INCIDENT

Aircraft Type and Registration:	Airbus A319-111, G-EZIU
No & Type of Engines:	2 CFM56 turbofan engines
Year of Manufacture:	2005
Date & Time (UTC):	6 February 2007 at 1146 hrs
Location:	En route to from Barcelona to Liverpool
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 6 Passengers - 78
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	Total 12,500 hours (of which 2,166 were on type) Last 90 days - 81 hours Last 28 days - 26 hours
Information Source:	AAIB Field Investigation

Synopsis

During a scheduled passenger flight from Barcelona to Liverpool, numerous caution messages and accompanying aural tones were generated, some of which occurred repeatedly for the remainder of the flight. Although the flight crew were unable to resolve the problem, they concluded that the messages were most probably spurious. A MAYDAY was declared and the aircraft was diverted to London Stansted, where it landed safely. No faults were confirmed that could have accounted for these symptoms, but an intermittent fault in one of the Display Management Computers was considered to be the most likely cause.

History of the flight

The co-pilot was the pilot flying on the scheduled passenger flight, which was uneventful until crossing the south coast of England, when the ENG 2 EGT DISCREPANCY Electronic Centralised Aircraft Monitor (ECAM) caution message appeared, with an accompanying aural tone.

The co-pilot continued to fly the aircraft on autopilot whilst the commander reviewed the ECAM checklist action items. The ENG 2 EGT OVER LIMIT caution message then appeared. The action items for this condition required the No 2 (right) engine thrust lever to be moved to idle and the engine to be shut down. The commander retarded the thrust lever and was considering the implications of shutting down

the engine, when the ENG 1 EGT OVER LIMIT caution message appeared. The ECAM actions for this message were identical, but related to the No 1 (left) engine. The commander observed that the ECAM engine parameter indications appeared normal and concluded that the caution messages were probably spurious and reinstated the No 2 engine thrust lever.

During this period, the normal indications on the captain's Primary Flight Display (PFD 1) and Navigation Display (ND 1) were replaced with red indications similar to those that appear during inertial reference system alignment. The red USE MAN PITCH TRIM warning and amber MAN PITCH TRIM ONLY caution messages also appeared intermittently on his PFD. These normally signify degradation of the flight control system operation, but this had not occurred. The CHECK ATT message appeared intermittently on the co-pilot's PFD (PFD 2) only.

The commander informed ATC of their situation and declared a MAYDAY. As there was fog at his intended destination of Liverpool, he requested a direct routing to Stansted, given its more favourable weather and long runway. The controller advised that Runway 23 was in use at Stansted and the commander programmed the Flight Management System (FMS) accordingly. When handed over to another controller, the crew were advised that Runway 05 was active. This further added to the crew's workload as the commander then had to reprogram the FMS for the different approach.

The ECAM continued to produce various cautions and associated aural tones throughout the rest of the flight, too frequently to be read, acted upon, or cancelled. The commander briefed the senior cabin crew member and informed the passengers of the intention to divert, a task complicated by the frequent sounding of aural tones. The pilots noted several other anomalies, including loss of the gross weight, outside air temperature and clock displays.

The crew were given radar headings to intercept the ILS for Runway 05 at Stansted, and the co-pilot armed the autopilot approach mode and engaged the second autopilot. The commander, who was looking out, assessed that they would overshoot the runway extended centreline and took control, manually flying the aircraft visually for the remainder of the approach. On selecting the landing gear down, one of the ECAM landing gear indications showed unsafe, even though the independent green 'gear down and locked' indicator lights were all illuminated. At approximately 700 ft agl, the No 1 engine N_1 indication turned amber and indicated slow rotation. The landing, which was attended by the Aerodrome Fire and Rescue Service, was uneventful.

The commander commented that the aircraft flew normally under manual control. The crew stated that there was no guidance in any of the manuals available on board the aircraft on how to deal with the combination of symptoms experienced during the flight.

