Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	15 May 2023
Location:	Hohn Military Airport
Aircraft:	Airplane
Manufacturer:	Learjet Corporation
Type:	Learjet 35A
Injuries to persons:	Two persons fatally injured
Damage:	Aircraft destroyed
Other Damage:	Crop damage
State File Number:	BFU23-0311-1X

Abstract

After a simulated engine failure was initiated during initial climb, the airplane yawed and rolled along its longitudinal axis, lost altitude and speed and impacted the ground with high energy next to the end of the runway.

Factual Information

History of the Flight

On the day of the occurrence, six Learjet flight crews of the operator involved planned to take off almost at the same time from Hohn Military Airport to different missions. The airplane involved was the third to take off.

Two pilots were on board of the Learjet 35A. The Pilot Flying (PF) sat in the left-hand seat and the Pilot Monitoring (PM) in the right.

It was planned to fly from Hohn to Wunstorf Military Airport and conduct several instrument approaches for training purposes of the local air traffic control personnel. At the same time, the flight was to be used as proficiency check for the pilot in the left-hand seat for his type and instrument rating for Learjet 20/30.

According to the Cockpit Voice Recorder (CVR) recording, the pilots completed the Before Starting Engine checklist prior to starting the engines. A Yaw Damper check and a so-called Full Travel check of the flight controls were performed, among other things. At 1224 hrs[1], the right engine was started; at 1226 hrs, the left. At 1237 hrs, while still on taxiway C3, the take-off emergency briefing was performed with the words: „[…] when airborn keine [no] Items ausser [except] gear below 500 ft, continue climb, in real life accelerate to V2 plus 30, Klappen [flaps] rein, slight climb weiter auf [to] […]“. At 1238 hrs, another Learjet received take-off clearance with simulated engine failure from the Tower. That flight crew asked over the radio if the single engine take-off was approved and the Tower once again acknowledged it. After the take-off of that Learjet, the flight crew taxied with the airplane involved on the runway to Ramp 1, turned and waited for the clearance to line up on runway 26. At 1244 hrs, the flight crew received the instruction to roll on to runway 26 and wait. They completed the Line-up check and the Before Take-off check. They planned to take-off with flaps 8° and engine full thrust with N1 of 96.6%. After they had received take-off clearance at about 1247 hrs, the airplane accelerated and took off at 1247:34 hrs, according to witnesses in the area of taxiway C3, and entered climb.

According to the CVR recording, after take-off the PF instructed the PM to retract the landing gear and engage the Yaw Damper. At 1247:39 hrs, the PM responded with: “Vorab verlierst du simuliert das rechte Triebwerk (in advance, you will lose the right engine)“, the PF acknowledged it by saying: “Copy, gear up“. Then the thrust of the

[1] All times local, unless otherwise stated.

right engine reduced, the left engine maintained the set take-off thrust. At that time, indicated speed was about 160 kt, according to the FDR. At 1247:44 hrs, the PF instructed: “Damper on”. At 1247:45 hrs, the PM answered “Jawohl (yes)”, almost at the same time the PF said quietly: “Oh shit“. At 1247:44 hrs, the PF called out loud several times: “Fuck” and at 1247:54 hrs the PM several times “Shit”. At 1247:55 hrs, the last recording was the landing gear warning generated by the airplane: “Too low“.
From the PM’s announcement about the simulated engine failure at 1247:39 hrs until the impact, Hohn Tower transmitted traffic information regarding two Tornado aircraft in the vicinity and instructed the frequency change to Hohn Radar.

Witnesses observed that the airplane performed a sort of snap roll and then crashed to the ground at the end of the runway. On impact, an explosive fireball occurred.

The pilots suffered fatal injuries and the airplane was destroyed.

Personnel Information

Pilot Flying

The 62-year-old PF held an Airline Transport Pilot License (ATPL(A)). The licence listed the type rating for Learjet 20/30 as pilot in command including IR each valid until 31 July 2023 and the ratings ST(A)[2] and BT(A)[3] each without expiry date. In addition, since November 2009 he held the Type Rating Instructor (TRI) Learjet 20/30 valid until 31 January 2024 and since February 2012, the Type Rating Examiner (TRE) for Learjet 20/30; valid until 28 February 2024.

His class 1 medical certificate was last issued on 30 March 2023 and valid until 16 October 2023. It listed the limitation VML[4].
According the operator’s statement, he had a total flying experience of about 11,955 hours. About 8,083 hours of them he had acquired on Learjet airplanes. According to the activity reports for examiners on file at the LBA, between March 2021 and March 2023, the pilot had conducted two examinations of other pilots on the accident aircraft and four on the sister aircraft, both were not equipped with Avcon Fins.

[2] Rating to tow gliders with airplanes
[3] Rating to tow banner with airplanes
[4] Correction for defective distant, intermediate and near vision.

Pilot Monitoring

The 58-year-old PM held an Airline Transport Pilot License (ATPL(A)). The licence listed the type rating for Learjet 20/30 as pilot in command including IR, each valid until 30 April 2024 and the ratings ST(A) and BT(A) each without expiry date. In addition, since December 2012 he held the Type Rating Instructor (TRI) Learjet 20/30 valid until 31 December 2024 and since April 2013, the Type Rating Examiner (TRE) for Learjet 20/30; valid until 30 April 2025.

His class 1 medical certificate was last issued on 25 August 2022 and valid until 8 September 2023. It listed the limitation VML.

According the operator's statement, he had a total flying experience of about 10,349 hours. About 6,265 hours of them he had acquired on Learjet airplanes.

In May 2021, he had performed a proficiency check with the PF, also on an airplane without Avcon Fins.

Aircraft Information

The Learjet 35A is a twin-engine low-wing aircraft in all-metal construction with a t-tail and retractable landing gear in nose wheel configuration. It is designed as transport aircraft for passengers and freight and any combination thereof. The airplane is equipped with a pressurized cabin for up to 10 persons (including the crew). It is fitted with two twin-shaft turbofan engines.

In 1973, the maiden flight of the type Learjet 35 occurred. The variant 35A was certified in 1976. In 1993, production of the airplane ended. The military variant is called C-21A. A total of 675 Learjet 35/35A were produced. The airplane involved was the last aircraft of this type to be built.

