SERIOUS INCIDENT

Aircraft Type and Registration:	Cessna 680 Citation Sovereign, G-CJCC
No & Type of Engines:	2 Pratt & Whitney Canada PW306C turbofan engines
Year of Manufacture:	2008
Date & Time (UTC):	30 September 2010 at 0825 hrs
Location:	During climb after departure from London Luton Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 5
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	6,500 hours (of which 350 were on type)
Information Source:	AAIB Field Investigation

Synopsis

The crew experienced an uncommanded transfer of fuel from the right to the left fuel tank after following the checklist procedures for a left main electrical bus fault indication. The aircraft subsequently became left wing heavy and exceeded the lateral imbalance limits. It returned to Luton Airport where a flapless landing was completed without further incident. As a result of this incident, Special Bulletin S1/2010 was published on 8 October 2010, containing two Safety Recommendations. The investigation established that the isolation of the left main bus had caused a false fuel cross-feed command which resulted in the uncommanded fuel transfer. The aircraft manufacturer has published a temporary flight crew procedure to mitigate the effects of a recurrence and has also issued a service bulletin to incorporate a design solution.

Eight further Safety Recommendations are made in this bulletin, relating to aircraft certification processes and flight recorder documentation.

History of the flight

The aircraft was operating a commercial passenger flight from London Luton Airport, to Milas-Bodrum Airport, Turkey. It departed with a full fuel load of approximately 11,000 lb. As it passed FL300 for FL320 in the climb, the DC EMER BUS L amber Crew Alerting System (CAS) message appeared. The crew referred to the Emergency/Abnormal Procedures checklist and, from the observed indications, concluded that there was a fault on the left main electrical bus. They completed the required action items, which included selecting the left generator OFF. They elected

to return to Luton as the weather there was favourable and it was only 20 minutes flying time.

When the left generator was selected OFF, a number of systems lost power, including the flaps, the left fuel quantity indication and the commander's Primary Flight Display (PFD). The commander handed control to the co-pilot, who remained the handling pilot for the rest of the flight. As the flight progressed, the co-pilot became aware that an increasing amount of right aileron control input was required to maintain a wings-level attitude. A flapless landing was completed at Luton Airport without further incident.

When the aircraft was powered up again, all systems appeared to operate normally, including the left fuel quantity indication. The left tank fuel quantity indication was approximately 5,500 lb (corresponding to full) and right tank indication was approximately 3,300 lb. The crew confirmed that they had not selected the fuel cross-feed during the flight.

Fuel system

Two separate integral wing fuel tanks, each with a capacity of 5,500 lb, provide fuel for the engines and auxiliary power unit. Each engine is normally supplied from its on-side fuel tank. An electrically-driven boost pump supplies fuel pressure for engine starting. A motive-flow pump provides fuel to the engine once it is running and the boost pump is then switched off. The engine-driven fuel pump provides excess fuel flow capacity, with the excess fuel being returned to the on-side tank. The excess flow is used to operate the motive-flow pump.

A selectable fuel cross-feed facility allows either fuel tank to supply the opposite engine. When selected, the cross-feed valve is commanded open and the electric boost pump in the selected tank operates. A signal is sent to the cross-fed engine to close the motive-flow shutoff valve to the tank not in use, so that any excess fuel flow is returned to the selected tank.

The maximum permissible lateral fuel imbalance is 400 lb, but this can be increased to a maximum of 800 lb in an emergency.

Flight recorders

The aircraft was equipped with a Cockpit Voice Recorder (CVR) and a Flight Data Recorder (FDR).

The CVR recorded the first part of the flight, including the crew's acknowledgement of the DC EMER BUS L amber CAS message. It continued to record their subsequent actions until power to the CVR was lost when the crew switched the left generator OFF. The CVR is powered from the left main electrical bus.

The FDR is powered from the right main electrical bus and remained powered throughout the flight. However, many of the FDR parameters are sourced from systems powered by the left bus and these parameters were lost when the left generator was switched OFF.

The FDR data show that the EMERGENCY LEFT DC parameter became active 15 minutes after takeoff, with an associated master caution. Approximately four minutes later, the left DC generator became inactive, with another associated master caution. This was accompanied by the loss of many parameters, including the left fuel quantity. Just prior to losing the left fuel quantity parameter, 4,896 lb of fuel was indicated in the left tank and 4,856 lb in the right tank. The aircraft landed forty minutes later. The next time power was restored to all systems the left fuel quantity was recorded as 5,520 lb and the right as 3,376 lb, an imbalance of 2,144 lb. This equates to an average fuel transfer rate of approximately 50 lb per minute.

