Investigation report

D1/2010L

Business Jet Dual Engine Flameout During Taxiing at Helsinki-Vantaa Airport on 6 March, 2010

Translation of the original Finnish report

OH-III

BOMBARDIER LEARJET 60

INVESTIGATION REPORT: D1/2010L **INVESTIGATORS:** Asko Nokelainen and Jan Nordlund
INVESTIGATION COMPLETED ON: 16.1.2013

Time:	Saturday, 6 March 2010 at 10:15 Finnish time (UTC+2)
Place:	Helsinki-Vantaa airport (EFHK)
Type of aircraft:	Bombardier Learjet 60, S/N 60-303
Registration:	OH-III
Powerplants:	Pratt & Whitney Canada PW305A LH S/N CA0466, TSN 1540, CSN 782 RH S/N CA0475, TSN 1532, CSN 776
Year of manufacture:	2006
Type of flight:	Business flight
Damage to aircraft:	No damage
Number of persons onboard:	Two-person crew, no passengers
Pilot in-command. licences:	ATPL(A)
Pilot in-command, flight experience:	**Total flight hours:** ca. 5000 h **Flight hours on this type:** ca. 650 h
Meteorological information:	Sky clear, steady wind at 10 kts, temperature -9 °C, QNH 1019

SYNOPSIS

An incident occurred at Helsinki-Vantaa airport on Saturday, 6 March 2010 at 10:15 Finnish time when the both engines of a Bombardier Learjet 60 simultaneously flamed out during taxiing. There were two crew members onboard. Safety Investigation Authority Finland (SIAF) appointed Investigator Asko Nokelainen to carry out a D-level investigation (D1/2010L) on this occurrence. Investigator Jan Nordlund served as the technical expert to the investigation.

1 FACTUAL INFORMATION

1.1 The occurrence

A Learjet 60, operated by Jetflite Oy, was about to depart for Moscow. Helsinki-Vantaa control tower cleared it to cross runway 22L, requesting it to expedite the crossing. A moment before entering RWY 22L the flight crew increased engine power. Once they were crossing the runway they reduced power. At this point in time both engines simultaneously flamed out. The flight crew let the aircraft coast across the runway to taxiway Y from where the aircraft was subsequently towed with its electric power still on and the Auxiliary Power Unit (APU) running. The pilots said that they left the throttle levers and other flight controls in the position where they were prior to the flameout. The occurrence was duly reported to the Finnish Transport Safety Agency (Trafi, CAA Finland).

1.2 Tests and research

Before the aircraft was put into the maintenance hangar fuel samples were collected from both engines and fuel tanks so as to detect possible water contamination. The aircraft had enough fuel for the flight and there were no traces of water in the fuel. The fuel samples were sent to Neste Oil Oyj laboratory for analysis. The engines' inlet and exhaust ducts were immediately inspected for damage or leaks. Shortly afterwards also the compressors, combustion chambers and turbines were borescoped. Jetflite's maintenance organisation did not detect any anomalies during these inspections.

Then the fuel filters were inspected and they were found to be clean. Both fuel standby and jet pumps were also inspected and found to be in normal working condition. The Flight Data Recorder (FDR) and Full Authority Digital Engine Control (FADEC) data were downloaded and sent to the engine manufacturer (Pratt & Whitney Canada, P&WC) for analysis.

From the FADEC data, the engines' fault codes and information on the functioning of certain valves and the fuel control unit during the event was obtained. The only significant fault code related to the incident was 'QF' (uncommanded shutdown) which, for its part, confirmed that the engines were not intentionally shut down. FDR data provided more detailed information over engine RPM and the actuation of the throttle levers. A fairly accurate picture of the events before and after the dual flameout was achieved by compiling all of the above mentioned information. Nonetheless, it did not immediately point to the root cause of the occurrence. On the other hand the data made it possible to rule out some potential causes for the flameout. Other analysis facilitated the elimination of external effects such as a strong crosswind or tailwind, or the jet blast from another aircraft.