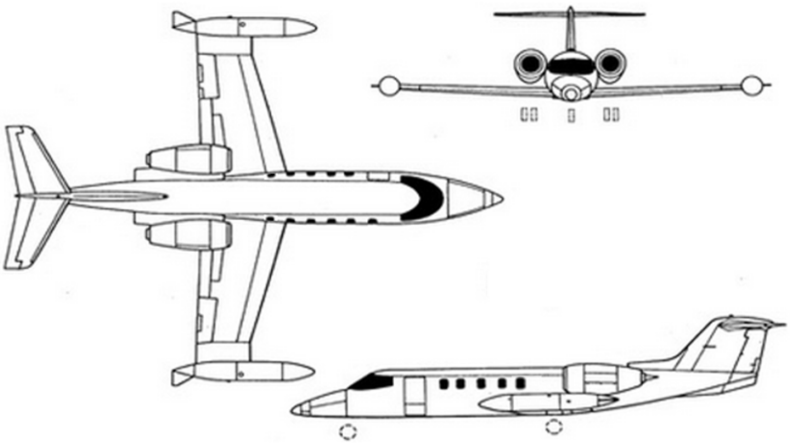


Fig. 1: Three-way view Learjet 35A Source: Manufacturer

According to the Flight Manual, Section I - Limitations 1-9, V_{mca}, the minimum flying speed where the airplane is controllable with a roll angle of 5°, if one engine suddenly fails and the remaining is operated with take-off thrust, was 110 KIAS.

According to Section III - Emergency Procedures 3-11, the engine failure emergency procedure after the decision speed V_1 read:

ABOVE V_1 SPEED

1. **Rudder and Ailerons — As required, for directional control.**
2. **Accelerate to V_R.**

NOTE **Directional control is improved if the nose wheel is kept on the runway until V_R.**

3. **Rotate at V_R; Climb at V_2.**
4. **GEAR — UP, when positive rate of climb is established.**
5. **When clear of obstacles, accelerate to V_2 + 30 and retract flaps.**

NOTE Lateral control is improved with tip tanks empty. If time permits, it is recommended that tip tank fuel be jettisoned.

6. FUEL JTSN Switch — ON (lights on); Off prior to touchdown. Time to reduce aircraft weight from maximum takeoff weight to maximum landing weight is approximately 40 minutes. Time to jettison fuel from tip tanks is approximately 5 minutes.
7. Refer to ENGINE SHUTDOWN IN FLIGHT procedure, Section IV, or ENGINE FIRE — SHUTDOWN procedure, this section.

Fig. 2: Engine failure emergency procedure after V_1 Source: Flight manual

The emergency procedure after in-flight engine failure read:

ENGINE FAILURE (CONT)

IN FLIGHT

1. Control Wheel Master Switch (MSW) — Depress and release. Yaw damper and autopilot will disengage.
2. Rudder and Ailerons — As required, for directional control.
3. Thrust Lever (operative engine) — Increase as required.
4. ENG SYNC Switch — OFF.
5. Rudder Trim — As required.
6. Yaw Damper — Engage.
7. Autopilot — As desired.
8. Refer to ENGINE SHUTDOWN IN FLIGHT procedure, Section IV.

Fig. 3: Emergency procedure after in-flight engine failure — Source: Flight manual

Pedal Forces and Rudder Deflection in Single-Engine Operation

The manufacturer provided the BFU with documentation from this type's test and certification flights from the 70s regarding the lateral controllability in single-engine operation. These included information concerning pedal forces and rudder deflection angles in single-engine operation at different airspeeds.

At 140 KCAS, flaps 20° extended, one engine with take-off thrust and one in idle, a pedal force of 115 lbs was required for a coordinated flight.

The static and dynamic test procedures to determine V_{mca} were performed with flaps extended by 20°. At about 100 KCAS, the maximum permissible pedal force of 180 lbs and the maximum rudder deflection of 30° were determined to maintain a coordinated flight attitude. At about 98 KCAS and flaps extended by 8°, a pedal force of 162 lbs and a required rudder deflection of 26° were determined.

Rudder Control System

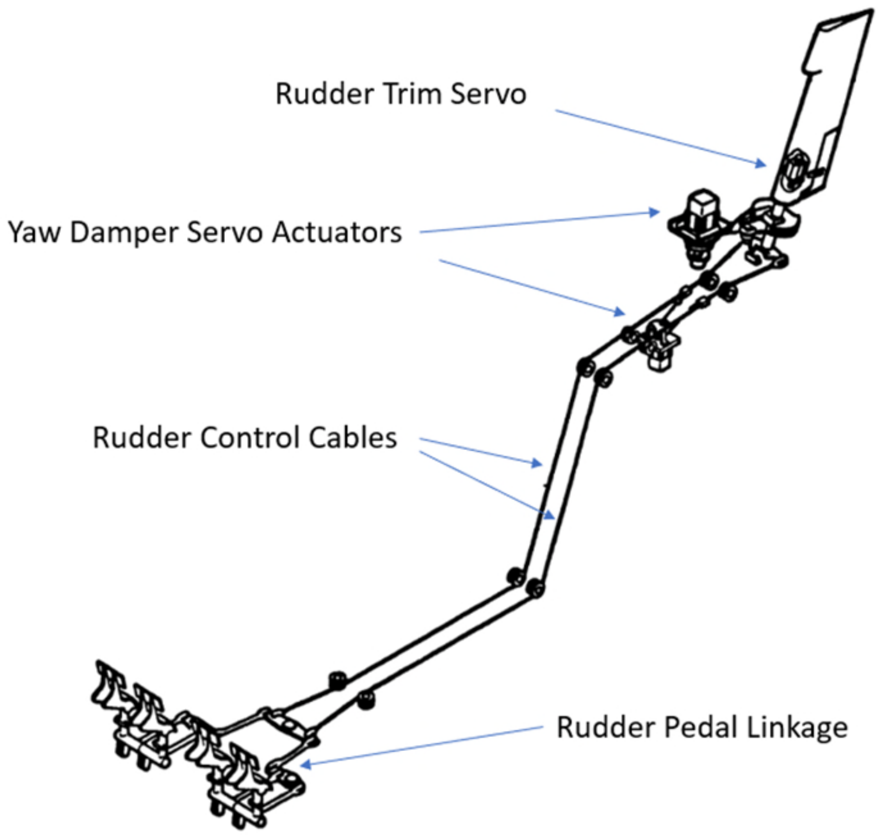


Fig. 4: Schematic diagram of the rudder control system — Source: Manufacturer, adaptation BFU

For the airplane involved, a functioning redundant yaw damper system was mandatory. In the context of starting the engines, the system had to be checked. For normal operation, the procedures stipulated the activation of one of the two yaw dampers after take-off until the flare prior to landing.