Both the left and right fuel flow parameters remained active throughout the flight and indicated similar fuel usage.

There are no FDR parameters relating to the cross-feed valve or the boost pump. Recorded data recovered from the engine controllers indicate that the motive-flow shutoff valves on both engines did not move during the incident.

Post-incident testing

During ground testing under AAIB supervision, it was established that removing power from the left main electrical bus caused the fuel cross-feed valve to open and the right fuel boost pump to operate, with the cross-feed selector switch in the OFF position. FUEL CROSSFEED and R BOOST PUMP messages were also displayed on the CAS. Tests on another, similar aircraft produced the same result.

Further investigation

Fuel control system

Normal fuel system control is fully automatic, with control being provided via the left and right electronic fuel control cards. Fuel system control is available in the flight deck through the fuel BOOST switches and the CROSSFEED selector knob. The cross-feed signal inputs on the left and right fuel control cards are electrically connected. The investigation identified that a loss of power on the left fuel control card will provide a low impedance input to the right hand fuel control card, generating a false fuel cross-feed command. This causes the fuel cross-feed valve to open and the right boost pump to start, but it does not close the motive-flow shutoff valve, with the result that uncommanded fuel transfer from the right to the left tank will occur.

Electrical system

The cause of the initial electrical event which caused the DC EMER BUS L amber CAS message to be displayed was investigated. After extensive troubleshooting and ground testing by the aircraft manufacturer's representatives, a power distribution printed circuit board was identified to be at fault. This was replaced and the fault did not reoccur.

Aircraft certification and testing

The US Federal Aviation Administration was the regulatory agency responsible for issuing the type certificate for the Cessna Citation 680 Sovereign; European type certification was later granted by EASA. There is considerable harmonisation of design standards between the USA and Europe and as such each regulator is willing to accept each other's certification through a validation process with only slight variations to meet any specific certification requirements of the accepting regulator. Nevertheless, the accepting regulator will usually be engaged with the primary regulator and the manufacturer during the initial certification process.

During the certification testing the aircraft manufacturer considered that both main electrical buses degrading to EMER was a more critical condition, from a safety analysis standpoint, than only one side degrading to EMER and therefore testing was focussed on the former condition. The test plan was written by the manufacturer and during the test plan review for certification the regulator concurred that the worst case scenario was adequate. For future aircraft designs incorporating a split bus electrical system, the manufacturer, in agreement with the regulator, intends to conduct testing with each side in turn in a degraded power mode while the other side remains in normal mode.

In this case, regardless of the cause of the initial failure, the approved checklist procedure specified in the Airplane Flight Manual followed by the crew resulted in an undesirable and potentially unsafe aircraft configuration. Therefore the following Safety Recommendation is made:

Safety Recommendation 2011-023

It is recommended that the Federal Aviation Administration (FAA) reviews the certification process for the Cessna Citation 680 Sovereign with the Cessna Aircraft Company to ensure that adherence to approved checklist procedures does not result in an unsafe aircraft configuration.

Flight Data Recorder documentation

Operator requirements

FDRs record binary data containing encoded information from aircraft systems. The FDR data is converted to engineering units (knots, feet etc.) by referencing detailed documentation specific to that aircraft installation. Commission Regulation (EC) 859/2008, referred to as EU-OPS, provides common technical requirements and administrative procedures applicable to commercial transportation by aeroplane. EU-OPS 1.160, '*Preservation, production and use of flight data recorder recordings*', (a) (4) states:

'(4) When a flight data recorder is required to be carried aboard an aeroplane, the operator of that aeroplane shall:

...(ii) Keep a document which presents the information necessary to retrieve and convert the stored data into engineering units.'

ICAO Annex 6 (ninth edition) Appendix 8 '*FLIGHT RECORDERS*' 2.3.3 also states:

'2.3.3 Documentation concerning parameter allocation, conversion equations, periodic calibration and other serviceability/maintenance information shall be maintained by the operator. The documentation needs to be sufficient to ensure that accident investigation authorities have the necessary information to read out the data in engineering units.'

