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**Schweizerische Sicherheitsuntersuchungsstelle SUST**
**Service suisse d'enquête de sécurité SESE**
**Servizio d'inchiesta svizzero sulla sicurezza SISI**
**Swiss Transportation Safety Investigation Board STSB**

# Summary Report

A summary investigation, in accordance with article 45 of the Ordinance on the Safety Investigation of Transport Incidents from 17th December 2014 (OSITI), as of 1st February 2015 (SR *742.161*) was carried out with regards to the following serious incident. This report was prepared to ensure that lessons can be learned from the incident in question.

| | | | | |
|---|---|---|---|---|
| **Aircraft** | Dassault Aviation, Falcon 2000EX | | HB-IAU | |
| **Operator** | Cat Aviation AG, P.O. Box 2223, 8060 Zurich Airport | | | |
| **Owner** | Private | | | |
| **Commander** | Swiss citizen, born in 1972 | | | |
| **Licence** | Airline Transport Pilot Licence Aeroplane (ATPL(A)) according European Aviation Safety Agency (EASA), issued by the Federal office of civil aviation (FOCA) | | | |
| **Flight hours** | **total** | 5580 h | **during the last 90 days** | 91:06 h |
| | **on the type of accident** | 814 h | **during the last 90 days** | 91:06 h |
| **Copilot** | German citizen, born in 1980 | | | |
| **Licence** | Commercial Pilot Licence Aeroplane (CPL(A)) EASA), issued by FOCA | | | |
| **Flight hours** | **total** | 3260 h | **during the last 90 days** | 89:25 h |
| | **on the type of accident** | 1212 h | **during the last 90 days** | 89:25 h |
| **Location** | 4 NM west of Zurich Airport (LSZH) | | | |
| **Coordinates** | N 47° 26' 34" / E 008° 26' 14" (WGS[1] 84) | | **Altitude** | Flight Level 70 |
| **Date and time** | 4 October 2018, 06:45 UTC (LT[2] = UTC[3] + 2 h) | | | |
| **Type of operation** | Charter | | | |
| **Flight rules** | Instrument Flight Rules (IFR) | | | |
| **Flight phase** | Take off and initial climb | | | |
| **Point of departure** | Zurich (LSZH) | | | |
| **Point of destination** | Paris le Bourget (LFPB) | | | |
| **Type of serious incident** | Engine shutdown due to fuel starvation | | | |

| **Injuries to persons** | **Crew** | **Passengers** | **Third persons** |
|---|---|---|---|
| **minor** | 0 | 0 | 0 |
| **None** | 3 | 2 | Not affected |

| | |
|---|---|
| **Damage to aircraft** | Not damaged |
| **Other damage** | None |

[1] WGS: World Geodetic System, the WGS 84 standard was adopted for aviation by decision of the International Civil Aviation Organization (ICAO) in 1989.

[2] LT: Local Time

[3] UTC: Universal Time Coordinated

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# Factual Information

## Course of Events

The business aircraft of type Falcon 2000EX registered as HB-IAU took off on 4 October 2018 at 06:43 UTC from Zurich Airport's runway 28 for a flight to Paris. Two pilots were on board, with a flight attendant and two passengers. The commander was the pilot flying (PF), the co-pilot the pilot monitoring (PM).

As the aircraft was climbing through Flight Level (FL) 70 about two minutes after take-off, the flight crew heard a dull bang and noticed the failure of the right engine. The copilot tried to inform the air traffic controller about the engine failure and realised that radio No. 2 was inoperative.

Using radio No. 1, he repeated the transmission, this time successfully, and requested immediate radar guidance for a return to Zurich Airport (*"request immediate vectors to come back to Zurich"*, cf. figure 1). Air traffic control responded to this request without delay and told them they could expect an instrument approach to runway 14. At 06:48 UTC, air traffic control asked whether the flight crew was ready for the instrument approach, but they replied in the negative.

The flight crew realised that the autopilot and the elevator trim had also failed. At the suggestion of the copilot, *right bus-tie* (*rotary switch*) was closed and both systems worked again (cf. information on relevant aircraft systems). Subsequently, the copilot worked through the checklist *"engine failure in flight"*, which also included the closing of the bus tie. In addition, because of the bang, the commander decided not to attempt an engine restart.

The copilot repeatedly advised the commander to declare an emergency, which he did at 06:52 UTC with the words *"Mayday, Mayday, Mayday"*. Air traffic control confirmed the receipt of this message and again asked the flight crew to report their readiness for the instrument approach. Shortly thereafter, air traffic control continued radar guidance with the instruction to turn onto a heading of 210° and cleared the flight to an altitude of 4000 ft above mean sea level (AMSL).