According to the manufacturer, the yaw damper servo actuators should be able to pull on the rudder cables with about 75 lbs. At the same time, in case of malfunction, it should be possible to override a yaw damper servo actuator with a maximum rudder pedal force of 75 lbs.

In Section II - Normal Procedures, Before Starting Engine the Flight Manual noted:

◆ 3. Flight Controls — Check. Full travel on all controls.

NOTE — Ensure that, during full rudder pedal movement, foot wear does not hinder movement of rudder pedals.

In the context of the investigation, the leg area of the left cockpit side of the operator's Learjet fleet was inspected and photographs were taken (Fig. 5). Different equipment status and wiring tracks above and behind the rudder pedals were found. Depending on the position of the foot, heel on the floor or in the air, a shoe can extend beyond the pedal (comparative photos were taken with size 44).

The CVR recording included a conversation of a flight prior to the accident flight, where one pilot was talking about his proficiency check on 11 May 2023 with another Learjet, where he had not pushed the rudder pedal far enough during a simulated engine failure, because he had bumped against some wiring[5] in the leg room and erroneously interpreted it as complete pedal travel.

The FDR had recorded the occurrence. The BFU was provided with the flight data for investigation purposes. After the right engine thrust had been reduced, the rudder input was sufficient for about 2 seconds to compensate for the one-sided thrust. Then the airplane began to yaw, and within 4 seconds rolled right to a bank angle of about 32° and then it was stabilised again. The course had changed by about 23° (Appendix 1: Comparison accident data with take-off on 11 May 2023).

[5] The investigation determined that it must have been an air pipe of the air conditioning

Fig. 5: Leg room of the left cockpit side in several Learjet 35A/36A Source: BFU

Airplane Involved

Manufacturer:	Learjet Corporation
Year of Manufacture:	1993
Manufacturer's Serial Number:	676
Maximum take-off mass:	18,300 lb / 8,300 kg
Maximum landing mass:	15,300 lb / 6,940 kg
Empty weight acc. to the weighing report (17 June 2021):	9,998 lb / 4,535 kg
Fuel quantity on board (15 May 2023):	5,500 lb / 2,494 kg
Operating Time:	9,846 hours
Landings:	6,739
Engine type:	Honeywell TFE731-2-2B

The Aircraft had a German certificate of registration and was operated by a German operator. The last Airworthiness Review Certificate (ARC) was issued on 7 September 2022 at a total operating time of 9,580 hours.

On the morning of the occurrence day, the airplane had been operated by another flight crew for 1:32 hours. Then it was refuelled and a technical check between flights performed. According to the mechanic conducting the check and the entry in the aircraft log book, this check did not reveal any irregularities or damage. The flight crew of the flight in the morning told the BFU that there had not been any irregularities or problems, everything functioned properly. The flight had been recorded by the CVR from take-off to engine shut down. The recording did not include any evidence of technical problems except for sluggishness of the Primary Yaw Damper the flight crew had observed and the change to the Secondary Yaw Damper.

The aircraft was fitted with a so-called "Century III with Softlite" wing, which had stall strips along the inner wing, Boundary Layer Energizers (BLE) along the outer wing and a stall fence across the entire wing chord. The engines were fitted with thrust reverser. Electrically and mechanically, they had been set to inactive. At the tail, the airplane was not equipped with so-called Avcon Fins / Strakes

According to the pilots' pre-flight preparation, the speeds were: V_1: 123 kt, V_R: 134 kt and V_2: 137 kt. Take-off mass was calculated with 15,821 lb and centre of gravity during take-off with 385.46 inches.

The operator's Operations Manual Part B, Chapter 2 Normal Procedures described take-off and callouts as follows.

PF	PNF
• Hold/release brakes acc. Takeoff type (see OM SPO B 2.1 Normal Procedure), then smoothly advance power levers to detent • (Release brakes and) hold NWS button on yoke	• Check for min. N1 within ITT Limits and tap PF hand
• Check IAS and release NWS button	• Observe IAS and call: "Speed alive" • Check NWS Light OUT, if not consider Abort
• Check IAS and call: "checked"	• Observe IAS and call: "100 knots"
When reaching V_1	
• Check IAS and release power levers	• Call: "Vee one"
When reaching V_R	
• Rotate aircraft to normal takeoff pitch angle	• Call: "Rotate"
• Command: "Gear up"	• When observing positive climb on Altimeter and VSI call: "Positive rate of climb" • Raise gear and check gear position • Call: "Gear up"
• Command (if desired): "Yaw damper on"	• Engage yaw damper
• Climb acc. NADP Procedure	• Call ATC (departure / radar) when appropriate
• Command: "Flaps up" • Set Anti-Ice Systems as required	• Check speed is above V_2+30 KIAS, retract flaps, check flap indication and call: "Flaps up"
At level off or 5.000 ft AGL	
• Request "After Takeoff/Climb" checklist • Respond as required	• Read "After takeoff/Climb" checklist and check items accomplished

Fig. 6: Take-off procedures and callouts   Source: Excerpt Operations Manual of the operator

Meteorological Information

According to the aviation routine weather report (METAR) of 1220 hrs of Hohn Military Airport, the following weather conditions prevailed:

Wind:	030° / 7 kt
Visibility:	More than 10 km
Cloud:	1-2 octas (FEW), lower limit of 5,000 ft AGL
Temperature:	21°C
Dewpoint:	3°C
QNH:	1,010 hPa

At the time of take-off clearance at 1246:50 hrs, the wind came from 60° with 10 kt.

Aids to Navigation

It was planned to conduct a take-off in accordance with instrument flight rules along the Hohn NH 126 Departure[6] and climb to FL60.

Radio Communications

The radio communications between Hohn Tower and the aircraft involved, the conversations between Hohn Tower and Hohn Radar and with the rescue personnel were recorded. Radio communications with the aircraft were conducted in English. The BFU was provided with the transcript of the recordings between 1224:05 hrs and 1250:48 hrs for investigation purposes.

