Airbus A320-232, G-EUUI

AAIB Bulletin No: 11/2004	Ref: EW/C2003/11/04	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Airbus A320-232, G-EUUI	
No & Type of Engines:	2 International Aero Engines (IAE) V2527-A5 turbofan engines	
Year of Manufacture:	2002	
Date & Time (UTC):	29 November 2003 at 1955 hrs	
Location:	Overhead Birmingham	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 7	Passengers - 92
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	39 years	
Commander's Flying Experience:	11,350 hours (of which 930 were on type)	
	Last 90 days - 166 hours	
	Last 28 days - 50 hours	
Information Source:	AAIB Field Investigation	

Synopsis

On a relatively clear evening, upon reaching the cruise level of Flight Level (FL) 280, the crew and passengers on a scheduled flight from London Heathrow to Edinburgh experienced momentary noise and vibration throughout the aircraft. This was repeated approximately one minute later. It was also reported that an orange flash, associated with the right engine, had been seen. The flight crew identified that No 2 engine had surged and recovered, with the engine indications returning to normal. The aircraft's Quick Reference Handbook, coupled with the training that the flight crew had received, provided them with inadequate guidance with which to fully assess the situation. Their initial intention to continue to Edinburgh was changed upon advice from the operator and the crew initiated a return to Heathrow. The engine then began to surge again and, once more, recovered, but this was followed by another series of surges. At this point the crew believed that the No 1 engine had also surged so they declared a MAYDAY and diverted, uneventfully, to Birmingham Airport. Subsequently, it was determined that a progressive fault in the No 2 engine P_2T_2 probe had signalled inaccurate values to the No 2 engine computer, resulting in incorrect scheduling of the compressor inlet guide vanes, and this was a direct cause of the engine surges. Four safety recommendations are made as a result of this investigation.

History of the Flight

The aircraft was en route from London Heathrow to Edinburgh on a scheduled passenger service. As it reached its cruising level at FL280, the crew and passengers heard two loud bangs and felt a shudder throughout the aircraft. The commander likened the noise to a combined "b-boom" and the cabin crew compared the shudder to driving over a 'sleeping policeman'. The flight crew initially thought that the aircraft had experienced some wake turbulence but the commander also considered that one of the engines might have 'surged' and he reported noticing the right (No 2) engine gauges rising to match those of the left (No 1) engine. He communicated his thoughts to the co-pilot who was the handling pilot for the sector. Shortly afterwards, about 40 to 60 seconds later, there was a repeat of the noise and shuddering and the commander drew the co-pilot's attention to the right engine EPR, N1 and EGT gauges, which had reduced and were recovering to the levels displayed on the left engine gauges. The two pilots agreed that the right engine had surged.

The flight crew selected the Electronic Centralised Aircraft Monitor (ECAM) page, which contained the other engine parameters, and compared the readings for the two engines. The only significant difference appeared to be that the right engine EGT reading was about 35-40°C hotter than that of the left engine. At this point the Aircraft Integrated Data System (AIDS) printed out an Engine Divergence Report, which was not entirely unusual, and the two pilots studied it but were unable to discern any useful information. They also referred to the Quick Reference Handbook (QRH) engine stall procedure, entitled ENG 1(2) STALL, but took no action as the procedure indicated there would be a 'ENG 1(2) STALL' message on the ECAM on aircraft fitted with IAE engines and no such message was seen. The commander had previously experienced a momentary surge in an engine on another type of aircraft, made by a different manufacturer. On that occasion the crew had taken no action and the fault had not recurred. In view of that knowledge he considered it appropriate not to follow the QRH procedure for this event, since the engine appeared to have recovered. The commander recalled that the other manufacturer referred to the phenomenon as an engine 'surge', whereas this manufacturer referred to it as an engine 'stall'.

The commander stated that he was about to contact the cabin crew when the Cabin Services Director (CSD) called the flight deck to report the noise and vibration that had been noticed in the cabin. The commander explained that the problem had been diagnosed as an engine surge, which had cleared, and that the instruments had returned to normal. He confirmed that the intention was to continue on to Edinburgh. Notwithstanding that, the commander instructed the CSD to make discrete enquiries in the cabin to ascertain if any of the cabin crew or passengers had seen or heard anything. The commander then contacted the company's engineers at London Heathrow Airport to discuss the events.