At 06:54 UTC the flight crew reported that they were now ready for the approach, whereupon they immediately received an instruction to turn to a heading of 170° and were cleared for the instrument approach to runway 14. However, as the aircraft was turning east in a left turn away from the final approach track (cf. figure 1), air traffic control then suggested heading corrections to the flight crew to lead the HB-IAU back to the final approach track.

At 06:56 UTC, air traffic control asked whether the airport was in sight. The flight crew answered in the negative and reported that they were now following the instrument approach (*"established"*). The air traffic control then gave the landing clearance, together with a wind from 040 degrees with 3 knots. The landing on runway 14 took place at 06:59 UTC. The flight crew expressed their appreciation for the support and rolled to the assigned parking position.

## Meteorological Information

In the vicinity of Zurich Airport, there was an extensive, thick layer of stratus clouds. The sun was shining along the Rhine. The wind on the ground was almost calm. Between 600 m and 1000 m above sea level, a moderate north-easterly wind with an average of 10 kt was blowing. At higher altitudes, the speed increased steadily and reached a maximum of 30 kt at around 2100 m above sea level.

At 06:50 UTC, shortly before the landing of the HB-IAU on runway 14, the following weather conditions were registered at Zurich Airport: Wind 3 kt from variable direction, visibility 5000 m due to humid haze, clouds 3/8 – 4/8 at 200 ft above ground, 5/8 - 7/8 at 300 ft above ground, 5/8 – 7/8 at 700 ft above ground, temperature 10 °C, dew point 9 °C, air pressure for altimeter setting 1027 hPa.

