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Air Accidents Investigation Branch

Department for Transport

AAIB Bulletin S1/2005
SPECIAL

AAIB Bulletin No: S1/2005	**Ref: EW/C2005/02/03**	**Category: 1.1**

Aircraft Type and Registration:	Airbus A340-642, G-VATL
Manufacturer's Serial Number:	376
No & Type of Engines:	4 Rolls-Royce Trent 556-61 turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	8 February 2005 at 0330 hrs
Location:	En-route from Hong Kong to London Heathrow
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 18 Passengers - 293
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	7,000 hours (of which 3,100 were on type) Last 90 days -120 hours Last 28 days - 85 hours
Information Source:	AAIB Field Investigation

Notification

The event was reported to the AAIB by the operator and to the Dutch Transport Safety Board (DTSB) by the AAIB. Dutch investigators commenced the investigation with the assistance of the operator but the next day the DTSB formally asked the AAIB to assume responsibility for the investigation.

History of the flight

The flight was scheduled to depart Hong Kong at 1535 hrs (2335 local) on 7 February with a scheduled arrival time at London Heathrow of 0450 hrs the next day. There was one relevant entry in the technical log prior to departure, both Fuel Control Monitoring Computers (FCMCs) had been reset at separate times on the previous sector. During the pre-flight preparation period for this flight there was one FCMC 2 and one FCMC 1 failure, the crew were able to carry out successful resets on each occasion.

The aircraft took off from Hong Kong at 1621 hrs. Shortly after takeoff there was an Electronic Centralised Aircraft Monitor (ECAM) alert advisory 'FCMC2 FAULT' displayed. There were no ECAM actions associated with this fault and the commander decided to delay any attempt at a computer reset until the aircraft had reached its cruising level. When the aircraft reached its initial cruise altitude the crew attempted an FCMC2 reset using the computer reset procedure in the Quick Reference Handbook (QRH). The reset attempt was unsuccessful. There were no further fuel system warnings, cautions or messages throughout the remainder of the flight.

The aircraft was cruising at Flight Level (FL) 380 in Dutch airspace when at 0330 hrs No 1 engine lost power. The flight crew secured the engine and the commander decided not to attempt to relight it but to continue towards Heathrow on three engines. The flight crew noticed that the fuel contents for the inner 1 fuel tank, which feeds engine No 1, was reading zero. Suspecting a possible fuel leak, a flight crew member was sent aft to inspect the engine area from the passenger cabin but nothing unusual was seen. However, soon afterwards, the crew observed the No 4 engine power fluctuate and noticed that the inner 4 fuel tank was also indicating zero fuel contents. The commander opened all the fuel crossfeed valves and the No 4 engine recovered. A 'MAYDAY' was declared and a diversion to Amsterdam Schipol Airport was initiated.

When the diversion commenced the total fuel on board was in excess of 25,000 kg but there were significant quantities of fuel located in the trim, centre and outer wing fuel tanks. Manual fuel transfer was started by the flight crew but they did not see immediately the expected indications of fuel transfer on the ECAM. Consequently, the flight crew remained uncertain of the exact fuel status. The diversion to Amsterdam continued and the aircraft landed there without further technical problems.

Flight data recorders

An extract of the relevant recorded flight data is shown at Figure 1. Takeoff occurred at 1621 hrs with a total recorded fuel of 135,450 kg. As the aircraft climbed, normal fuel transfer occurred. At 1928 hrs, at FL 354, transfer from the centre fuel tank stopped; the tank quantity at that time was 5,300 kg. The aircraft continued en route until at 0328 hrs the inner 1 fuel tank quantity indication reached zero; 40 seconds later the No 1 engine started to run down and the engine was subsequently shutdown. At 0340 hrs the inner 4 fuel tank quantity reduced to zero and the No 4 engine started to run down. At 0345 hrs the flight crew attempted to restart the No 1 engine, but they were unsuccessful. Shortly afterwards at 0347 hrs, the flight crew manually started fuel transfer from the trim, centre and outer tanks to the four inner fuel tanks. At 0349 hrs there was an increase in all four inner fuel tank quantities. The inner fuel tank quantities continued to increase as fuel was transferred from the trim, centre and outer tanks. Touchdown was at 0410 hrs, with a total of 22,960 kg of fuel remaining, with the inner 1 through 4 fuel tank quantities of 2,641 kg, 5,922 kg, 5,370 kg and 2,583 kg respectively. Fuel continued to transfer to the inner tanks until the engines were shut down.