The commander was advised by his company that the aircraft should return to Heathrow, where there was better engineering cover than at Edinburgh. The co-pilot made the necessary calls to ATC to reverse course, pointing out that the aircraft was not declaring an emergency, and the commander briefed the crew on the new intentions. Following his enquiries, the CSD informed the commander that a passenger, who was sat at the rear of the cabin on the right hand side, had seen an orange flash in the vicinity of the right engine at the time of the noise and vibration.

Having completed the turn back towards Heathrow, the crew experienced another surge on the right engine. This again cleared. However, five to ten minutes later, when the aircraft was just to the north of Birmingham, there was a series of surges on the right engine and an IGNITION message appeared on the ECAM, indicating that continuous ignition had been activated on one or both of the engines. The flight crew selected manual ignition to back up the automatic system and it was the commander's recollection that they also selected the engine anti-icing on for both engines with a view to increasing the engine 'surge margin'. This latter selection was prompted by a discussion that the crew had had earlier, during their review of the QRH, on the actions they would take in the event that the situation deteriorated. The switching on of the engine anti-ice systems would also have triggered continuous ignition, if it had not already been activated.

The commander stated that he was considering reducing the thrust on the right engine, during a short break in the engine surges, when there was another series of surges on that engine and he and the co-pilot believed that they also saw indications of a surge on the left engine. Both pilots were convinced and agreed that they were now experiencing surges in both engines, the cause of which they did not know, and they elected to divert to Birmingham airport, which was directly below the aircraft. The commander made a MAYDAY call and briefed the CSD and purser on the procedures for the diversion to Birmingham. The decision was made to brief the passengers for an emergency landing but the commander made an announcement to reassure them that this was only being done as a precaution since the crew were not anticipating any major problem during the remainder of the flight. That said, the commander was keen to land at Birmingham without delay. Consequently, his priority became the completion of the preparations for landing rather than any QRH drill for an unknown problem on both engines.

The co-pilot recalled that it was during the descent that the flight crew selected both engine anti-ice systems on, to give a higher idle N1 and increase the surge margin. Later in the descent, as the aircraft was passing about FL150, the flight crew disengaged the autothrust, which had remained engaged throughout, and advanced both thrust levers to give 50-60% N1 on each engine to check their response to a change in thrust. All indications were normal and autothrust was re-engaged. The remainder of the descent and approach were completed without further incident and the aircraft landed on Runway 15 at Birmingham. The aircraft, accompanied by the Airport Fire Service (AFS), was taxied on to a stand where it was shut down and the passengers disembarked.

The commander stated that the weather during the flight had been good, with only a scattering of cloud during the departure from Heathrow.

Procedures

The aircraft manufacturer had produced separate engine stall abnormal procedures for A320 aircraft in the Flight Crew Operating Manual (FCOM), depending on whether they were fitted with IAE engines or CFM engines, and had distilled these abnormal procedures into separate QRH checklists. The operator had reproduced these abnormal procedures in their Operations Manual (OM) as separate drills and had combined the manufacturer's two QRH checklists into one checklist in the QRH carried in their aircraft.

Sections of the aircraft manufacturer's ENG 1(2) STALL abnormal procedure, for aircraft fitted with IAE engines, are omitted in their equivalent QRH checklist. These include the guidance material at the beginning of the abnormal procedure. This states:

> *A stall may be indicated by varying degrees of abnormal engine noises, accompanied by flame from the engine exhaust (and possibly from the engine inlet in [a] severe case), fluctuating performance parameters, sluggish or no throttle response, high EGT and/or a rapid EGT rise when thrust lever is advanced.*

This preamble illustrates that an engine surge can cause a wide variety of symptoms and, as such, represents valuable advice to flight crews.

Later in the procedure, after an instruction to check that the engine parameters on the affected engine are normal with the thrust lever at idle, the drill continues as follows:

> *ENG A. ICE (affected engine)...ON*
>
> *WING A. ICE ....ON*
>
> *Operation of engine and wing anti ice will increase the stall margin, but EGT will increase accordingly.*
>
> *THR LEVER (affected engine)..SLOWLY ADVANCE •*
>
> **If stall recurs :**

THR LEVER (affected engine)..REDUCE

Reduce thrust and operate below the stall threshold.