By 15 March 2010, the preliminary investigation carried out by SIAF had uncovered certain noteworthy matters from FADEC data. The most important one concerned bleed-off valve (BOV) system behaviour during the flameout event. The investigators believed that the valve control commands appeared to be improper for the situation. The findings were reported to the engine manufacturer, accompanied by a request to provide comments pertaining to a possible software glitch in the FADEC system. The engine manufacturer replied that since the engine type has been tested and certificated this, in their opinion, could not be the case.

The engine manufacturer, as a result of their in-house investigation, had decided to have both engines' three bleed-off valves replaced, including their solenoid valves. The aircraft manufacturer had already ordered the replacement of the four check valves between the boost pumps and motive flow valve assemblies.

On the basis of the aforementioned component replacements and inspections, pending the successful outcome of the Power Assurance test runs, both the engine manufacturer and the aircraft manufacturer were ready to consider the aircraft airworthy. The test runs were successfully completed on 17 March. Both engines started normally and they also responded normally to all, including rapid throttle movements. Alongside other checks and tests, attempts were made to force the throttle levers into the fuel cut-off position, i.e. shutting the engines down without actuating their safety catches. Even though there was no indication of any nonstandard use of the fuel system during this occurrence, various cross-feed and other fuel system configurations were also tested. None of these tests resulted in engine flameouts, nor did they generate FADEC fault codes.

Since the FDR parameters precisely indicated the throttle lever movements including their timing prior to the flameout event, an accurate re-enactment was arranged at the behest of an SIAF investigator. On the second attempt the left engine flamed out, generating the same 'QF' fault code as it did during the actual occurrence. After a few additional attempts they also achieved a right engine flameout.

As the investigation continued, PWC recommended that a corresponding test be run on an identical Learjet 60 aircraft. This was done on 23 March 2010. Identical throttle lever movements on an another aircraft resulted in identical, repeated flameouts. This was the case, too, when the continuous ignition was selected on. SIAF informed the Transportation Safety Board (TSB) of Canada of this occurrence. TSB, in turn, appointed their accredited representative to follow the investigation.