The frequency of Hohn Tower (141,700 Mhz) was almost continuously occupied, due to the number of aircraft, the required taxi coordination due to the construction work at the airport, the transmission of IFR and take-off clearances and other information.

In addition, radio communications between the Tower and the Learjets were part of the CVR recording.

[6] Procedure: Climb straight ahead to 2,500 ft, continue as cleared by ATC, no turn before DER

Aerodrome Information

Hohn Military Airport (ETHN) is located about 1.5 NM north-east of the town Hohn. Airport elevation is 39 ft AMSL. The airport was equipped with one asphalt runway with the designations 08 and 26. It was 2,440 m long and 30 m wide.

At the time of the occurrence, construction work was performed in the area of the eastern taxiways. Therefore, airplanes had to enter the runway via taxiway C3 and then backtrack to the beginning of runway 26.

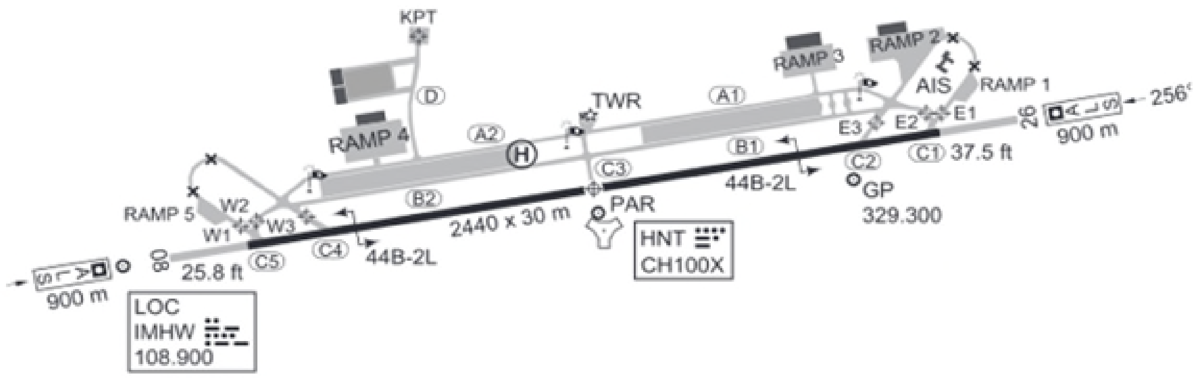


Fig. 7: Aerodrome chart Source: MIL-AIP

Flight Recorders

The airplane was equipped with a Universal CVR-120 and a L3 Harris (Fairchild) F1000 FDR.

The CVR's outside showed slight traces of fire. Mechanical damage was barely visible. Due to possible thermal stress, it was decided to remove the CPMU[7] and perform the read-out using a Golden Chassi[8]. Data of six channels had been recorded. For the occurrence flight, recordings of four audio channels (PF, PM, PA, Area Hifi) of 30 minutes each were available. In addition, two audio channels (Area Lofi and Mix) of two hours recording time each were available.

The FDR showed external mechanical damage and slight traces of fire. Components had become loose inside the recorder. It was opened and the CPMU removed. Read-out was performed using a Golden Chassi. A total of 351,836 seconds (97.73 hours)

[7] Crash protected memory unit
[8] Manufacturer specific readout unit

of flight data had been recorded. Data of the occurrence flight had also been recorded (Fig. 8). From 1047:07 UTC, thrust of both engines increased. From 1047:15 UTC, indicated airspeed increased. The callouts “100”, V_1” and “Rotate” corresponded with the recorded speed values. At 1047:31 UTC, the fuselage nose rose, the airplane took off and began to climb with about 18°. At 1047:41 UTC, right engine thrust was reduced. Lateral acceleration increased immediately. From 1047:44 UTC, the airplane rolled right. At 1047:47 UTC, maximum lateral acceleration was reached. From this time on, the flight data of all axes showed strongly fluctuating parameters. At 1047:56 UTC, the impact occurred.