## Radar Recording and Radiotelephony Communication

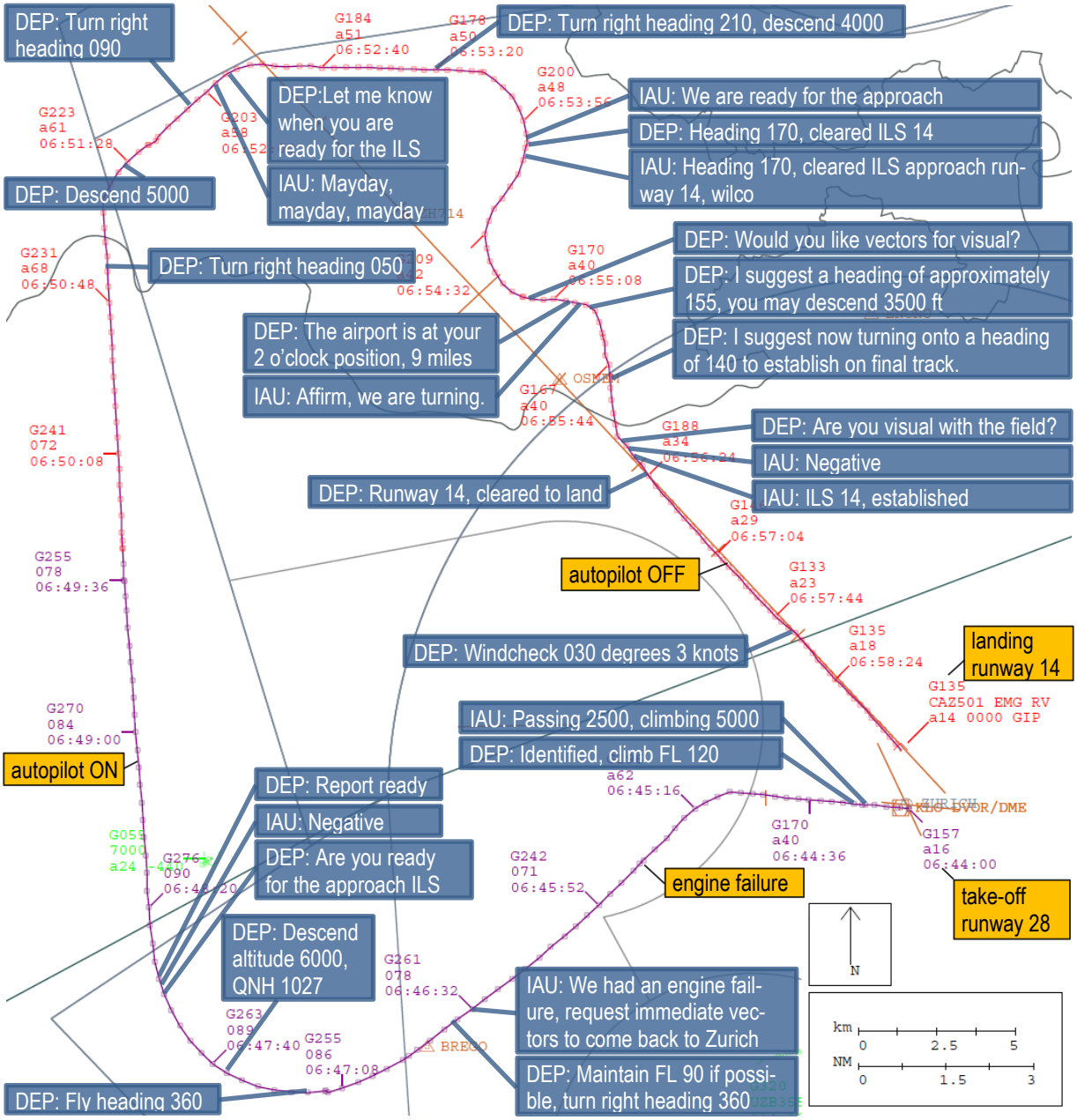


**Figure 1:** Flight path of the Falcon 2000EX according to radar recording with speed over ground in kt (G), altitudes above sea level in 100 ft (a) or flight level, and time in UTC. Selected air traffic control (DEP) and Falcon (IAU) radio transmissions are marked in blue.

## Technical Information

The stored data of the electronic engine control unit did not give any indication of a malfunction of the engine. The visual inspection of the engine, however, revealed that the emergency fuel shut-off valve (cf. figure 2) was closed. The closure of the emergency fuel shut-off valve, which was only intended to interrupt the fuel supply if the low-pressure turbine shaft broke, led to the shutdown of the engine.

The affected engine had been installed on the HB-IAU on 2 October 2018 after repair work. The rigging of the emergency fuel shut-off valve was checked. The next day, training flights were carried out with the HB-IAU without complaint.

After the engine shutdown on October 4, 2018, the valve was reset and it was determined that the rigging was outside the tolerance range. The valve was therefore readjusted in accordance with the maintenance instructions.

A follow-up check carried out after four further flights on 16 October 2018 showed that the rigging had shifted again by 0.050 inches. The subsequent adjustment had to be repeated three times until a stable result was obtained. The description of the adjustment procedure in the current documentation is very complicated.

An in-depth investigation finally revealed, when pulled by hand, the Bowden cable leading to the valve was stiff, difficult to move and jerky, and that the restoring force of a spring installed inside the valve was reduced. As a precautionary measure, both components were then replaced and sent to the manufacturer for investigation.

### Information on relevant Aircraft Systems

The emergency fuel shut-off valve is used to interrupt the fuel supply directly at the engine if the low-pressure turbine shaft breaks. It is permanently open and can be closed rapidly and irreversibly only once by moving its actuating lever beyond a trigger point. This happens automatically and cannot be influenced from the cockpit. The control lever has an adjustable connection to a Bowden cable (cf. figure 2).