Once parked on stand, the flight crew photographed the ECAM, which displayed the following messages:

CANCELLED CAUTION

ENG 1 N2 OVER LIMIT
ENG 2 N2 OVER LIMIT
ENG 2 EGT OVER LIMIT
ENG 1 N2 DISCREPANCY
ENG 1 EGT DISCREPANCY
ENG 1 N1 DISCREPANCY

Aircraft information

Electronic Instrument System

The Airbus A319 is equipped with an Electronic Instrument System (EIS) which includes six Display Units (DU): the Captain's and Co-pilot's PFD and ND, the Engine/Warning Display (EWD) and the Systems Display (SD).

The PFDs supply the flight crew with the short-term information required to fly the aircraft, including attitude, airspeed, vertical speed and altitude. They also display flight path trajectory deviation and autopilot/autothrottle mode selection information. The NDs present navigation and weather radar information. Loss of valid parameter data to a DU is indicated by a red cross appearing in the area of the screen where the parameter is normally displayed.

The EIS also incorporates three identical Display Management Computers (DMC). During normal operations the captain's PFD and ND, the EWD and SD are supplied by DMC 1 and the co-pilot's displays by DMC 2. DMC 3 is available as a standby and can be selected to replace DMC 1 or 2 via the EIS DMC rotary switch on the Switching Panel.

ECAM system

The ECAM system incorporates the EWD and SD. The EWD presents engine primary and fuel quantity indications, flight control information and warning and/or caution messages. The SD presents aircraft status messages and system synoptic diagrams. In the event of an aircraft system fault, warning or caution messages will appear on the lower left of the EWD screen, together with a list of abnormal or emergency actions to be performed by the crew. Some warnings and cautions (eg engine messages) have a higher priority than other messages and these will therefore appear at the top of the ECAM actions list.

Display Management Computers

The DMCs operate both as data concentrators for the DUs and graphics generators for some aircraft parameters. The DMCs also generate the engine exceedence thresholds and transmit them to the Flight Warning Computers (FWC). The DMCs receive data from aircraft systems via multiple input buses. Each DMC has a single output data bus which is used to transmit the engine exceedence thresholds to the FWC and data to a number of other aircraft systems including the FDR. Each DMC also has dedicated ARINC 629 connections with other DMCs for data exchange.

The DMCs contain electronic circuit boards which perform various functions. Two of these include major components which are designated as 'PUMA 0' and 'PUMA 1'. The PUMA 0 is responsible for handling some of the input data to the DMC and for sending all data to the single output data bus. It is connected to, amongst other components, a Central Processor Unit (CPU) for data processing and Static Random Access Memory (SRAM) for data storage. Engine parameter data is processed in parallel by both the PUMA 0 and PUMA 1 such that in the event of a fault in either component, engine parameters will continue to be displayed on the ECAM.

If a DMC ceases to provide any data to a DU, the complete DU image is replaced by the message INVALID DATA.

Flight Warning Computers

There are two identical FWCs, which operate simultaneously. They generate visual and aural alerts, and the alphanumeric codes corresponding to the text

messages that are displayed on the Warning and Status parts of the ECAM DUs. These are sent to the DMC for display.

Engine parameter data displayed on the ECAM via the DMCs is compared with data from the Engine Control Units (ECUs). The FWCs compare these data and if there is a mismatch, will generate an ECAM discrepancy caution message for the affected engine parameter(s). The FWCs will also generate an ECAM caution message if a discrepancy is detected between the roll or pitch angle outputs from the captain's and co-pilot's DMCs.

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Recorded Information

The aircraft was fitted with a solid-state, two-hour, four-channel Cockpit Voice Recorder (CVR) and a solid-state Flight Data Recorder (FDR).

The relevant FDR data started with G-EZIU just north of the Isle of Wight, heading north, cruising at FL380, at an indicated airspeed of 246 kt. The autopilot and autothrottle were engaged and the engines were operating normally. At 11:46:43 hrs, the CVR recorded the sound of a Master Caution single chime tone[1]. At around the same time, a number of FDR parameters exhibited unusual behaviour (Figure 1).