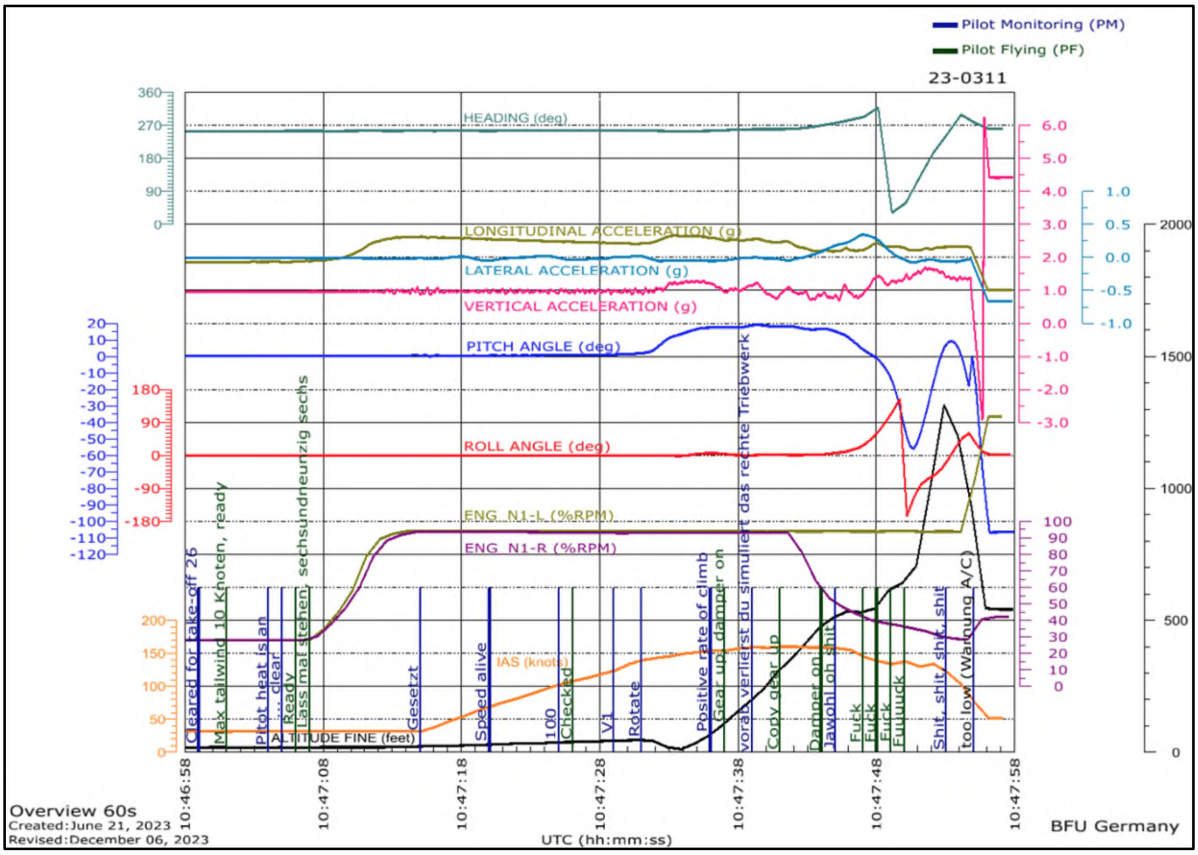


Fig. 8: Recorded flight data during the last 60 seconds including CVR recordings (below) Source: BFU

In addition, ADS-B data (Fig. 9) from the internet and military radar recordings were available for the investigation.

Fig. 9: ADS-B coordinates and time stamps of the airplane Source: ADS-B Exchange, adaptation BFU

Each engine was equipped with a Digital Electronic Engine Control (DEEC). The DEECs were send to the engine manufacturer who was able to download the data of the accident flight (Appendix 3). There was no evidence of engine malfunction. Neither was there any evidence of thrust increase of the right engine to remedy the flight situation.

The operator provided comparative data sets from take-offs with simulated engine failure for investigation purposes. They were from the sister aircraft without Avcon Fins / Strakes and one other Learjet with. A cockpit video of a take-off with simulated engine failure was also provided. This was compared with the FDR data of the accident flight (Appendix 2).

Wreckage and Impact Information

The accident site (Fig. 10) was located at the military airport about 200 m north of the end of runway 26. The main wreckage had the coordinates 54°18'41N/9°30'57O. The area over which the largest part of the wreckage had been scattered was limited in the north by a low building, in the east by apron 5, in the south by an earth wall and in the west by a ditch. Some smaller fracture pieces had passed over the building and the ditch. Parts of a flight bag was lying on the roof of the building.

Traces of the initial ground contact were found in approximately 290° about 40 m from parking position 50 at apron 5. From this point on, the ground was covered in a fan-like pattern, approximately at an angle of 45° to the left and right, with scorched vegetation and upturned earth. To the left, this area extended to the centre of the earth wall and ran across it. To the right, the fan-like pattern ended after about 10 m. After that, the traces continued approximately straight in the direction of about 290°.

Approximately 9 m behind the initial ground traces, wreckage parts of a tiptank were found. The main wreckage, consisting of the cockpit, the cabin and the right wing, was lying about 25 m from the initial ground traces, a little behind the north end of the earth wall. The left wing was found about 15 m in the direction of 290° from the main wreckage. In the area of the main wreckage, the main course of the accident site changed to about 250°. The two engines and the empennage were found in this direction about 30 m away.

Fig. 10: Accident site, view direction about 260° Source: BFU

The main wreckage was lying on the back and pointed in the direction of 110°. The aft fuselage part had been severed at the wing mounting. The cabin area was strongly compressed, torn open and mostly burnt. The cockpit was lying on top of the front cabin area. It had been destroyed by the impact and then burned. The body of one of the pilots was in the cockpit's wreckage and was burnt. The body of the second pilot was lying about 6 m in front of the cockpit on the ground and was also burnt.

Individual instruments and panels were only partially recognisable and assignable to their original functions because they had been substantially damaged by fire. The two burnt thrust levers were recognisable, among other things. The left thrust lever was found in a front position and the right in a position shifted backwards to it. In the wreckage, the nose landing gear wheel could be recognised. The cabin roof, its sides and the interior were mostly burnt.

The right wing was lying in crash direction parallel and to the left of the main wreckage. It was lying on its lower surface, the wing nose pointed in the direction of 009°. The wing had been destroyed by the impact and then burnt. The retracted landing gear could be seen in the area of the wing root. Parts of the flaps were still visible at the trailing edge.

The left wing was lying on its upper surface. It was almost completely intact and only slightly burnt. At the root area, landing gear linkage and damper cylinder were visible. The damper pipe with the wheels and brakes had slipped out and were lying in the vicinity of the wreckage about 10 m in the direction of 120°. At this wing, the flaps were still present. The aileron had been severed and was lying about 7 m behind the wing. The aileron trim tab was almost in neutral.

On both wings, the tiptanks had been severed. Their fracture pieces were found in different areas of the accident site.

The aft part of the fuselage including the two engines were lying about 25 m in the direction of 250° behind the main wreckage. It was substantially damaged and slightly burnt. The two recorders were found in the wreckage of the tail section.

At the left engine, the air intake, large parts of the cowling and several mounting parts were missing. The fan was sooty and its border areas damaged. The thrust reverser was retracted.

At the right engine, the air intake, large parts of the cowling and several mounting parts were missing. The fan was shiny and its border areas damaged. The spinner was missing. The thrust reverser was retracted.

The missing cowling and mounting parts and the right engine's spinner were found in various degrees of damage in different areas of the accident site.

The empennage was lying on the upper surface of the horizontal stabiliser. Structurally, it was separated from the fuselage tail in the root area. One ruder control cable and one antenna cable were still attached to the rear fuselage. The other control cables for rudder and elevator were torn. The left elevator was bent upward at the centre and torn off. It was lying about 5 m north of the empennage. The right horizontal stabilizer showed some deformations.

Fig. 11: Empennage including damage at the rudder Source: BFU

The upper half of the rudder was still attached to the empennage, the lower half was torn off. The actuator tube for the rudder, the rudder trim mass and the servo including control rod for the rudder trim tab were found in the area of the destroyed cabin. The servo arm was in about 90°, i. e. almost neutral position. These components were surrounded by strongly melted and burnt aluminium residues. Remnants of torn control cables were also found in this area.