The operator could not provide the AAIB with controlled documentation that met the above requirements. The Regulator, in this case the CAA, had assumed that the information was readily available from the manufacturer. When asked to source the appropriate documentation, the operator referred to the company that carried out the annual replay of the FDR. That organisation had carried out the FDR raw data conversions by referencing an uncontrolled document. The CAA has published guidance for the content and format of the required documentation under CAP 731 '*Approval, Operational Serviceability and Readout of Flight Data recorder Systems and Cockpit Voice Recorder*s'. The absence of readily available controlled documentation concerning FDR parameter conversions could hinder accident investigations. Therefore the following Safety Recommendations are made:

Safety Recommendation 2011-024

It is recommended that the Civil Aviation Authority ensure that UK operators of aircraft equipped with flight data recorders hold and maintain controlled documentation that satisfies the intent of CAP 731 and complies with the requirements of EU-OPS 1.160 (a) (4) (ii).

Safety Recommendation 2011-025

It is recommended that the Civil Aviation Authority include in their processes associated with the issuing of Air Operator Certificates a check to ensure that the operator's procedures comply with requirements of EU-OPS 1.160 (a) (4) (ii).

Manufacturer's requirements

The organisation most likely to possess the information and expertise required to generate a suitable FDR decode document is the organisation that designed the FDR installation. In this case, the FDR installation was 'as delivered' by the aircraft manufacturer and formed part of the aircraft's type certification. However, the aircraft manufacturer did not have any controlled documentation that provided the necessary detail. The aircraft manufacturer referred to the avionic system equipment manufacturer who was able to provide a controlled document with sufficient detail for the purposes of this investigation. However, this document is proprietary to the equipment manufacturer and was not shared with the aircraft operator, which was therefore unable to fulfil its obligations under Regulation (EC) 859/2008 to keep such a document.

FDR documentation issues have been identified in other AAIB investigations. Recent examples include the investigations into the incidents to Cessna 680, G-CDCX, on 9 December 2010 and Gulfstream G150, D-CKDM, on 6 February 2011. These involved different operators, aircraft models, aircraft manufacturers and FDR system manufacturers.

Commission Regulation (EC) No 1702/2003 of 24 September 2003 Part 21 requirement 21A.61 '*Instruction for continued airworthiness*' states:

'(a) The holder of the type-certificate…shall furnish at least one set of complete instructions for continued airworthiness…to each known owner of one or more aircraft…upon issue of the first certificate of airworthiness for the affected aircraft…and thereafter make those instructions available on request to any other person required to comply with any of the terms of those instructions. …'

This does not explicitly reference flight data recorder documentation and this is not reflected in any guidance material. However, correspondence with the CAA and EASA established that Part 21 requirement 21A.61 implicitly includes the FDR documentation. The same is true for requirements 21A.107 and 21A.120, which are applicable to holders of Minor and Major design change approvals respectively.

EASA CS 25.1529, CS 25.1729 and associated Appendix H similarly refer to '*Instruction for continued airworthiness*' and are interpreted as implicitly inclusive of the FDR documentation.

The implicit inclusion of FDR documentation in the above requirements is at odds with the lack of such documentation given that the Cessna Citation 680 Sovereign was granted an EASA type certificate. The following Safety Recommendation is therefore made:

Safety Recommendation 2011-026

It is recommended that the European Aviation Safety Agency ensures that design organisations under their jurisdiction responsible for approvals affecting Flight Data Recorder (FDR) installations, hold the documentation required for decoding the FDR data, and that the documentation is to a suitable standard and available to operators.

EASA is in the process of developing EU-OPS. Proposals include FDR recording annual inspections and other checks, in line with ICAO Annex 6, Part I and Annex II-B of EUROCAE ED-112, the flight recorder standard. These proposals further emphasise the need for appropriate FDR documentation available to the operator.

Given that the above design requirements do not explicitly require FDR documentation that supports current and proposed FDR operational requirements, the following Safety Recommendation is made:

Safety Recommendation 2011-027

It is recommended that the European Aviation Safety Agency review their certification requirements, guidance and procedures to ensure that controlled documentation, sufficient to satisfy operator flight data recorder documentation requirements, are explicitly part of the type certification and supplemental type certification processes where flight data recorder installations are involved.