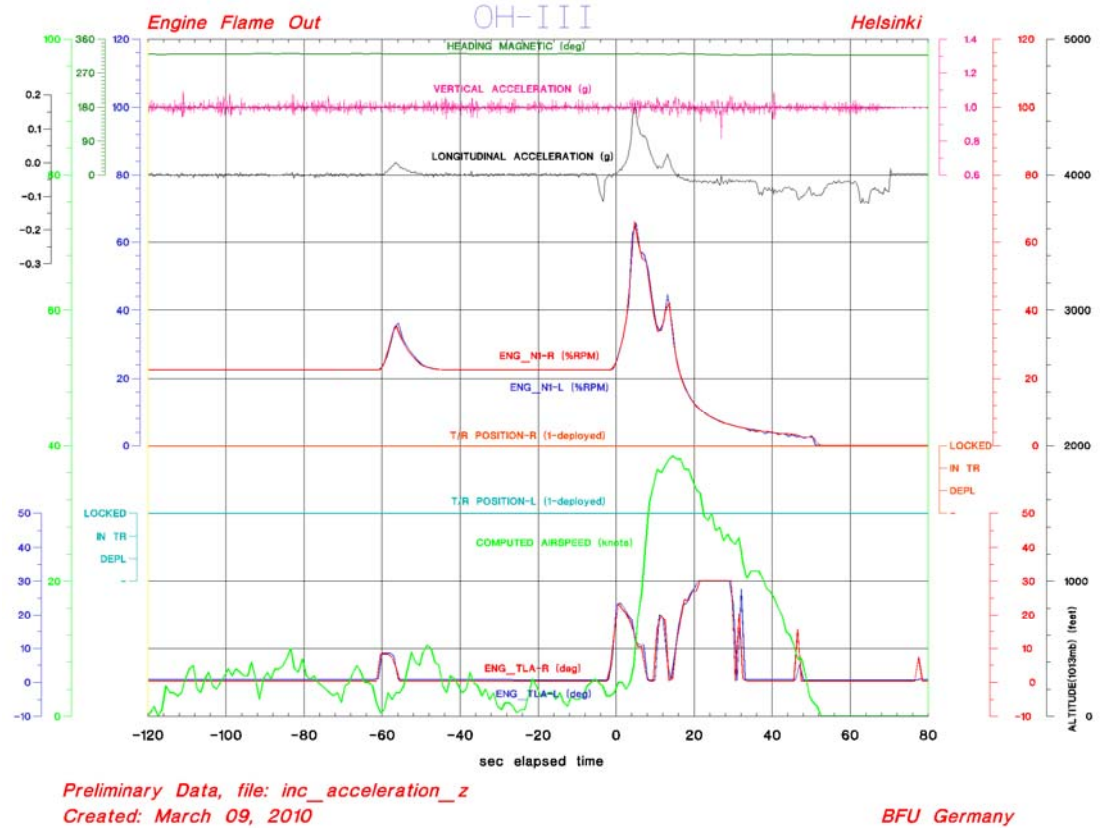

Figure 1. An FDR printout of the occurrence, produced by the German Federal Bureau of Aircraft Accident Investigation (Bundesstelle für Flugunfalluntersuchung BFU).

Following this, Bombardier and PWC asked Jetflite to conduct a thorough inspection of both aircraft's fuel systems. These inspections detected some contamination in fuel tanks. The collected fuel samples were analysed to establish the nature of the contaminants. While fungi and anti-icing additive by-products were detected in the fuel, their quantities were so minute that their contribution to the flameout event was considered to be unlikely. Furthermore, even after repeated cleanings and component changes, the engines still had a tendency to flame out. The engine that was previously removed from one of the affected aircraft also repeatedly flamed out in standardised conditions during bench tests conducted at PWC facilities in May 2010. This confirmed that the fuel did not cause the flameout events.

In early April 2010 both Jetflite and PWC carried out several inspections, component and part replacements as well as test runs. During some test runs PWC recorded real-time full resolution FADEC data to enable a more detailed analysis of the results. The removed components were sent to their manufacturers for inspection. However, no significant functional anomalies were detected in them. Even when the removed components were replaced by other, inspected and overhauled ones the flameout tendency persisted. In addition to tests conducted at ground idle, further testing was performed with the systems of the aircraft simulated at a weight-off-wheels situation, so as to force the engines to run at flight idle. This had no discernible effect on the prevalence of the flameout tendency; the same applied when the continuous ignition was selected on. However, when the engines did not flame out during a test run on 9 April 2010, both Bombardier and PWC stated that they considered OH-III to be airworthy.

On 16 April 2010 Jetflite still decided to carry out test runs on OH-III and another Learjet 60 aircraft. As a result, an engine flamed out on both aircraft. At this point PWC re-

quested that the left engine of the other aircraft be removed and delivered to them for further testing. Additionally, they asked Jetflite to ferry OH-III to Amsterdam for fault isolation and a possible replacement of both engines. Jetflite agreed to these requests.

Following this, on 20 April 2010, SIAF communicated to the EASA and other authorities that they were concerned about the problem possibly involving a considerable number of aircraft. In addition, SIAF articulated their unease over Bombardier's and PWC's eagerness to pronounce the aircraft airworthy while being uncertain of the cause or nature of the problem.

The engine that PWC had requested to be removed from the other affected aircraft behaved identically in the test bench and in the aircraft. Similar throttle lever movements resulted in repeated flameouts. By this stage most of the engine's fuel system components had already been replaced and it and the engine had been thoroughly inspected. Concurrently, this positively eliminated the possibility that aircraft systems or fuel contamination would be the culprit for the flameout tendency. Furthermore, it was noted that the engine's test run parameters, as applicable, corresponded to those of a new or overhauled engine, and that normal certification tests do not expose this particular flameout tendency. At the end of the day, from PWC's standpoint the engine seemed to meet its certification and manufacturing requirements and it did not exhibit any discernible malfunction. Still, for some reason, the engine would flame out due to a low fuel/air ratio in 3 to 5% of the attempts when a specific throttle movement was carried out.

As per the test report the abovementioned throttle lever movement was achieved as follows: *Rapid throttle movements from ground idle to high power followed by immediate rapid throttle movement back to ground idle without allowing the engine to stabilise. Peak corrected N2 is 82.1 ± 0.72% and bleed-off valve (BOV) time from open to close is 0.95 ± 0.15 seconds*.