The above two advisory sentences, after the action to switch the WING A-ICE to ON and the instruction to REDUCE the THR LEVER, respectively, are, again, absent in the manufacturer's QRH procedure.

The manufacturer's FCOM procedure also states that, in flight:

Only ENG1(2) STALL is displayed on ECAM

This information is reproduced in the QRH procedure.

After this incident, the operator drafted a revised ENG 1(2) STALL abnormal and emergency procedure for the QRH, which included the initial preamble at the beginning of the manufacturer's full FCOM procedure. However, not all the explanatory material contained in the manufacturer's procedure was added in this revision, which had yet to be issued at the time of writing.

The operator stated that the volume of the Operations Manual which contains the full ENG 1(2) STALL procedure is available to crews in flight. However, the workload during an abnormal event could be such that crews would normally only be expected to refer to the ECAM and QRH and not resort to another publication, unless previously trained to do so.

Crew Training

Before this incident, the Operator had limited the engine stall training given to flight crew operating the A320 to an exercise in the simulator during conversion training. During that exercise the affected engine continued to stall until the QRH drill was completed. There was no recurrent training for this abnormal event.

Since this incident, crews have been receiving recurrent training on engine stall procedures in the A320 simulator and are shown a video, produced by an engine manufacturer, which explains the range of malfunctions that modern turbofan engines can experience. Included in these malfunctions are compressor stalls/engine surges and an illustration is given of a 'compressor stall/engine surge' abnormal procedure for a generic engine. The title of this procedure addresses the confusion between engine 'stalls' and 'surges', in that it identifies the compressor as the section which 'stalls' resulting in the engine 'surging'. The video also highlights the wide variety of symptoms associated with engine surges, the fact that sometimes engines recover without flight crew intervention and that at other times flight crew action is required. This video had previously been seen by flight crew on the operator's Boeing fleet.

Engine Description and Operation

The V2500 turbofan engine is a two spool, axial flow, high bypass ratio turbofan engine. It has a single stage fan, a four stage Low Pressure (LP) compressor (booster) and a ten stage High Pressure (HP) compressor. The LP compressor is driven by a five stage LP turbine and the HP compressor is driven by a two stage HP turbine. It is equipped with a Full Authority Digital Engine Control (FADEC), which provides engine control and monitoring via a dual channel Electronic Engine Control (EEC) unit, and this takes data inputs from dedicated engine sensors to monitor and control the engine. The FADEC manages power according to two thrust modes; manual mode, where thrust is computed depending on Thrust Lever Angle (TLA), and autothrust mode, where an Engine Pressure Ratio (EPR) target is computed by the Flight Management and Guidance Computer (FMCG). The EEC compares this EPR target with the actual EPR and, together with other engine sensor data, calculates an error signal. The signal is then used to adjust the fuel flow and compressor airflow in order to achieve the required EPR.

Engine inlet pressure (P_2) and total air temperature (T_2) is measured by a 'P_2T_2' probe located immediately ahead of the fan and on the upper inside surface of the engine inlet cowl, Figure 1.