AAIB correspondence with the US Federal Aviation Authority indicated that FDR documentation is not required as part of the FAA type certification process. This leaves a gap whereby system-specific documentation required by the operator is not required to be produced by the aircraft manufacturer. Therefore the following Safety Recommendation is made:

Safety Recommendation 2011-028

It is recommended that the Federal Aviation Administration ensure that controlled documentation, sufficient to satisfy operator flight data recorder documentation requirements, is part of the type certification and supplemental type certification processes where flight data recorder installations are involved.

Flight recorder documentation quality

CAP 731, produced by the CAA, provides comprehensive guidance on the level of information expected in the documentation kept by the operator. The FAA document AC 20-141B also provides guidance standards for flight data recorder documentation. No similar guidance is available from EASA; therefore the following Safety Recommendation is made:

Safety Recommendation 2011-029

It is recommended that the European Aviation Safety Agency provides guidance detailing the standards for the flight data recorder documentation required for the certification of systems or system changes associated with flight data recorders.

Aircraft manufacturer

As a result of this investigation, the aircraft manufacturer began creating a controlled document to meet the operator's needs for this aircraft type, but not to any specific document standard. Another AAIB investigation into an incident on 9 December 2010, involving a different aircraft type (a Cessna Citation X, registration G-CDCX), found a similar lack of controlled documentation for FDR parameter conversion. The following Safety Recommendation is therefore made:

Safety Recommendation 2011-030

It is recommended that Cessna Aircraft Company issue controlled documents, applicable to Cessna aircraft equipped with flight data recorders, that satisfy the EU-OPS 1.160 (a) (4) (ii) requirement, and make them available to all operators of the applicable aircraft. Furthermore, it is recommended that the documentation issued should follow the guidance given in Federal Aviation Administration document AC 20-141B and UK Civil Aviation Authority document CAP 731.

The aircraft manufacturer responded to this Safety Recommendation by issuing controlled documents AES-680-177 for model 680 aircraft and AES-75-161 for model 750 aircraft, which fully define the Flight Data Recorder parameters. These will be provided, at no charge, to any operator requesting them. The aircraft manufacturer intends to include complete parameter information with each FDR's Instructions for Continued Airworthiness (ICA) for each aircraft model. A full set of ICA documents is provided to every operator at the time of aircraft delivery.

Safety actions taken

AAIB Special Bulletin S1/2010 was published on 8 October 2010, containing two Safety Recommendations. The Recommendations and the actions taken are described as follows:

Safety Recommendation 2010-090

It is recommended that the Cessna Aircraft Company immediately informs all operators of Cessna Citation 680 Sovereign aircraft that uncommanded fuel transfer will occur during aircraft operation if the left main electrical bus is not powered.

In response to this Safety Recommendation, the Cessna Aircraft Company issued a briefing to Cessna Citation Sovereign operators on 14 October 2010. This briefing included the temporary mitigating action of pulling the appropriate FUEL BOOST circuit breaker to prevent fuel transfer should a similar condition occur. A temporary change to the Airplane Flight Manual and checklist was approved by the FAA on 15 October 2010 and this was subsequently e-mailed to the operator on 08 November 2010.

Safety Recommendation 2010-091

It is recommended that the Federal Aviation Administration (FAA) require the Cessna Aircraft Company to take suitable actions for the Cessna Citation 680 Sovereign, to prevent uncommanded fuel transfer during aircraft operation when the left main electrical bus is not powered.

To address aircraft already in service, ECR 70611 '*680 Fuel Crossfeed Improvement for Field - Service Bulletin*' was approved in December 2010 and is applicable to aircraft serial numbers 680-0001 thru 6800289 and 680-0291 thru 680-0296. Cessna issued Service Bulletin SB680-24-11 on 22 December 2010, requiring installation of diodes on the fuel control cards on all in-service aircraft. The FAA has taken actions to issue an Airworthiness Directive mandating Service Bulletin SB680-24-11. The compliance time for the SB will be within 400 flight hours or one year from the date of issuance of the AD, whichever occurs first.

To address this fault on new production aircraft, Cessna ECR 70612 '*680 Fuel Crossfeed Improvement for Production*' was approved in October 2010. ECR 70612 is applicable to aircraft serial numbers 680-0290 and 680-0297 and on. All new aircraft delivered since October 2010 have this design change incorporated.