The engine manufacturer's report, dated 8 December 2010, states that they inspected three of the four engines related to this investigation. Each one passed the tests runs required of overhauled engines. No anomalies were found in these inspections. As per PWC analysis it may be *very remotely possible* for a PW305A engine to flame out in the air with the subject throttle movement. In the event of an in-air flameout below 20,000 feet, the engine control system will automatically set ignition on when engine speed (N2 RPM) falls 2.5% below the scheduled engine flight idle speed. After a flameout in the air the engine will recover within 26 to 90 seconds, depending on the conditions. Judging by the engine type's operating history and the low probability for a flameout event, the engine manufacturer believes that the engine is not prone to a flameout even with the specific throttle movement described above. According to the manufacturer, dual in-flight flameouts are considered *very remote to improbable*. The event does not damage the engine, nor does it render the engine incapable of being restarted, either by auto-relight or by normal crew action. Finally, in the manufacturer's opinion, given the resulting low risk of dual engine flameout, no specific action is required from the manufacturer or the operators.

Hydromechanical Units (HMU) from two different manufacturers have been certified as interchangeable in PW305A engines. Together with the FADEC, the HMU regulates the fuel flow to the engine's fuel nozzles and, ultimately, to the combustion chamber. At the time of the occurrence all of the inspected engines had Lucas-manufactured HMUs of P/N 1891-12 (PWC P/N 31B4469-07). During bench testing PWC replaced the Lucas-manufactured HMU with another Lucas-manufactured HMU. With this HMU they were still able to duplicate the flameouts with the same 3-5% probability. The Lucas unit was then replaced with a Woodward-manufactured HMU of P/N 8060-527 (PWC P/N 30B5059-04). Thereafter the engines no longer exhibited the flameout tendency in the test bench.

2 ANALYSIS

2.1 Dual engine flameout

Judging by the results of the tests the dual flameout event was probably caused by a disturbance of the fuel/air ratio when a specific throttle movement was used with the Lucas-manufactured Hydromechanical Units (HMU) installed.

Even though the HMUs manufactured by Lucas and Woodward are built to meet identical control system requirements they are somewhat dissimilar in design. It is apparent that this causes their slight, albeit critical by chance, difference in responding to throttle lever movement.

The investigation did not find any other cause that could have explained the occurrence. It is evident that the engine control system could not control the operation of the engine when the abovementioned throttle lever movements were applied, letting the fuel/air ratio become too lean.

2.2 Organisational information

Several times during the course of the investigation both Bombardier, the aircraft manufacturer and Pratt & Whitney Canada, the engine manufacturer, pronounced the aircraft airworthy. Safety Investigation Authority Finland considers the manufacturers' seemingly low threshold for pronouncing the aircraft airworthy, even when the cause of the occurrence was yet to be found, to be problematic. Moreover, the practice of recommending a simultaneous replacement of several system components can also be regarded as questionable. This practice eliminates the opportunity of determining each replaced component's role in the occurrence. Losing this information may adversely affect aviation safety.

The investigators hold that Jetflite's action, as the operator of the aircraft, was professional and safety-oriented at all times.

3 CONCLUSIONS

3.1 Findings

1. The flight crew had valid licences and the required ratings.

2. The certificate of registration and the airworthiness certificate were valid.

3. Both engines of the aircraft flamed out suddenly during taxiing as it was crossing runway 22L at Helsinki-Vantaa airport.

4. The engine did not receive a shutdown command from the flight crew nor from the engine control unit (FADEC).

5. Throttle levers were moved in a fashion that can be considered normal.

6. No anomalies were found in the fuel feed to the engines.

7. Neither meteorological conditions nor external factors were found to have contributed to the flameout tendency.

8. The fuel was found to meet its quality requirements and the minor quantities of contaminants that were detected in it did not contribute to the flameout event.

9. No functional faults were found in aircraft systems or engine components.

10. A re-enactment of occurrence time throttle lever movements resulted in repeated flameouts in two individual Learjet 60 aircraft. Simulating the aircraft to in-flight status nor the selection of continuous ignition did not appear to affect the tendency to flame out.