Aircraft examination

On arrival at Amsterdam, the Central Maintenance Computer produced a Post Flight Report (PFR) which detailed the cockpit effects and faults detected and recorded by the computer during the flight. The aircraft was then physically examined in accordance with advice provided by the aircraft manufacturer. This included verification of the fuel quantity indications against fuel contents measured using the tank magnetic level indicators. Tests were conducted on fuel pump operation, valve operation, cockpit lighting and warning displays; these tests did not reveal any abnormal operations. The engines were run and no problems were experienced including the starting of engine No 1. A manual refuel was carried out and the aircraft was flown on a non-revenue flight to Heathrow.

Following the aircraft's arrival at Heathrow, it was moved into a hangar for further investigation. The low-level fuel warnings for inner 1 and inner 4 fuel tanks were verified as working normally and valve operation was confirmed. After this, the two FCMCs, the two Fuel Data Concentrators (FDC), the two Flight Warning Computers (FWC) and the two System Data Acquisition Concentrators (SDAC) were inspected and removed from the aircraft for further testing. Inspection of the computers, their associated wiring, connectors and the security of their installations did not reveal any defects.

Computer tests

The computers removed from G-VATL were sent to their respective manufacturers for further tests. Prior to bench testing and full acceptance tests, data within the internal memories of the

two FCMCs, two FWCs and two SDACs were downloaded. The FDCs do not contain any internal memory but they were subjected to bench and full acceptance testing. These tests did not reveal any defects and all the computers performed as expected.

Downloaded computer data

The data downloaded from the FCMCs indicated that FCMC 2 suffered a loss of ARINC 429[1] data bus A at 1934 hrs and failures of some discrete output commands from the FCMC in control at that time. Which FCMC was in control is not known. The FWCs also reported two occurrences of ARINC 429 data bus A and data bus B output failures from FCMC 2. One instance of output failure can be accounted for by the flight crew's in-flight reset of FCMC 2. The other instance cannot be correlated against any crew action.

Safety action

On 10 February 2005 the aircraft operator issued a Company Notice to the effect that the inner tank fuel contents should be monitored and were any tank to show less than 1,500 kg, manual transfer should be initiated. Also, any ECAM fuel system warnings in flight would require the crew to monitor the fuel transfer for correct operation for the remainder of the flight.

On 15 February 2005 the aircraft manufacturer issued an Operator Information Telex / Flight Operation Telex (OIT/FOT) that contained operational advice to pilots which was to monitor the ECAM fuel page every 30 minutes. The OIT/FOT also provided a procedure to apply should automatic fuel transfer be lost.

FCMC Master/Slave determination

The basic A330/340 and the later model A340-500 and -600 aircraft have different fuel systems. On the A340-500 and -600 series each FCMC calculates the operation of the fuel system based on inputs from various data sources. To prevent confusion, only one FCMC can output commands; this is known as the 'master' FCMC. The master FCMC then commands valves and pumps to operate and it sends out warning and display signals to the FWCs. The other FCMC is known as the slave; it continues to calculate commands and monitors the master FCMC, but its ability to send out command signals is suppressed. The master FCMC is governed by health status; this status is determined internally by each FCMC. The healthiest FCMC is given master status. There is a possibility that the master FCMC may have an output failure and so may lose the ability to control the fuel system. However, the remaining slave FCMC may already be at a lower health status and cannot, therefore, become the master unit. This means that the master

[1] A Standard digital data highway for civil aircraft

FCMC may remain as master without the ability to provide command or warning signals. Therefore the following safety recommendation is made:

Safety Recommendation 2005-36

Airbus should review the FCMC master/slave determination logic of the affected Airbus A340 aircraft so that an FCMC with a detected discrete output failure or ARINC 429 data bus output failure cannot remain the master FCMC or become the master FCMC.

Low fuel level warning indications

In normal operation, the low fuel level warning for the inner fuel tanks is calculated by both FCMCs based on fuel quantity information from the FDCs. When the calculated fuel mass drops below 1,000 kg for more than 60 seconds, an ARINC 429 signal is sent from the master FCMC to the FWCs for the display of the relevant 'FUEL INR 1(2 3 4) LO LVL' warnings on the ECAM.

If both FCMCs have failed, then the FWCs use a discrete parameter generated by the FDCs to provide the warning of an inner tank low fuel level. The FDC low-level discrete parameter is set when the fuel level in the tank drops to a specific volumetric level, this means that it will trigger at various fuel masses due to changes in fuel density and temperature. For inner 1 and inner 4 fuel tanks the FDC can trigger the fuel low level discrete at a fuel mass of between 1,180 kg and 1,430 kg.

This means the low fuel level discrete from the FDC is usually received by the FWCs before the low level ARINC 429 signal from the master FCMC. The FWCs ignore the FDC discrete signal unless one or both FWCs has detected that both FCMCs have failed. This logic means that the back-up low level warning from the FDC is ignored if everything appears normal with the FCMCs. The expectation would be for the back-up system to have an overriding ability to trigger a warning and should not be dependant on the status of other systems. The following safety recommendation is made.