Figure 1

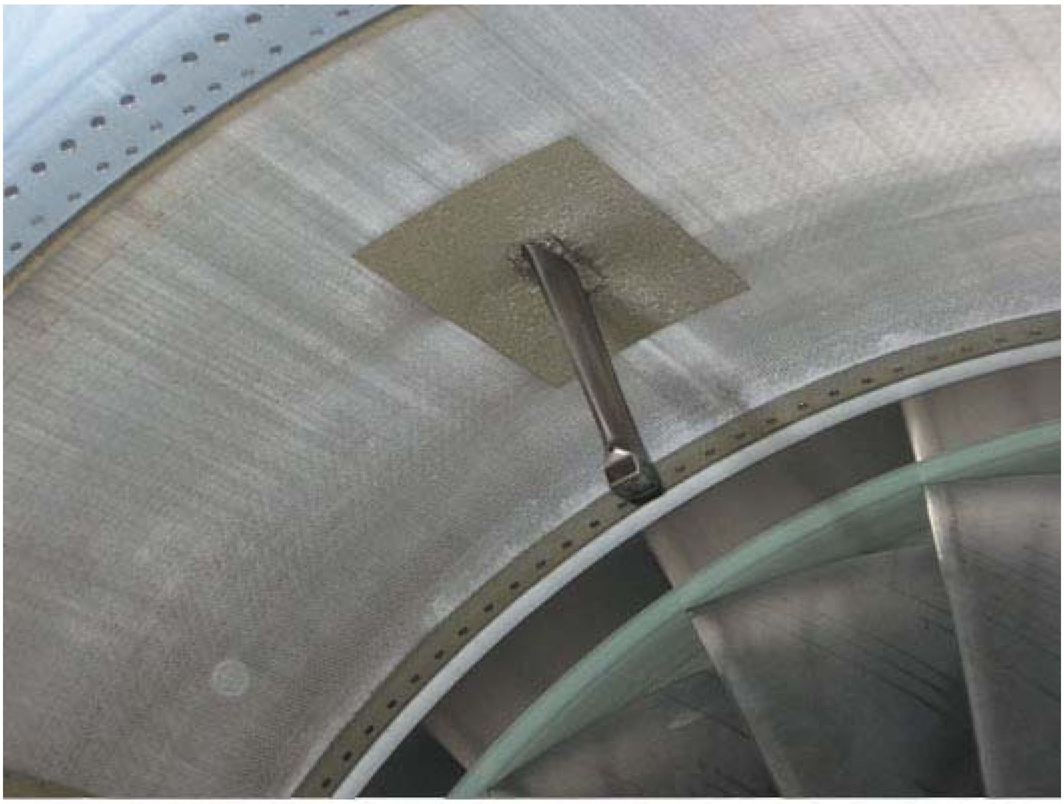

Figure 1

It has two independent electrical resistance elements which sense temperature. The EEC also takes aircraft information from both the left and the right Air Data Inertial Reference Unit (ADIRU), of which there are three fitted to the aircraft, and these units take data from two airframe mounted Total Air Temperature (TAT) sensors. Under normal operating conditions, if all temperature sources are valid, the engine is controlled using TAT values from the left ADIRU as the data source for ambient temperature. Should there be a difference (beyond a given range) between this TAT and that sensed by engine's P_2T_2 probe, then the TAT signal is rejected and individual engine T_2 data is used. If the engine's P_2T_2 probe signal is not valid (ie loss of signal or out of range), then the EEC uses the left ADIRU TAT and automatically reverts to controlling N1 rather than EPR. N1 Mode is annunciated to the crew by a Master Caution caption and an aural warning (single chime). However, should the left ADIRU TAT not be valid, but the right ADIRU and engine's P_2T_2 probe are in agreement, then the EEC will use the right ADIRU value.

Engine Surge Protection

An engine surge, also called an engine stall, is associated with an unstable airflow within the compressor and this may cause loud 'pops', 'bangs' and engine vibration. In most cases the condition is of short duration and will either correct itself or can be corrected by reducing power. Engine compressor airflow control is achieved by a booster stage bleed valve (BV), a variable stator vane (VSV) system, three valves bleeding HP compressor stage 7 air (identified as 7A, 7B and 7C), and one valve bleeding stage 10 air. The EEC controls the VSV angles in the front of the HP compressor to prevent the choking of the downstream HP compressor stages as engine operating conditions vary. All BVs are commanded open as part of the surge recovery logic. The BVs are pressurised to the closed position using 'muscle air' bled from the HP compressor and are each controlled by a dedicated solenoid valve. These valves divert the pressurised air supply from the BV when commanded to the open position. Should a bleed valve stick open, then excess air will bleed from the HP compressor, resulting in a higher EGT for a given engine speed due to the increased fuel flow required to compensate for the loss of compressor efficiency.

Engine Surge Identification

The EEC software standard installed on G-EUUI was SCN-16, on both engines; this enables engine surge annunciation on the ECAM in the event that a surge causes engine parameters to exceed specified limits for longer than two seconds. This usually indicates a failure within the engine and that the surge is irrecoverable. Later revisions to the software are designed to give an ECAM warning whenever any surge is detected. This upgrade also assists in troubleshooting faults and maintenance, since it indicates not only that a surge has occurred, which may or may not be detected by the flight deck crew, but also in which engine.

Engine Examination

The standard troubleshooting procedure for an engine surge was carried out on the No 2 engine; the magnetic chip detectors were removed and inspected and no significant debris was noted. The fuel filter was removed and found to be clean. The VSV system was tested for freedom of movement and for any damage, including bent or disconnected levers; no defect was found. The cabin bleed air Non-Return Valve (NRV) was removed and checked for free operation; no binding or evidence of sticking was found. The HP compressor was subjected to a borescope examination; all visible stages were inspected and nothing unusual was found.