11. The engine that was removed from the other aircraft in the investigation repeatedly flamed out in the PWC test bench. It would fail even when fitted with a FADEC unit that was modified for testing purposes, and after several engine components and other parts had been replaced.

12. The flameout tendency was only detected in engines fitted with Lucas-manufactured HMU units. The engine manufacturer's tests showed that with a Woodward-manufactured HMU the fuel flow was slightly higher at the critical moment.

13. Pratt & Whitney Canada state in their report, dated 8 December 2010, that they do not consider any fleet-wide corrective action to be necessary for the Learjet 60 fleet. Despite this, Woodward-manufactured HMUs were retrofitted to the engines of both Jetflite's aircraft.

3.2 Probable causes and contributing factors

The investigation found no explicit cause for the dual flameout. On the basis of the conducted investigations however, the probable cause of the flameout event was a disturbance of the fuel/air ratio in conjunction with a specific throttle movement and, particularly when the Lucas-manufactured Hydromechanical Units (HMU) were in use.

4 SAFETY RECOMMENDATIONS

Pratt & Whitney Canada, the engine manufacturer, states in their report that while the abovementioned throttle lever movement may cause an in-flight flameout on a PW305A engine, they consider it very remotely possible. They also state that the possibility of a dual in-flight flameout is considered very remote to improbable. The analysis did not speculate as to the cause of the flameout tendency.

Safety Investigation Authority Finland recommends that Pratt & Whitney Canada continue the analysis of PW305A engine control units so as to determine and eliminate the root cause of the detected flameout tendency. It would be desirable if Transport Canada, as the issuer of the engine's type certificate, would contribute to this process.

Safety Investigation Authority Finland further recommends that Transport Canada require the engine manufacturer to determine the root cause for the flameout tendency, and to propose the corrective action in eliminating the flameout tendency.

Appendix 1

SUMMARY OF THE COMMENTS TO THE DRAFT FINAL REPORT

FINNISH TRANSPORT SAFETY AGENCY

The Finnish Transport Safety Agency had no comments.

FINAVIA OYJ

Finavia Oyj had no comments.

BOMBARDIER AEROSPACE

Bombardier Aerospace had no comments.

JETFLITE OY

Jetflite Oy had no comments.

EUROPEAN AVIATION SAFETY AGENCY

European Aviation Safety Agency had no comments.

PRATT & WHITNEY CANADA

Pratt & Whitney Canada (PWC) comments the first recommendation in their letter to TSB Canada dated August 20, 2012. PWC disagrees with the recommendation and states the following:
While the investigation has established that there is a possibility that an occasional flameout may be experienced during ground handling operation, there is no evidence to suggest that the specific throttle manoeuvre performed on ground, and required to induce flameout, would be replicated in flight. Nor is there evidence that an engine in flight, with the benefit of inlet ram inlet ram associated with the forward speed of the aircraft, would be subject to a flameout even if the specific throttle manoeuvre were to be performed.

PWC states that it will continue to monitor the in-service fleet to ensure its continued safety.

TRANSPORT CANADA

Transport Canada (TC) commented the Safety Recommendations in their response dated September 5, 2012. According to the comments, TC reports that it has been working closely with PWC during the investigation process and is satisfied with and supports the testing, methodology and analysis carried out by PWC. TC therefore considers that the recommendation for TC involvement in PWC's analysis process has been fulfilled.

Transport Canada adds that they do not share the SIAF's view regarding the manufacturer's seemingly low threshold for pronouncing the aircraft airworthy.

Concerning the second recommendation, TC shares the PWC view that the probability of an in-flight dual flameout due to the specific throttle movements is “Extremely Improbable” due to the “specific and unusual nature” of the throttle movements. After having also taken into consideration other information such as the results of the investigations, the operational history of the engine and the statements of the manufacturers, TC is of the opinion that the flameout behaviour in question does not constitute a flight safety hazard and therefore TC will not pursue any further action.

Transport Canada states that it will continue to monitor the in-service fleet to ensure its continued safety.