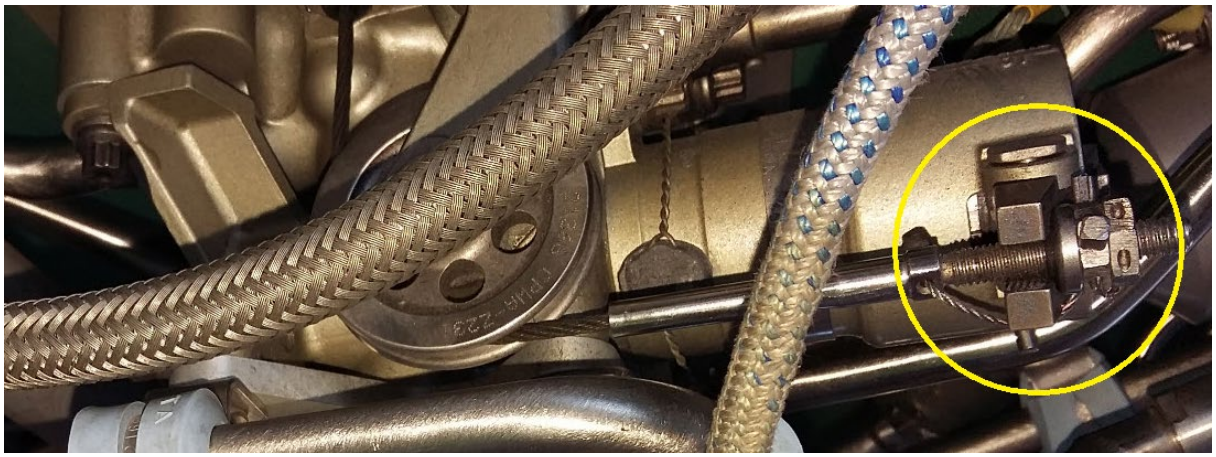

**Figure 2**: The emergency fuel shut-off valve with its actuating lever and its adjustable connection (yellow circle) to the Bowden cable via a pulley.

The electrical system of the aircraft contains the distribution busbars left main bus and right main bus, which in normal operation are fed by the generator of the corresponding engine. After the shutdown of the right generator, the right main bus is de-energized and can be replaced by the left generator by manual operation of the right bus-tie rotary switch. The three systems (radio, autopilot and elevator trim) which in this case failed as result of the engine shutting down are supplied via the right main bus.

### Evaluation of the Flight Data Recorder

Due to the difficulties encountered during the aircraft interception of the localizer for runway 14, the data of the flight data recorder were subjected to an in-depth analysis. This showed that the crew had programmed the autopilot according to the instructions of the air traffic controller, i.e. to intercept the instrument approach with the heading mode engaged (170°) and the approach mode armed.

Consequently, the autopilot, which was following a heading of 210°, then initiated a left turn. During the left turn, there was a disturbance in the signal of the localizer which caused a change in the autopilot programming to roll mode engaged and approach mode disarmed. The crew corrected this at 16:54:53 UTC after the aircraft had turned to an easterly heading (cf. figure 3).

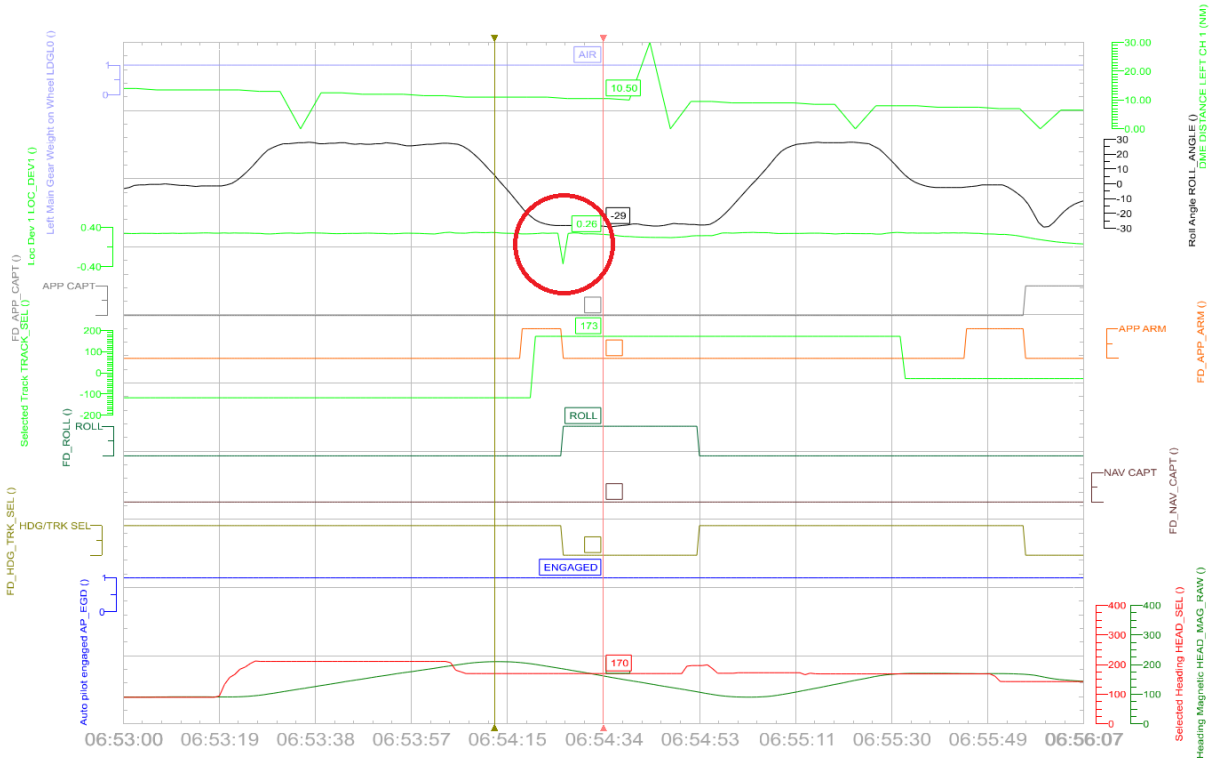


**Figure 3**: The evaluation of the flight data recorder shows a single and short-term disturbance in the signal of the localizer (red circle), which resulted in a change of the programming of the autopilot.