The standard troubleshooting procedure was also carried out on the No 1 engine with no faults being found.

All BVs and solenoids on both engines were tested using a portable test set, which allows each bleed valve to be pressurised using a hand pump and the solenoid valve to be electrically energised, and all were found to be operating correctly. However, anomalies were noted on the solenoid valves on No 2 Engine. During the course of testing the stage 7A BV solenoid, there was doubt as to whether this valve emitted a sound of exhausting air. The test was repeated and exhausting air was heard; however, this unit was removed for further investigation. The stage 10 solenoid valve pressure hold test failed, suggesting there may have been some contamination within the valve preventing proper sealing; this solenoid valve was also removed for further examination.

The removed solenoid bleed valves were subsequently taken to the manufacturer and subjected to a production acceptance test (PAT). The results for both valves were satisfactory, indicating that the performance of the units met the requirements for operation. However, when the units were stripped, some internal corrosion was found, although this apparently had not affected the correct functioning of the units as shown by the PAT. The component manufacturer stated that such corrosion had not been seen previously in this type of solenoid valve.

The EEC Built-in Test Equipment (BITE) check was performed on both engines. The No 1 Engine EEC passed the check without errors but the No 2 engine produced errors relating to the T_2 indication.

Centralised Fault Display System

Most of the aircraft electronic systems interface with the Centralised Fault Display System (CFDS), the main component of which is the Centralised Fault Data Interface Unit (CFDIU). Faults are classified according to priority; Class 1 messages requiring immediate action by the crew are displayed on the Electronic Centralised Aircraft Monitor (ECAM). Class 2 messages, possibly requiring deferrable maintenance action, are displayed on the ECAM as status messages. These Class 1 and 2 messages are stored in the CFDIU and can be accessed via the Multipurpose Control Display Units (MCDU) on the flight deck pedestal. They are presented in the form of Post Flight or Last Leg

Reports. Further messages categorised as Scheduled Maintenance Reports (SMRs) and Class 3 messages (no impact on safety) are stored within the CFDIU and can be accessed by maintenance personnel. SMR faults are required to be addressed as part of the next scheduled maintenance, ie within the next 500 hours, whilst Class 3 messages relate to 'unlimited despatch' faults.

No relevant faults were recorded in the CFDIU Post Flight Report for either engine. However, further interrogation of the EEC on No 2 engine revealed two Class 3 messages, as follows:

LEG	**DATE**	**UTC**	**ATA**	**CELL**
-00	Nov 29	1949	753242	63
VSV MECH/BLD VLV/LPC2				
-05	Nov 29	0841	753242	62
VSV MECH/BLD VLV/LPC2				

These messages indicated that a surge had occurred on the incident sector (LEG -00) at 1949 hrs and that a similar surge also occurred five legs previously (LEG -05). No surge messages were recorded for the No 1 engine. The surge message was latched as a Class 3 message at the first time it was detected, but the system is such that further surges experienced on the incident flight would not have been recorded as additional messages.

A SMR message was also logged on the incident flight, at 1938 hrs. The P_2T_2/ADIRS1/2/EEC2 message resulted from a T_2 Sensor Soft Fault (T_2SSF) recorded in the CFDIU, and was recorded together with a 'snapshot' of information taken at the time the fault was detected. A T_2SSF fault record is set when both T_2 channels differ from the TAT output from the left ADIRU by more than 8ºC for more than 10 seconds. This message is overwritten each time the fault is detected.

A basic EEC check, via the Data Management Unit (DMU), revealed that both the No 1 engine P_2T_2 probe and aircraft TAT were in agreement to within 1°C but that the No 2 engine probe indicated a value 38°C lower.

Flight Recorders

The two hour duration Cockpit Voice Recorder (CVR) was replayed by the AAIB. However, the recording of the incident flight had been overwritten and contained no useful information. The Quick Access Recorder (QAR) data was downloaded by the operator and this confirmed that surges on No 2 Engine on the incident flight had occurred. It also showed that an almost identical surge occurred on the No 2 engine five flights previously and that no surges had occurred on the No 1 engine.

