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ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2007-027
Final

Engine in-flight shutdown South of Java, Indonesia 23 July 2007

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Abstract

At approximately 1944 Coordinated Universal Time on 23 July 2007, an Airbus Industrie A330-202 aircraft, registered VH-EBE, was about 4 hours into its flight from Bangkok, Thailand to Melbourne, Australia, when the left (No-1) engine had an uncommanded shutdown.

The flight crew attempted unsuccessfully to restart the engine and subsequently diverted to Denpasar Airport, Indonesia. The operator's maintenance staff inspected the aircraft and performed a series of tests and examinations, which revealed that the engine electronic control unit (ECU) for the No-1 engine had malfunctioned.

The defective ECU was sent to the component manufacturer for a detailed inspection. That inspection found a short circuit in the input output module (IOM) circuit board that developed from a microscopic air void in the insulation compound of the circuit board layers.

As a result of this incident, the aircraft operator replaced the ECUs in a number of aircraft, and the board manufacturer amended its production standards and procedures.

FACTUAL INFORMATION

Sequence of events

On 23 July 2007, an Airbus Industrie A330-202 (A330) aircraft, registered VH-EBE, was being operated on a scheduled passenger service from Bangkok, Thailand to Melbourne, Australia.

At approximately 1944 UTC[1], about 4 hours after departure from Bangkok, the pilot in command observed the left (No-1) engine's power indicating instrument displays decreasing in value, indicating an uncommanded engine shutdown/engine failure. At about the same time, the electronic centralized aircraft monitoring (ECAM) unit emitted a single chime and displayed an 'Eng 1 Fail' message. The flight crew transmitted a PAN[2] call, advised air traffic control (ATC) of an engine failure and requested a clearance to descend to a lower altitude. The crew attempted to restart the engine, but were unsuccessful and diverted the aircraft to Denpasar Airport, Indonesia.

After landing, the operator's maintenance staff performed a general visual inspection of the No-1 engine, a General Electric CF6-80E1, and found no evidence of damage.

The ECAM unit was interrogated and the following messages were recovered:

- Channel A fault - HMU (E1-4000KC) FMV pos/J5 on PRF
- Channel B ECU fault - HMU (E1-4000KC) FMV TM/J6/ECU (E1-4000KS).

1 The 24-hour clock is used in this report to describe the time of day as particular events occurred. As the incident took place in international waters, Coordinated Universal Time (UTC) has been used.

2 PAN-PAN transmission is made in the case of an urgency condition that concerns the safety of an aircraft or its occupants, but where the flight crew does not require immediate assistance.

Further fault finding was conducted, including a detailed inspection of the No-1 engine electronic control unit (ECU), the electrical harnesses and the hydro-mechanical unit[3] (HMU) for damage.

A 'wet spin[4]' was performed on the No-1 engine. That test showed that the high pressure fuel shut-off valve (HP SOV) that was contained within the HMU was not opening. The operator transposed the left and right engine ECUs as part of the fault isolation process and then repeated the wet spin. That confirmed that the ECU that was originally fitted to the No-1 engine was faulty.

At the time of the incident, the ECU had operated for about 319 hours, and 47 cycles, since new.

The No-1 ECU was sent to the component manufacturer in the United States (US) for a detailed examination.

Electronic control unit function

The A330 incorporates a full authority digital engine control (FADEC) system. The FADEC had a number of functions, including: engine control, fault isolation, maintenance test and condition monitoring.

During flight, the FADEC controlled: the fuel flow, power management, air system valve and actuator control, integrated drive generator oil cooling, core compartment cooling, bore cooling, ignition control, reverse system control engine start, engine monitoring and fault isolation.

The ECU was a part of the engine FADEC system, and included built-in redundancy through the use of two fail-safe electronic channels ('A' and 'B'). The unit was designed so that either channel could control engine operation in the event of a single channel failure.

Electronic control unit test and inspection

The aircraft operator and ECU manufacturer retrieved the unit's non-volatile memory and confirmed the operator's test results that were established during the ECAM interrogation in Indonesia.

The manufacturer performed thermal imaging tests on the ECU, and identified a 'hot' spot in the printed wiring board of the channel 'B' input-output module (IOM).

A Computer Tomography[5] (CT) scan of the IOM confirmed the presence of defects in the region of the R16 resistor. That defect allowed arcing that chemically decomposed the dielectric[6] material between the IOM board layers into carbon, which created a low resistance path, and allowed a - 25 volt current to short circuit between layers 7 and 8.

The short circuit occurred at a position in the circuit after the channel 'B' fuel metering valve (FMV) torque motor disconnect relay, making that device redundant. The FMV remained closed as the negative current from channel 'B' was larger than the maximum positive current that channel' A' could command.

