INCIDENT

Aircraft Type and Registration:	Boeing 737-36Q, G-THOJ
No & type of Engines:	2 CFM 56-3C1 turbofan engines
Year of Manufacture:	1997
Date & Time (UTC):	13 August 2006 at 1640 hrs
Location:	In the cruise at FL350 from Cardiff to Malaga
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 145
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	6,053 hours (of which 1,076 were on type) Last 90 days - 188 hours Last 28 days - 82 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent inquiries by the AAIB

Synopsis

On 11 August, the aircraft suffered an in-flight failure of the DC Battery Bus, resulting in the loss of several aircraft systems including the standby ADI. Subsequent examination identified no defects with the aircraft but, during a flight to Malaga on the 13 August, the DC Battery Bus failed again. Despite further investigation, no defects were identified and the aircraft departed on the return flight. Whilst taxiing, the aircraft suffered a third failure and, after returning to the stand, it was confirmed that the R1 relay had failed. A previous AAIB investigation into a similar incident (G-EZYN, AAIB Bulletin 4/2006) resulted in the publication of AAIB Safety Recommendation 2005-65, which is directly relevant to the failure experienced by G-THOJ. Therefore no further safety recommendations are made.

History of the flight

On the 11 August, the aircraft was at FL340 en-route Malaga to Cardiff when the flight crew noticed a yellow '*SPD LIMIT*' caution on both EADIs[1]. On checking the overhead panel, the flight crew found the following captions illuminated; '*SPEED TRIM FAIL*' '*MACH TRIM FAIL*' and '*AUTO SLAT FAIL*'. In addition, the engine N1 and fuel flow indications were lost, the standby ADI, both clocks and the master caution panel (MCP) failed, the DC Battery Bus showed zero voltage and both EADIs had become monochromatic. Although the 'equipment cooling supply' OFF light was not illuminated, the crew recognised the monochromatic EADI displays as indicating a loss of their cooling air

Footnote

[1] Electronic Attitude Direction Indicators.

flow. The cooling fan power supply was switched to 'ALTERNATE', which restored the displays to normal operation. After reviewing the status of the remaining systems, the flight crew confirmed that there had been no degradation to the aircraft's approach and landing capabilities and elected to continue to Cardiff. Due to the aircraft's interphone becoming inoperative, the flight crew briefed the senior cabin crew member directly and further communications were relayed through another member of the cabin crew. As the landing gear was deployed during the approach to Cardiff, all of the aircraft's systems previously lost were restored and the aircraft carried out an uneventful landing. Subsequent inspection and testing of the aircraft's systems, however, failed to identify any defects and the aircraft was returned to service.

On 13 August, the aircraft was at FL350, flying from Cardiff to Malaga when a 'click' was heard from the P6 circuit breaker panel in the cockpit and the DC Battery Bus failed. This produced the same symptoms and loss of systems as in the event of 11 August. The flight crew referred to the QRH[2] but later reported that it was of limited use in isolating the failure and restoring systems. After establishing an HF[3] link with their engineering department, the crew were able to restore some systems and the aircraft continued to its destination without further incident.

Investigation

After landing, a company engineer inspected the R1 relay, the suspected cause of the DC Battery Bus failure, and found it to be apparently serviceable. The engineer completed the Technical Log and the aircraft was dispatched for its return flight. However, whilst taxiing, the aircraft once again suffered a failure of the DC Battery Bus and returned to the stand. A replacement R1 relay was dispatched from the UK and, after installation and appropriate satisfactory system checks, the aircraft was returned to service, with no further problems being reported.

The EADIs are designed to operate without cooling for a minimum of 90 minutes. However, should an overheat condition be detected, the displays will shut down immediately, leaving the flight crew with the Standby Attitude Indicator (SAI) as the sole source of attitude information. In selecting the alternate power supply for the cooling fans, the flight crew restored the cooling airflow, thereby preventing the EADI symbol generators from overheating.