At 19:49:24 hrs, as the EPR command reduced on both engines when the aircraft was levelling at FL280, there was a surge on the No 2 engine. This was indicated by a divergence of the actual EPR from the commanded EPR, accompanied by a dip in the fuel flow. This was followed by two further surges at 19:49:31 and 19:52:10 hrs, indicating that the engine had not fully stabilised following the previous occurrence. The fuel flow data showed a reduction at these times indicating that the EEC surge recovery logic control was operating to allow the engine to recover. The surge events were all coincident with autothrust commands to reduce engine power. The EGT data showed that, subsequent to these surges, a difference of 35-40°C existed between the values for the No 1 and No 2 engines. Further analysis of the data by the engine manufacturer revealed that the VSV angle was approximately 7° more open on the No 2 engine than the No 1 engine, as a result of the difference in T_2 sensed by each engine. The position of the VSVs demanded by the EEC depend on the T_2 temperature measurement and the effect of a considerably lower T_2 was to schedule the vanes more open than necessary, thus increasing the air mass flow to the HP compressor.

During the cruise at 20:10:45 hrs, when the autothrust signalled a small reduction in engine power, the EPR command reduced on both engines. The No 2 engine surged and this was followed by a secondary surge at 20:10:55 hrs as the power was reduced further. The EPR value decayed to around 0.93 whilst the No 1 engine EPR remained at the commanded value of 0.96. There was a further surge on No 2 engine at 20:11:25 hrs followed by a secondary surge at 20:11:37 hrs, again associated with small power changes.

When the autothrust reduced engine power to commence the descent into Birmingham, at 20:12:08 hrs, the No 2 engine surged again followed by a secondary surge at 20:12:16 hrs. A higher EGT was noted on the No 2 engine compared to the No 1 engine during the descent.

Aircraft History

Both engines had been fitted to this aircraft since new and both had completed 1,620 hours and 959 cycles.

Analysis by the operator of previous takeoff and cruise reports from AIDS indicated that, around 7 November 2003, the No 2 engine T_2 value had started to diverge from the No 1 engine and the aircraft TAT probe readings. Based on the stored data, it is expected that the T_2SSF fault would first have been detected around 20 November 2003. However, the SMR messages on which T_2SSF faults are recorded were only checked by the operator every 500 hours.

P_2T_2 probe examination

The P_2T_2 probe was removed and examined by its manufacturer. The probe consists of an aerodynamic housing inside which a tube, containing the two independent electrical resistance temperature sensing elements, are located. These two elements (Channels A and B) are contained within inner and outer shields and cracks were found within both elements, Figure 2.