After the first Master Caution tone, three more were recorded over the next 11 seconds. A further three were recorded before the commander stated "THRUST LEVER TO IDLE OK". Master Caution tones continued to be generated at the rate of one approximately every four seconds. The data shows the No 2 engine thrust lever was retarded around 28 seconds after the first Master Caution. The autothrottle responded by increasing the No 1 engine N_1 from 82% to 88%. The data showed that, 26 seconds after being retarded, the No 2 engine thrust lever began to advance over a period of 38 seconds, after which it was in the same position as that of the No 1 engine.

During the first three minutes after the first ECAM caution, a total of 61 Master Caution chimes were recorded on the CVR. During the taxi after landing, the rate of Master Caution triggering reduced to roughly one every six to ten seconds. In the 33 minutes between the first and last audible Master Caution, around 460 Master Cautions were recorded by the CVR.

No indication of any DMC fault was recorded by the FDR during the entire flight.

Aircraft examination

A review of the aircraft maintenance troubleshooting data following the incident confirmed that numerous ECAM caution messages had been generated during the flight, many of which were recurrent. The 'Post Flight Report', which records the 40 most recent faults, included the following DISCREPANCY messages: ENG 2 N1, ENG 2 N2, ENG 2 EGT, NAV ATT, ENG 1 FF and ENG 2 FF.

The operator's engine trend monitoring data did not highlight any evidence of a developing problem on either engine. The engine parameters for the incident flight were downloaded from the engine ECUs; these showed that no engine faults had been recorded during the incident flight and nor had any engine limits been exceeded. A series of engine ground runs were then performed, during which the EIS DMC switch was selected to all positions to check for correct DMC switching. Both engines performed normally and no ECAM messages were generated.

Footnote

[1] The Master Caution alert is not recorded on the FDR. The CVR and FDR have been time-aligned to allow the trigger points for Master Caution to be ascertained.