The wreckage was recovered and stored in a hangar at the military airport. On 1 June 2023, the wreckage was examined once more. No indications of technical impairments causing the accident were found in regard to the control elements, control cables, pulleys and linkages of the control surfaces.

On 7 August 2023, the two yaw damper servo actuators, the left rudder pedal of the PF and the fracture area of the rudder were removed from the wreckage for further examinations. In addition, the pedal forces a yaw damper servo actuator generates for full deflection and the required pedal force to activate the yaw damper capstan slip clutch were measured at another similar aircraft.

The electric motors of the two yaw damper servo actuators could be turned by hand unobtrusively. The release force of the slip clutch (target value 120-126 inch-pounds) was measured for the primary yaw damper servo with 170-175 inch-pounds in both directions and for the secondary yaw damper servo with about 110 inch-pounds in one direction and about 130 inch-pounds in the other. The slip clutch of the primary yaw damper servo opened “slightly rattling”, not even, the one of the secondary yaw damper servo slid through evenly, without rattling. The disassembly of the slip clutch showed that it was slightly greased and the friction disks were in good condition. Evidence of damage was not determined, in spite of the heat exposure.

Measurement of the pedal force at the comparison aircraft determined that the yaw damper servo actuator generated about 55 inch-pounds at full deflection and its slip clutch opened at about 105 inch-ponds.

The macroscopic examination of the fracture surface of the rudder pedal[9] and the rudder skin and the examination of the rudder’s fractured torque tube did not reveal any evidence of previous damage or signs of fatigue fracture, they were forced ruptures.

Medical and Pathological Information

According to the CVR recordings, both pilots were speaking with each other up until the accident. The recordings did not reveal any health problems or other indications of impairments.

A post-mortem examination was performed on the bodies of both pilots. According to the post-mortem report, both pilots died of poly trauma. There were no indications of smoke inhalation. There was no evidence of physical limitations that could have interfered with the operation of an aircraft.

Fire

Witnesses did not see any smoke, flames or other indications of an in-flight fire. On impact, a large ball of fire had immediately erupted with a high reaching cloud of black smoke.

At once, Hohn Tower had alerted the airport fire brigade and rescue personnel. A few minutes after impact, the first two fire service vehicles arrived at the accident site.

[9] The Institute of Joining and Welding Technology at the TU Braunschweig examined the fracture surfaces.

Survival Aspects

Due to the high impact forces, the destruction of the fuselage structure and the immediate onset of fire, the accident was non-survivable.

Organisational and Management Information

The operator involved held a permit by the Luftfahrt-Bundesamt (LBA, German civil aviation authority) for high-risk commercial specialised operations (SPO). Based on this permit, they also had the approval from the German Military Aviation Authority for aerial target demonstration and related maintenance flights as well as related technical check and proficiency check flights. The operator had its own maintenance organisation in accordance with EASA Part 145.

The company headquarters was at Hohn Military Airport. It operated a fleet of Learjet 35A and 36A for aerial target demonstration and flight calibration. The tail sections of all aircraft, except two, were equipped with Avcon Fins

In the scope of proficiency checks for the purpose of rating extension or renewal, a simulated engine failure shortly after reaching V_2 was required, among other things.[10]

At the accident site, pages of the operator's internal training briefing guides were found. These included specifications regarding preparation, briefings, debriefing, documentation, provisions, weather minima, minimum altitudes, speeds and power settings, touch and go landing and flight test tolerance.

According to the training briefing guide, take-offs with simulated engine failure should be registered with the tower in advance. According to the statement of the tower crew, this did not occur by phone or as radio message, according to the CVR. Chapter 6 - Weather Minima and Minimum Altitudes, II Simulated Emergencies, stipulated: *Engine failures shall be simulated by setting idle thrust and shall not be initiated below 200 ft and below V_2+10 during take-off. It is the responsibility of the examiner to thoroughly brief the applicant on every simulated abnormal or emergency procedure to be checked during a check flight.*

[10] Report of the examiner of the skill test / proficiency check for airplanes with multiple pilots and technically complicated aircraft with single pilots TR MPA, SP complex HPA MP/SP-OPS (at the time of the accident: LBA, Rev. 7.0 of 30.10.2022)

The entire CVR recording, from starting avionics, to engine start-up, to the announcement of the simulated engine failure during initial climb, did not include any mention of a planned engine failure after reaching V_2.

According to witnesses, both pilots performed a pre-flight briefing. While boarding the airplane, they are said to have talked about the missing Avcon Fins and to have noted that Single Engine flying is therefore special.

The PF had called the responsible personnel at Wunstorf Military Airport, prior to the flight. According to their statement, the phone call was about the mission and the flight. Planned emergency procedures and/or single engine take-off or approaches were not part of the conversation.

There was no EASA qualified simulator for this aircraft type. There were two training facilities in the USA with FAA certified full flight simulators for Learjet 35. The operator involved had planned to construct their own simulator, a so-called FTD 2/FNPT II MCC[11], independent of the accident. It was delivered by the end of 2023 and is currently undergoing certification by the LBA. It is planned, as far as possible in terms of certification, to conduct the training of their own employees with the FTD 2/FNPT II MCC. In the long run, this should also be offered to third-party personnel.

Coordination of the Simulated Emergency Procedure with Air Traffic Control

The procedure "Take-off with simulated engine failure" is approved for departure at Hohn, after request by pilots (mostly during start-up, occasionally by telephone in advance), by air traffic control and coordination with Bremen ACC, Eider Sector, Schleswig Radar, Hohn Radar and Hohn Tower, if traffic permits.

The Airspace structure (sectorization), considering the relatively small area of responsibility of Hohn, requires coordination with the adjoining sectors "prior to" departure.

The procedure is an integral part of the air traffic control training. The respective information is kept rather general. The tower controller expects a certain "yaw" shortly after take-off, then a flatter climb, an increased workflow in the cockpit and avoids radioing the pilots and tries to allow less radio transmissions on the frequency. The latter is the ideal and cannot be guaranteed.

[11] Type specific training device (FTD), capable of Multi Crew Coordination (MCC) training in accordance with EASA CS-FSTD (A) Issue 2

The frequency change to Radar (Hohn or Bremen) is delayed. Under visual flight rules if a continuous climb and a retracted landing gear is observed. Instrument flight rules about 20 seconds after take-off. [12]

Additional Information

The BFU asked the operator's pilots for information concerning the performance of the airplane involved in general and during initiation of a simulated engine failure in particular.