Figure 2

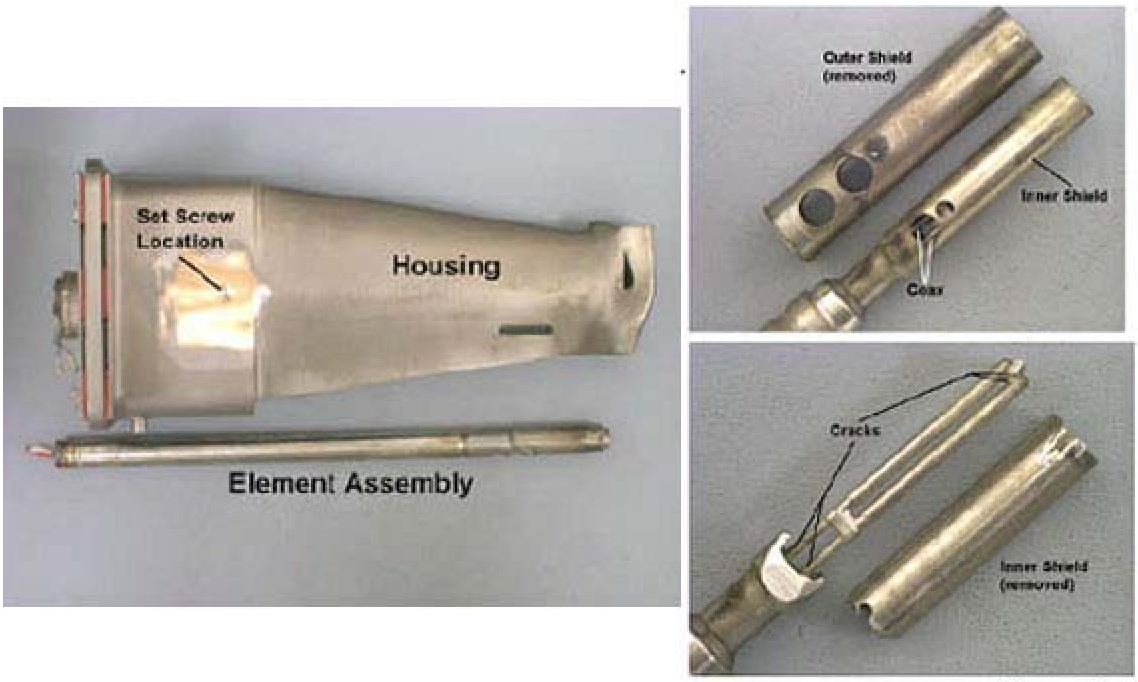

Figure 2

These had allowed moisture to enter the dielectric material within the resistance elements and cause false temperature indications on both channels. The initial testing confirmed that, compared with the test points, a low temperature on Channel A was recorded, but Channel B results were closer to the test point. It was likely that the time between the incident and the probe examination allowed any moisture to dry out, at different rates, and hence be responsible for Channels A and B producing different test results.

Previous history of failures

The design of the P_2T_2 probe has changed from the original during the A320 program. The subject probe is known as a 'long' probe, and was introduced in 1999, since when 1,170 such probes have entered service. According to the probe manufacturer, there have been five previous potential dual element failures and one single element failure of the 'long' probe. One of these events was reported by a different operator in July 2003, when an engine surge was experienced during descent, this being accompanied by an ENG 1 STALL ECAM message. The actions detailed in the trouble shooting manual were carried out and the aircraft returned to service, but without the probe fault being detected. On the next flight further surges were experienced during initial climb and subsequent analysis of the FDR data indicated a fault with the T_2 temperature measurement.

Statistical analysis suggests that this defect slightly reflects an 'infant mortality' problem, based on the relatively low in-service time of the failed probes and the number of serviceable higher time probes in service. The analysis maintains that the dual engine occurrence probability is less than 1xE-9, and suggests that this does not pose an immediate threat to safety. However, as the additional data maintains that the occurrence rate for dual element failure is higher than predicted in the Failure Modes Effects Analysis (FMEA), the manufacturer continues to work to determine the reason for the failures.

Discussion

During the initial short duration surges on the right engine, the flight crew were presented with symptoms for which the QRH and their training gave them inadequate guidance. Had the QRH checklist included all the advice and instructions contained in the aircraft manufacturer's full FCOM abnormal procedure, then the crew may have been prompted to take action at the outset of the surges and complete the ENG 1(2) STALL drill. However, the manufacturer's procedure indicated that on this aircraft type, with IAE engines fitted, there would be an ENG 1(2) STALL message on the ECAM in the event of an engine surge. This was misleading. G-EUUI was operating with the SCN-16 EEC software standard, which was not able to inform the crew that a surge had occurred unless the surge caused engine parameters to exceed specified limits for longer than two seconds (or in which engine). As the preamble at the beginning of the aircraft manufacturer's FCOM abnormal procedure illustrated, an engine surge could be associated with a wide variety of symptoms.

The flight crew's decision not to follow the QRH procedure for a 'stall' on the right engine, up to the point that they decided to divert, was understandable since it accorded with a reasonable interpretation of that QRH drill. When both engines were thought to be surging, which was a mistaken belief because the left engine was in fact operating normally, there was a suspicion that the crew was facing a more complicated problem. With that in mind, they carried out part of the ENG STALL procedure, but not all of it. This was the result of a keen desire to land at Birmingham without delay, not being sure what was wrong with the engines. Had the crew been given all the relevant information, as contained in the manufacturer's FCOM abnormal procedure, in the operator's QRH, plus the knowledge that an engine stall (surge) might not prompt an ECAM message, then they would have had all the advice needed for them to know that it was appropriate to follow the ENG STALL procedure. In doing so the situation would not have developed as it did.

If the latest EEC software standard had been installed, a surge warning would have been displayed on the ECAM after the initial short surge. This would have assisted the flight crew in determining which engine was surging and would have fitted with the manufacturer's ENG 1(2) STALL procedure. All V2500-A5 operators are being encouraged by the manufacturer to adopt the new software standard as soon as possible.