In the event of the loss of the DC Battery Bus, the B737-300/400/500 series does not produce a discrete warning to alert flight crews. Failure of this Bus results in the loss of several aircraft systems, but should not prevent the aircraft from continuing to operate safely. However, in addition to the loss of normal power to the equipment cooling fans, power to the equipment cooling air low-flow sensors is also lost. This prevents the equipment cooling OFF light illuminating, which would normally alert the flight crew to the need of selecting the alternate cooling fan power supply. The loss of cooling air results in a build up of heat within the EADI symbol generators, which then automatically switch to a monochromatic mode to reduce heat generation.

The SAI fitted to G-THOJ was powered by the DC Battery Bus and, when the relay failed, power to the SAI was lost, although there was a delay between the loss of power and the toppling of the SAI gyroscope. Had the flight crew failed to recognise the monochromatic EADI displays as symptomatic of a loss of equipment cooling

Footnote

2 Quick Reference Handbook.
3 High Frequency radio link.

air it was possible that they would have eventually lost all attitude information.

Information from the manufacturer confirmed that there are approximately 1,400 B737-300/400/500 aircraft currently fitted with SAIs powered by the DC Battery Bus.

Defect history

On 20 July 1997, a similar incident occurred to a B737-500, EI-CDT, which was investigated by the Danish Air Accident Investigation Board. Their report made two Safety Recommendations, which resulted in the publication by the manufacturer of Flight Operations Technical Bulletin 737-300/400/500 98-1, concerning 'Battery Bus Failure'. This provided advice for operators on how to construct a non-normal procedure for a R1 relay failure, taking into account the specific electrical configuration of their own aircraft. Also, a manufacturer's Service Letter, No 737-SL-24-120, was issued which identified relays with specific part numbers that were recommended for installation in the 'R1' position, in order to improve reliability of the system. However, the R1 relay that failed on G-THOJ was one of the 'recommended' types. It was not established from the aircraft's maintenance records how long the relay had been fitted to the aircraft.

The relay used in the R1 position is an electro-mechanical device which, despite improvements over the years to increase their reliability, suffer occasional mechanical failure. Such failures may not be straightforward; the restoration of electrical systems following landing gear deployment in the first event and after the flight crew's actions on the subsequent flight, may have been a coincidence, but illustrate the intermittent nature of the defect prior to the complete failure of the R1 relay.

On 22 March 2005, B737-300 G-EZYN suffered a similar failure of the R1 relay and this incident was investigated by the AAIB (Bulletin 4/2006). As a result the manufacturer issued Alert Service Bulletin 737-21A1156 in June 2006. This Service Bulletin provides instructions for a modification to separate the normal power supply to the equipment cooling fans from that for the equipment bay low air flow sensor, for those aircraft with a SAI powered from the DC Battery Bus. After embodiment, the low flow sensors would remain powered after a DC Battery Bus failure. This ensures that the equipment cooling OFF light illuminates, thus giving the flight crew a positive indication of the loss of equipment cooling air flow and, possibly, failure of the DC Battery Bus.

The AAIB investigation into the G-EZYN incident resulted in the following Safety Recommendation:

> ***'Safety Recommendation No 2005-65***
>
> *It is recommended that the Federal Aviation Administration require that the Boeing Airplane Company examine the various electrical configurations of in-service Boeing 737 aircraft with the intention of providing operators with an Operations Manual Procedure that deals with loss of power from the Battery Busbar'*

Conclusions

Following the issue of this safety recommendation, the manufacturer has taken the view that as there are a relatively high number of different electrical system configurations on affected aircraft, it is not practical to develop a procedure to cover all such aircraft. The Flight Operations Technical Bulletin 737-300/400/500 98-1, concerning 'Battery Bus Failure', already provides advice for operators on how to construct a non-normal procedure for a R1 relay failure, taking into account the specific electrical configuration of their own aircraft. This, in conjunction with the release of Alert Service Bulletin 737-21A1156, which ensures that the crew are alerted to a failure of EFIS cooling airflow and the possibility of a DC Battery Bus failure, would appear to address the potential problem of loss of all attitude information following a R1 relay failure. Therefore, no further safety recommendations are made.