In general, the aircraft involved had behaved like the others of the operator's fleet. Although each aircraft was unique, there were no significant peculiarities.

In regard to the reaction when initiating single-engine flight during initial climb, they said that in Learjet-fashion it immediately began to yaw and roll to the side of the reduced engine. The faster engine thrust was reduced the more severe the yaw and roll movement became. Both could be compensated by appropriate rudder and aileron input. The yaw and roll movements were more pronounced than with aircraft equipped with Avcon Fins. In a stabilised yaw and bank attitude (skidding), due to insufficient use of rudder, roll control with the aileron was limited. In order to achieve full roll control, the yaw angle had to be reduced first.

The BFU asked all flight instructors and examiners of the operator for information concerning the process of and actions during a simulated engine failure in initial climb.

It showed that immediate activation of the yaw damper was unusual and should generally only take place after the PF had stabilised the airplane and the PM had trimmed it with the rudder trim and an altitude of more than 1,500 ft AGL was reached, after the PF had requested it. Usually, the simulated engine failure had been ended by supplying engine thrust after the attitude been stabilised and about 1,500 ft AGL were reached and then the yaw damper was activated for the twin-engine operation.

Avcon Fins / Strakes

The airplane involved was one of two aircraft of the operator's fleet which was not fitted with Avcon Fins/Strakes at the tail.

According to Avcon Industries, Avcon Fins are supplementary fitted Strakes or aerodynamic auxiliary surfaces at the tail section. In combination with the vertical tail they

[12] Written statement of air traffic control Hohn of 1 September 2023

increase stability in all three axes and reduce air drag by smoothing the air flow in the area of the rear cone. In the case of the Learjet 35/36, they eliminate the certification and dispatch requirements for a functional yaw damper system.

Fig. 12: Tail section of a Learjet without (original) and with Avcon Fins Source: Operator, adaptation BFU

Risks during Flight Training and Proficiency Checks

In the past, training and proficiency check accidents have occurred time and again.

Examples are:

BFU 3X020-09: *The accident occurred, because the pilot in command decided to train simulated engine failure in very low altitude even though with this aircraft type - PZL-104 „Wilga 35" - this is not safely possible.* […]

BFU18-1170-3X: *During approach with simulated engine failure, roll along the longitudinal axis and loss of control occurred during go-around of the twin-engine aircraft in single-engine operation in low altitude.*

BFU21-0150-3X: *During demonstration of an engine failure in initial climb, the helicopter touched down hard at the end of the autorotation and flip over.*

BFU22-0947-3X: *The accident occurred due to low initial altitude for a spontaneous training scenario which was not part of the training handbook to acquire the class rating.* […]

During the investigation, it was usually determined that in the well-meant sense for training and during proficiency checks, increased risks were accepted in order to increase the realism of a simulated emergency situation.

Flick or Snap Roll

There different types of flying manoeuvres which are called roll:

- Aileron Roll
- Barrell Roll
- Flick or Snap Roll

Flick rolls (called 'snap rolls' in the USA) are initiated by rapid pitch and yaw control inputs, causing one wing to partially stall whilst the other still flies - leading to instantaneous high acceleration in roll.[13]

Uncoordinated Flight with unequal engine Thrust

Attempting to control an airplane in asymmetric flight without using the rudder is potentially dangerous, since the large sideslip angle required could, on some airplane types, lead to fin stall and subsequent loss of control. In addition, adverse aileron yaw may significantly increase the yawing moment to be controlled, and the drag produced by the extreme yaw attitude may be so high that level flight cannot be maintained. In practice, no attempt should be made to counter the asymmetric yawing moment by banking towards the live engine and leaving the rudder central or free.[14]

Aerodynamic at the Wing and Empennage

The BFU commissioned the Technische Universität Braunschweig, the Institute of Flight Guidance (IFF), with the reconstruction of the trajectory and the aerodynamic examination based on FDR and ADSB data of the accident flight.

In summary, the scientists came to the conclusion:

The angle of attack and the yaw angle were calculated based on the reconstructed trajectory and the pitch and roll angle the FDR had recorded. Both reconstructed trajectories provided similar angle of attacks and yaw angles. Thus, it can be assumed that the reconstructed trajectories are accurate enough to make a reliable statement about the angle of attack and the yaw angle. It is clear that the airplane, after it had reached a yaw angle of more than -20° (clockwise), was subject to stall. This analysis concludes that up until the impact, the airplane could not recover the stall.

[13] https://historic.aerobatics.org.uk/judging/judging-flickrolls.htm
[14] https://www.cast-safety.org/pdf/5_asymmetric_flight.pdf

After the one-sided simulated engine failure had been initiated, yaw angle (negative) and yaw rate continued to increase. In this phase, there are no abnormalities which indicate sudden control inputs.

The course of the accident can be described as follows. After the right-hand simulated engine failure, over about 4 seconds, the airplane develops a negative yaw angle of more than -20°. This is accompanied by a positive yaw rate. Presumably, stall initially occurs at the vertical tail, immediately afterwards at the wing. After the beginning of the stall, a complex movement occurs. At the time of the stall, the left wing, which is yawing forward, is pulled up. A severe rotation of the airplane is the result; in the beginning it mostly rolls and pitches. The angle of attack is consistently larger than usual, which is why the stall continues. After the severe rotation, roll and pitch rate slow and for a short time the airplane assumes a horizontal flight attitude with a heading in take-off direction. Prior to that, however, the airplane had lost altitude and the speed vector mainly points towards the ground. The airplane is still in stall. In addition, a high yaw rate existed. This may be mainly due to the fact that the right engine is still switched off. Subsequently, the airplane rolls with a positive roll and yaw rate out of the horizontal flight attitude further down and impacts the ground.

Analysis

Occurrence

During a simulated one-sided engine failure in initial climb with high engine thrust, within a few seconds control of the airplane was lost. Once engine thrust was reduced on the right engine, the airplane immediately began to yaw towards the side of the simulated engine failure. Due to the airspeed, the yawing condition should have been controlled and counteracted with the rudder, which the comparative data also shows.