Having experienced the first surges on No 2 engine as the aircraft levelled at FL280, the later power reduction commanded on both engines to an EPR of 0.96, which was accompanied by the noise of No 2 engine surging, may have given the flight deck crew the impression, albeit erroneous, that both engines had in fact surged. It was this belief that led the crew to divert to Birmingham Airport. In the light of that, it was a reasonable and prudent decision to take.

Examination of the engines identified a fault on the No 2 Engine T_2 sensor and analysis of the data confirmed that there had been surges only on this engine. Analysis of the onboard maintenance system identified that the T_2 sensor was reading a significantly lower temperature than that of either the No 1 engine or the aircraft TAT probes, the effect of this being for the VSV system to set an incorrect VSV angle for the engine operating conditions. This led to a reduced surge margin during engine power reduction and hence the surges experienced. Analysis of the EGT data showed that, after the first surges, a difference of 35-40°C existed between the EGT of the two engines which did not exist following the second surges. The most likely explanation for this was a sticking BV or solenoid, as the temperature difference was consistent with a stage 7 BV stuck open. The higher EGT noted on the No 2 engine compared to the No 1 engine during descent into Birmingham was probably attributable to a leaking BV. However, the subsequent examination by the manufacturer confirmed the correct operation of the bleed valves, despite the presence of some internal corrosion within the solenoid unit of the stage 10 BV.

The classification of the T_2SSF message as Class 3, led to the P_2T_2 probe failure not being identified until after this incident had occurred, although the CFDIU had probably received the first failure message some nine days prior to this flight. Although in this case the aircraft landed safely, the continued dispatch of the aircraft with a failure known only to the onboard maintenance system, could have led to a more serious engine surge problem on a subsequent flight. The loss of a primary engine input, such as TAT, would appear to require a higher priority in the CFDS so that a status message in the post flight report is produced.

Safety Recommendations

The EEC logic normally takes the TAT values from the left ADIRU. However should the difference between the aircraft TAT and the equivalent temperature sensed by an engine's T_2 probe exceed a given range, the TAT signal is rejected and individual engine T_2 data is used. This provides an independent temperature signal for each engine should a problem exist with the aircraft's left ADIRU TAT value. However, in this case the logic led the EEC to select an erroneous TAT signal when it had already recorded the T_2SSF fault message relating to this signal, even though two valid sources, from the left and right aircraft ADIRUs, were available. In addition, a soft fault such as the erroneous T_2 signal in this case, was not brought to the attention of the flight or maintenance crews by the monitoring systems on board the aircraft due to the way in which it had been classified. Therefore the following three recommendations are made:

Safety Recommendation 2004-59

It is recommended that Airbus Industrie and IAE review the EEC logic on the V2500 engine fitted to the A320 aircraft, regarding the selection of a temperature source, in the event that the system detects a greater than normally permitted difference between the available sources, so that an erroneous signal is not used for engine control.

Safety Recommendation 2004-60

It is recommended that Airbus Industrie review the logic of the Centralised Fault Data Interface Unit (CFDIU) and the Engine Electronic Control (EEC) on A320 aircraft fitted with the V2500 engine, with respect to the Class 3 classification (a fault having no impact on flight safety) of a T2 Sensor Soft Fault (SSF), so that soft faults, such as an erroneous signal, are brought to the attention of flight and maintenance crews at the earliest opportunity.

Safety Recommendation 2004-61

It is recommended that Airbus Industrie review the ENG 1(2) STALL abnormal procedure for the A320 to reflect the ECAM messages which crews can or cannot expect to see during engine stall events on aircraft fitted with IAE V2500 engines, taking account of the EEC software standard installed.

Had the operator's QRH checklist, which was derived from the QRH provided by the aircraft manufacturer, included all the relevant advice and instructions already contained in the manufacturer's FCOM procedure, then the crew may have been prompted to take action at the onset of the surges and complete the ENG 1(2) STALL drill. The following recommendation is therefore made.

Safety Recommendation 2004-62

It is recommended that Airbus Industrie review the content of the ENG 1(2) STALL checklist, as it appears in their A320 QRH, to ensure that it includes all the advice and information contained in the abnormal procedure for the same event, as laid out in their Flight Crew Operations Manual.