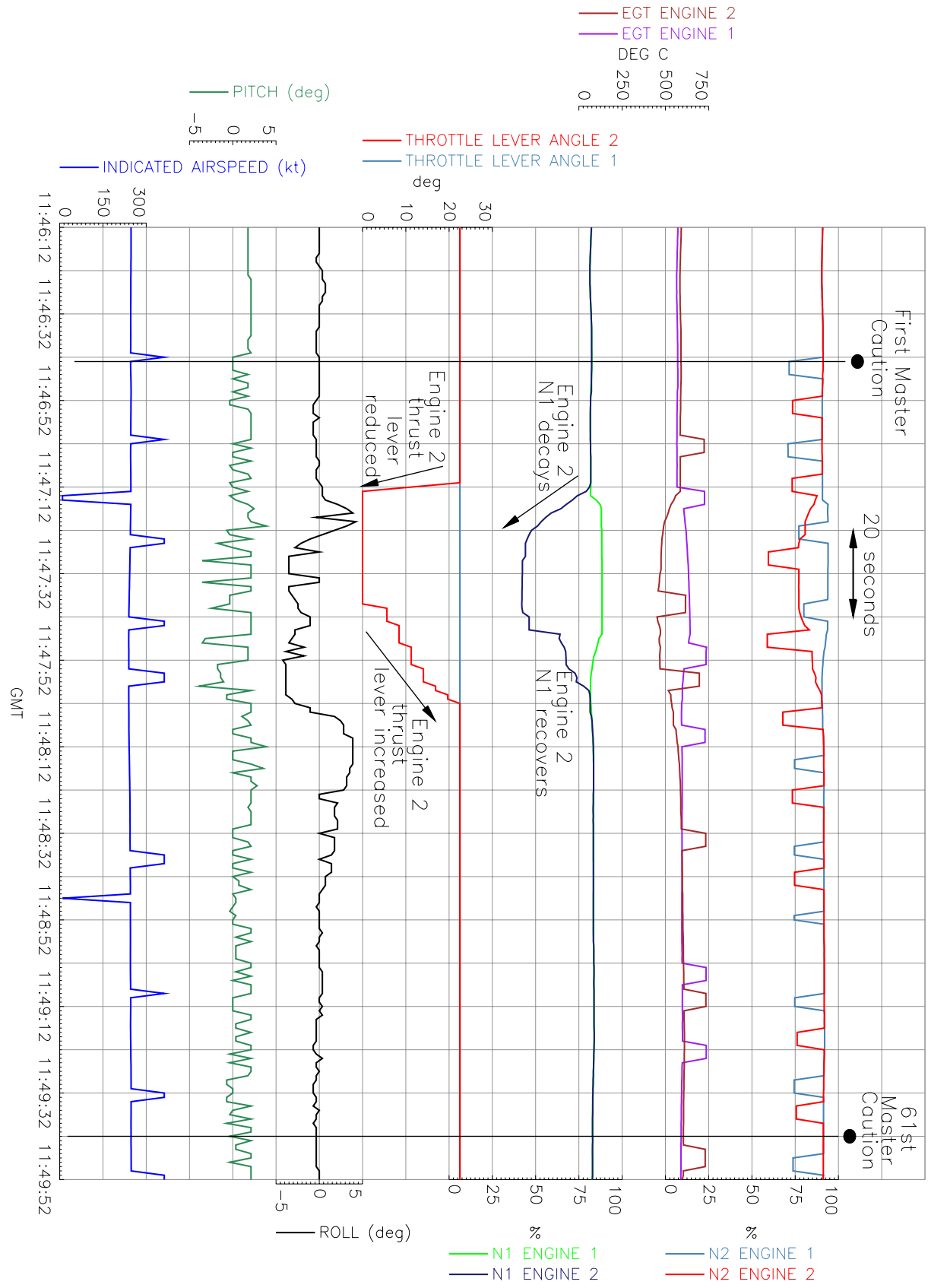

Figure 1

G-EZIU Relevant FDR Parameters

DMC 1 testing

The DMC 1 was removed from the aircraft and returned to the manufacturer for further investigation, where the contents of its BITE memory were downloaded. This revealed that during this and a previous incident in September 2006, data on the input data buses to DMC 1 had been declared invalid by the DMC. No faults were identified on the DMC 1 output databus.

The reason why DMC 1 had declared the input data as invalid was not evident. The manufacturer undertook extensive testing of the DMC, specifically on the input/output data handling of the PUMA 0 circuit board and on the SRAM. Whilst they were unable to establish the cause of the loss of the input data buses, they concluded that a corruption in the 'PUMA 0' SRAM was the most likely cause of the symptoms experienced by the flight crew.

Background information

The aircraft manufacturer stated that no other occurrences of this problem have been reported since the introduction of this EIS standard on A320-family aircraft. At February 2008, it was estimated that the total operating hours of this DMC type on A320-family aircraft was in excess of 5 million flight hours. The same hardware standard of DMC is also installed on A340-500/600 aircraft and some A340-200/-300 and A330 aircraft, which significantly increases this number.

Previous occurrence

G-EZIU experienced a similar event on 29 September 2006, during which the flight crew reported that the ENG 2 N1 DISCREPANCY ECAM message repeatedly appeared and disappeared. Similar discrepancy messages for Engine No 1, Fuel on Board and Fuel Flow were also generated. The ECAM messages ceased when the crew selected DMC 3 to supply the captain's instruments by setting the EIS DMC switch to CAPT 3. The reported symptoms could not be reproduced during subsequent troubleshooting and the aircraft was returned to service.

Information provided to pilots

The operator used a 'less paper cockpit' philosophy in which printed operating manuals were replaced by electronic documents accessible on laptop computers. The Quick Reference Handbook (QRH) was the only printed document containing operational procedures available in the cockpit.