The type of IOM board was common to all ECU's fitted to the operator's aircraft that were powered by CF6-80E1 engines. The manufacturer of the ECU stated that '…the IOM board is common to all CF6-80E1, CFM56-5C and GE90-94B engines, and all FADEC2-equipped CFM56-7B engines.'

ANALYSIS

The reason for the shutdown of the left (No-1) engine was determined to be fuel starvation that was the result of a defect in the channel 'B' input-output module (IOM) board of the engine's electronic control unit (ECU).

A microscopic air void between layers 7 and 8 of the IOM board created a low resistance path, which allowed that part of the board to overheat and decompose the dielectric material into

3 A component that metered fuel to the engine by using the hydraulic force of fuel, and regulating that force by diverting it into servo signals. Those signals operated internal valves and actuators that corresponded to the electrical signals that interfaced with the ECU.

4 A maintenance technique where the engine start sequence was initiated on the ground with the ignition selected to OFF. That would normally allow the fuel system to operate without engine ignition.

5 A digital geometry process used to generate a three dimensional image of the inside of an object.

6 Non-conducting substance.

carbon. That breakdown in insulation allowed a high negative current (- 25 volt) to short circuit, and signal the fuel metering valve torque motor to close, starving the engine of fuel.

The location of the defect, and the resulting high signal voltage 'locked out' the fail-safe channel, allowing the defective channel to control the engine, and to prevent the crew from restarting the engine.

FINDINGS

From the evidence available, the following findings are made with respect to the uncommanded in-flight engine shut down involving Airbus Industrie A330-202 aircraft, registered VH-EBE, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- Microscopic air voids between layers of the input-output board allowed heat to radiate and break down the insulation compound. That allowed a large negative current to short circuit, and to prevent the other channel from taking over, rendering the fail-safe system ineffective.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Ineffective fail-safe

Although not identified as a safety issue, the printed wiring board (PWB) and engine control unit (ECU) manufacturers, and aircraft operator undertook safety action to address the factors in the development of this incident.

Action taken by the printed wiring board manufacturer

As a result of this incident, the manufacturer of the PWB updated its manufacturing test standard 'SG424' to include a new adjacency distance criteria of 150 mils[7] between:

- the power supplies and ground
- the different power supplies themselves
- critical signals, the power supplies and ground.

The PWB manufacturer also incorporated a new 500 V PWB insulation resistance test, with the intent of reducing the risk of voltage leaks.

All of the manufacturer's existing stock of unpopulated input-output module (IOM) PWB's was retested to the higher dielectric test standard, with no defects found. Similar testing of all IOMs that were supplied to the ECU manufacturer since September 2008 also found no defects.

The IOM manufacturer also changed its manufacturing standard 'SG403' that related to the manufacture of the PWB. That change included the redesign of the PWB from a single, 100 micron polyimide material board to two, 50 micron polyimide material boards that formed a double ply assembly (termed the 'IOM series 2 board'). The aim was to reduce the likelihood of a through-thickness air void. Those new boards will also undergo the new 500 V insulation resistance test standard 'SG424'.

The first IOM series 2 board will be used from PWB S/N 08K5165 onwards. The manufacturer stated that '...based on current usage rates and shipment of units to the ECU manufacturer, it is anticipated that these new 'IOM series 2' units will begin shipment around March 2009.'

7 A unit of length equal to 0.001 of an inch.

Action taken by the engine ECU/engine manufacturer

The ECU manufacturer evaluated the possibility of turning off the (+/- 25V) power supply to the inactive ECU channel, which could be incorporated through an electronic software change in the unit. The manufacturer stated that the proposed software change was submitted to company management for consideration and possible future development. That program was in the early planning stages at the time of this report. The incorporation of that modification in the ECU in this incident would most probably have allowed the operation of the fail-safe channel, and the engine may have continued to operate.

Action taken by the operator

As a result of this incident, the operator fitted a mature ECU to each of their CF6-80E1-powered aircraft that had less than 120 aircraft cycles since new.[8]

SOURCES AND SUBMISSIONS

Sources of information

The sources of information for this investigation included the printed wiring board, engine and aircraft manufacturers and the aircraft operator.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the Executive Director about the draft report.

A draft of this report was provided to the printed wiring board, engine and aircraft manufacturers; the aircraft operator; the Civil Aviation Safety Authority (CASA); the National Transportation Safety Board (NTSB); and the French Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile.

Submissions were received from the engine and aircraft manufacturers, and the aircraft operator. Those submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

8 The IOM manufacturer indicated that the risk of an ineffective fail-safe in ECUs that had already accrued time in service was '...extremely improbable.'