Safety Recommendation 2005-37

Airbus should review the logic of the low fuel level warnings on affected Airbus A340 aircraft so that the FDC low fuel level discrete parameter always triggers a low fuel level warning, regardless of the condition of the other fuel control systems.

Conduct of the investigation

Under the provision of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996, the Chief Inspector of Air Accidents has ordered that an Inspector's Investigation be conducted into the circumstances of this serious incident. The investigation will work to establish the root cause for the initial failure of the automatic fuel transfer and the reason for the lack of fuel system warnings and proper indications during the flight.

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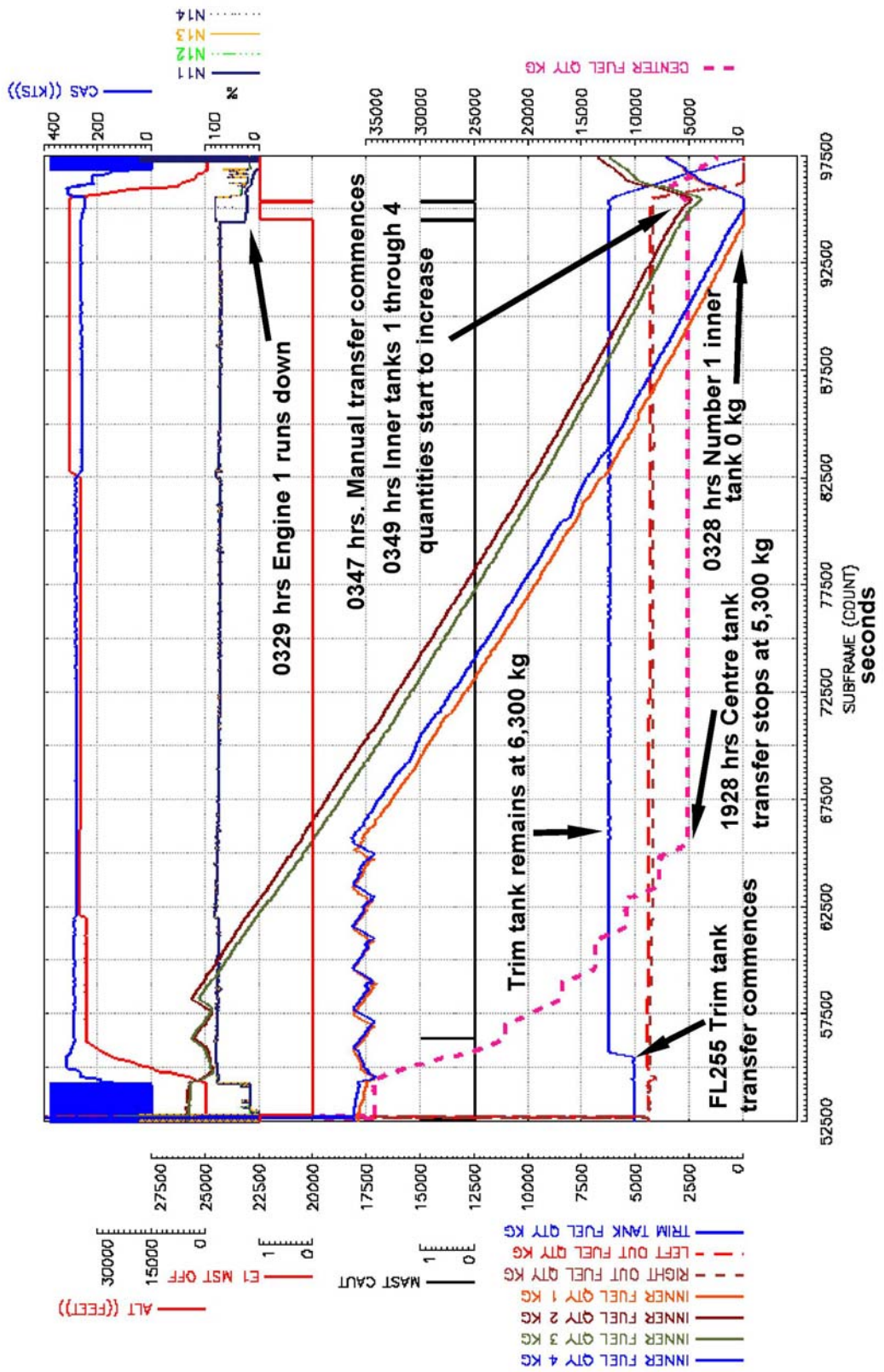

Figure 1 – An Extract of Relevant Flight Data