The Airbus philosophy relies on the ECAM system to indicate to pilots the actions to be taken in most normal, abnormal and emergency situations. Pilots are required to commit only a small number of checklists to memory; EIS DMC switching is not one of them.

Analysis

Reported symptoms

Despite extensive on and off-aircraft testing, no hard faults were found that could account for the symptoms experienced during the incident flight.

The DMC 1 BITE data showed that, during this and the previous incident, data received by the PUMA 0 was judged to be invalid. The information on the captain's displays that used the PUMA 0 interface would have become unavailable; this was indicated by the crew report that the captain's PFD and ND indications were similar to those that appear during inertial reference system alignment. The engine parameters are processed by both the PUMA 0 and PUMA 1 in parallel within the DMC, so the engine parameter information on ECAM remained unaffected during this incident as the

data was provided by the PUMA 1. Other anomalies noted by the flight crew could also be explained by the invalid input data and corrupted output data from the PUMA 0.

The invalid data transmitted by PUMA 0 could also have caused the FWC to detect a discrepancy between the engine parameter values from the engine ECUs and DMC 1. This would have caused an ECAM discrepancy caution to be generated for the affected engine parameter(s). The fact that the ECAM engine caution messages repeatedly appeared and disappeared suggested that the fault condition on the PUMA 0 circuit board was intermittent. The FWC also generated a NAV ATT DISCREPANCY amber alert as a result of the discrepancy in roll or pitch values between the captain's and co-pilot's DMCs. This also resulted in the intermittent display of the CHECK ATT message on the co-pilot's PFD.

Data from the engine ECUs indicated that neither engine had exceeded any limits. It is probable that the data corruption within DMC 1 resulted in the exceedence thresholds being incorrectly set too low, so that when these were transmitted to the FWCs, exceedence cautions were generated.

All this is consistent with the manufacturer's supposition that a SRAM problem on the PUMA 0 circuit board in DMC 1 was the most likely cause of the incident.

Crew response

The ECAM caution messages initially presented to the pilots related to engine parameter discrepancies and exceedences. The ECAM action items would have therefore directed their attention towards the behaviour of the engines rather than the performance of the displays.

Given the nature of the fault, it was impossible for the pilots either to complete these ECAM procedures or cancel the messages, so the ECAM system could not assist them to address the loss of information on PFD 1 and ND 1. The only source of information readily available in the cockpit for this purpose, other than the ECAM, was the QRH, but this did not contain an obvious procedure for addressing this particular situation. This combination of factors probably persuaded the pilots not to attempt further remedial action, but to land the aircraft as soon as possible.

In the previous incident on 29 September 2006, the flight crew concluded, in less confusing circumstances, that the ECAM engine discrepancy messages were spurious and switched the captain's instruments to DMC 3, after which the messages ceased. In this more complex incident, the combination of symptoms observed by the crew did not obviously point towards a DMC fault and there was no readily available procedure nor any memory drill for dealing with such a situation. The crew did not try to recover the displays via DMC switching because it was not evident to them that a DMC fault had occurred.

The following Safety Recommendation is therefore made:

Safety Recommendation 2009-058

It is recommended that Airbus either amend the Quick Reference Handbook of Airbus aircraft with switchable EIS DMC selections, or introduce a memory drill, to emphasise that EIS DMC switching may be an appropriate response to abnormal display unit operation, even if no 'INVALID DATA' message is displayed.

Conclusion

Despite extensive testing, the equipment manufacturer was unable to reproduce a hard fault that could account

for the PUMA 0 input data being declared invalid and output data being corrupted. Nevertheless, the symptoms reported by the flight crew and recorded data are consistent with the manufacturer's supposition that the incident was caused by corruption of SRAM that affected the PUMA 0 in DMC 1.

On this occasion the circumstances were such that the crew were unable to diagnose that the symptoms were display-related and they therefore did not select the EIS DMC switch to 'CAPT 3'. It was subsequently determined, as a result of this investigation, that this would have resolved the problem.