysis, the crew interpreted this as an engine failure, without the propeller autofeathering. The total failure of the BFT in the right engine, described in section 2.1, was not directly detectable by the crew. Before they had chance to respond, the FADEC had already regulated the right engine to idle.

By starting the auxiliary power unit (APU) according to the aircraft manufacturer's specifications, a redundancy in the electrical system supply is established (cf. section 0). The fact that the APU which was susceptible to malfunctioning was left running for the planned flight to Zurich, enabled the crew to carry out the subsequent manipulations to secure the engine and to perform the single-engined approach in a coordinated manner.

Since the approach procedures in Lugano are generally very challenging, it is common practice for operators not to land in Lugano after an engine failure. The nearest suitable airport is Milan-Malpensa (LIMC), which is located approximately 44 km south-south-west of Lugano. The crew also decided in this case to discontinue the flight over the alps towards Zurich and to divert to Milan. This decision was reasonable.

As soon as the situation allowed, the crew attempted to re-start the engine. This was a correct prioritisation.

At this time the crew had no reference that the start attempt would not succeed. Because of the existing faults around the BFT and the resulting operating condition of the FADEC, a re-start of the engine became no longer possible.

The crew then concentrated on preparing the approach to Milan with one engine inoperative. Since such a situation is the subject of repeated exercises in the simulator for the crew, this approach at Milan-Malpensa was routine.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for scheduled air transport.
- Both the mass and centre of gravity of the aircraft were within the permissible limits to the aircraft flight manual (AFM) at the time of the serious incident.
- The last weekly / 62 flight hours check was carried out on 25 November 2013 at 30,581 hours.
- On both engines, channel A of the redundant digital controller for all engine functions (full authority digital engine control - FADEC) was active.
- The signal from the left connector of the beta feedback transducer (BFT) for measuring the propeller blade angle was not available due to the short circuit which occurred.
- As a result, the FADEC switched to fault accommodation mode and regulated the engine to idle.
- The left connector to the BFT sensor was loose.
- The left connector channel to the BFT did not pass the electrical test due to a short circuit between the connector pins.
- A functional test of the BFT with the connectors removed unveiled that the basic functions of the BFT complied with the specifications.

3.1.2 Crew

- The crew were in possession of the required licences for the flight.
- There is no evidence of any crew health problems during the serious incident.

3.1.3 History of the flight

- At 06:36 UTC, HB-IZW lifted off and climbed in a southerly direction to follow standard instrument departure route (SID) CANNE 1U in the direction of Zurich.
- At 06:39:45 UTC, the flight recorder registered a reduction of the right propeller blade angle from 38° to -5.4°.
- The engine indicating and crew alerting system (EICAS) registered the amber caution R PROP CTL FAULT.
- The crew then shut down the right engine and discontinued the flight to Zurich in order to divert to Milan-Malpensa.
- An attempt to re-start the right engine was unsuccessful.
- At 07:13 UTC the aircraft landed on runway 35R in Milan-Malpensa with one engine inoperative.
- The 25 passengers and three crew members disembarked the aircraft normally on the apron. No-one was injured.

3.1.4 General conditions

- The weather conditions had no effect on the serious incident.

3.2 Causes

The serious incident is attributable to the fact that the total failure of the beta feedback transducer (BFT) for measuring the propeller blade angle led to a loss of control of the right engine due to a loose connector, so the engine had to be shut down by the crew.

4 Safety recommendations, safety advices and measures taken since the serious incident

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the serious incident

None

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Berne, 14 November 2017 Swiss Transportation Safety Investigation Board