### Further Investigations

The engine manufacturer Pratt & Whitney Canada Corp. stated that the reason for the closure of the emergency fuel shut-off valve could not be determined with certainty and that the valve and the Bowden cable had no defects. No malfunction had occurred in 2.5 million flight hours on valves of the same type, and only on 4 occasions in 16 million flight hours on comparable valves, each time after a reinstallation of the engine. In 3 of these cases, the malfunction could be attributed to an incorrect rigging. Based on the feedback provided during the course of the present investigation, the maintenance specification was revised to enhance its comprehension; a supplemental revision containing instructions for checking the cable for freedom of movement in the emergency fuel shut-off valve reset procedure is planned for June 2021.

## Analysis

### Technical Aspects

According to the engine manufacturer, all comparable cases occurred after the reinstallation of the engine. In the present case too, the emergency fuel shut-off valve was activated shortly after the engine was reinstalled, so that the otherwise fully functional engine failed due to a lack of fuel supply. The muffled bang perceived by the flight crew indicated a stall of the compressor blades of the engine (compressor stall) resulting from the rapid shutdown of the engine.

The follow-up inspection carried out on 16 October 2018 revealed that the rigging had shifted 0.050 inches, well less than the required distance to activate the fuel shut-off mechanism. The examination and testing of the emergency fuel shut-off valve and the cable did not identify any deficiencies that would have precluded normal operation or inadvertent tripping of the fuel shut-off valve.

The failures of a radio, the autopilot and the elevator trim which were observed sequentially by the crew, occurred simultaneously with the shutdown of the right generator as a result of the

engine shutdown. This corresponded to the design of the Falcon 2000EX electrical system. By operating the right bus-tie rotary switch according to the engine failure checklist, the crew was able to recover these systems.

### Operational Aspects

Shortly after the engine failure, the flight crew demanded that air traffic control immediately take over the navigation for a return to Zurich with the phrase *"request immediate vectors to come back to Zurich"*. This was an appropriate decision and was safety-conscious. However, this wording implied that the return itself should take place as quickly as possible, which subsequently prompted the air traffic controller to ask *"are you ready for the approach?"*

After the flight crew answered in the negative to the air traffic controller's question, he understandably continued the radar guidance for an instrument approach to runway 14, since the flight crew did not delay the approach by flying holding patterns, for example. The emergency message sent at a later point in time seemed to further underline the desire for a landing as soon as possible.

After the flight crew had reported their readiness for the approach when turning to a heading of 210°, the air traffic controller corrected his heading instruction to 170°, which was to lead the aircraft to intercept the localizer. The subsequent deviation of the flight path from this instruction can be explained by a change in the autopilot programming caused by a brief disturbance in the localizer transmitter signal.

The left turn to the east and leading away from the localizer, instead of a southerly heading, must be attributed to insufficient monitoring of the flight instruments by both pilots. The time pressure imposed on themselves by the flight crew may have contributed to this. The air traffic controller made suggestions for corrections and still assumed that a landing would be necessary as soon as possible.

The return to the departure airport was hasty. An immediate landing was neither necessary following the engine failure nor suitable due to the weather conditions with low clouds. After the radio message *"request immediate vectors to come back to Zurich"*, the air traffic controller did his utmost to enable a landing as soon as possible.

## Conclusions

The engine shutdown was due to the fact that the emergency fuel shut-off valve was activated because of its incorrect rigging and, as a result, interrupted the fuel supply. The cause of the incorrect rigging could not be conclusively established.

Since the manufacturer has revised the maintenance specification in October 2019 for ease of comprehension, and plans to supplement the instructions in June 2021 to check the freedom of movement of the Bowden cable during the reset of the fuel shut-off valve rigging procedure, the STSB concludes the investigation based on Art. 45 para. 1 of the OSITI with the present summary report.

The German version of this report is the original and therefore authoritative version.

Bern, 19 January 2021 Swiss Transportation Safety Investigation Board