In addition to the yaw, a few seconds later, the airplane began to roll to the side of the failed engine. It has to be assumed that by continuously increasing yawing angle, controlling the roll with the ailerons was no longer possible until finally the right wing stalled.

According to the recordings, thrust of the right engine was not increased or the one of the left decreased which would have indicated an attempt to terminate the simulated emergency situation.

In spite of an airspeed of more than V_2, about 7 seconds after engine thrust was decreased, the airplane performed a kind of flick roll and crashed.

Flight Crew

Both pilots held the aeronautically required licences and ratings to conduct the flight. Both were flight instructor for Learjet 20/30 type ratings and flight examiners for this type. Both had a high total flying experience as well as type experience. Due to the number of performed flights and checks, both pilots were familiar with airplanes with and without Avcon Fins. In the company, both enjoyed a high level of seniority and professional standing.

Aircraft

In general, a Learjet 35A is a highly motorised aircraft. High climb rates and further acceleration are possible even in single-engine operation. Accidents in single-engine operation have occurred in the past. Among other things, these accidents were caused by one-sided engine thrust which resulted in loss of control of the aircraft.

The certification flights for the type and the decade-long experience with the aircraft type show, that single-engine operation can be performed in a controlled manner even with take-off thrust with immediate use of a large rudder deflection and aileron application against the failed engine with an airspeed of V_2 or higher.

The applicable emergency procedure stipulated speed increase to at least V_2 and the use of the yaw damper after attitude had been stabilised into a slight bank angle against the failed engine by applying immediate strong rudder pedal input and the ailerons and after the rudder was re-trimmed.

The airplane involved was one of two aircraft of the operator’s fleet which was not fitted with Avcon Fins / Strakes at the tail. Therefore, it had less directional stability and required immediate reaction by the PF to control attitude in case of engine failure with take-off thrust and still low airspeed.

The airplane was continuously maintained. The maintenance documentation of the last inspections and operating time overviews the BFU was provided with, did not indicate any technical malfunctions.

Prior to the accident flight, the airplane had been operated on the same day. The CVR recordings and the statements of the flight crew of that flight and the mechanic who conducted a check between flights, did not indicate any possible technical impairments.

Investigations

Technical

According to the CVR recording, prior to take-off, the pilots had checked the unlimited movement of the controls, the autopilot, the stall warning and the yaw damper, among other things. Therefore, it can be ruled out that the control/gustlock was still installed.

According to the fuel documentation and the CVR, the airplane was evenly fuelled.

Prior to engine start-up, they had checked the control surface trim settings. After the accident, the servos of the trim, the rudder and the aileron were in the neutral position. Therefore, there were no indications of unintentional attitudes or impairment of attitude control.

In the FDR data, take-off run and initial climb up until the reduction of right engine thrust appear unremarkable and controlled as well as almost identical to the comparison flights. For the PF, the control inputs most likely resulted in the expected reactions of the aircraft. At least, on the CVR there were no other comments.

Due to the damage, the examinations were partially limited, but did not reveal any indications of technical impairments or separation of control cables and linkages.

Since the lower part of the rudder, into which the rudder is articulated, had been torn off, the rudder, the fracture surfaces of the rudder skin and the rudder torque tube were examined. There were no indications of fatigue fracture or pre-existing damage. The disconnection in the rudder, the fracture of both skin sides and the fracture of the torque tube were the result of impact-related overload.

The left rudder pedal of the PF was also examined by the BFU and the TU Braunschweig. There, too, was no evidence of pre-existing damage. Due to the fracture surface and the damage on the pedal, it has to be assumed that it was torn off as a result of overload during the accident.

Both yaw damper servo actuators were removed from the wreckage and examined and the corresponding slip clutches checked. The examination determined that overriding a defective or blocked yaw damper servo or one deflecting in the wrong direction would have been possible. The servo forces at the pedal were measured at a similar Learjet. The BFU is of the opinion that the pilot would have been able to “override” it. In addition, the FDR data shows that the lateral acceleration already increased before the yaw damper was activated. At the time it was activated, the increase in lateral acceleration decreased for a short time. Subsequently, it is not assumed that the activated yaw damper or the servo deflected in the wrong direction.

Thus, there were no indications of a technical cause for an impossible or restricted rudder deflection.

The recordings did not reveal any evidence of engine malfunctions. One-sided in-flight activation of a thrust reverser could also be ruled out, due to the deactivation, the mechanical locking and their closed condition at the accident site.

Operational

With the reduction of engine thrust, the aircraft began to yaw. This means that with the onset of uneven engine thrust, the rudder was no longer deflected to a sufficient degree to control it. Technical/mechanical reasons which prevented a sufficient deflection were not revealed during the investigation. The data of the comparison flights showed that the parameters were not unusual and control should have been maintained.

Cooperation / CRM during the Emergency Procedure / Monitoring PM

Both pilots spoke to each other as equals. There was no seniority between them. They supported each other with the checks and tasks in the cockpit. It appeared like a familiar process which had been carried out many times before. The callouts during take-off run initially corresponded with the common process of a normal take-off with two engines.

A simulated engine failure was certainly to be expected because it was part of the usual proficiency check. However, prior to take-off, a briefing should have occurred, where required actions and the distribution of tasks were discussed. A possibly necessary termination of the simulated manoeuvre should also have been discussed.

During the occurrence, which lasted a few seconds, both pilots did not articulate which problem they had or give instructions to control the flight attitude. The softly spoken “oh shit” of the PF suggests that at that moment he knew that something was wrong or that the airplane was reacting differently than he had anticipated because of his control inputs and his situational awareness. The almost immediate expletive “fuck” appears as if at that moment he realises a control error, a missing use of rudder, loss of control, the uncontrolled yaw and roll to the right.

Due to the high experience of the PF, the PM/examiner was certainly not as vigilant and prepared to interfere as if a less experienced pilot performed the checkflight. Since the PF was instructor and examiner for the type involved, the PM certainly reacted with a delay, consciously or unconsciously. The assumption that the PM observed the PF during the emergency procedure, and the fact that he did not voice any verbal instructions, suggest that initially the PF’s control inputs appeared to him as sufficient and correct and the loss of control, the rolling to the right, came as a complete surprise for him as well.

There is no other explanation as to why the strong yawing condition, which due to the high lateral force must have had a physical effect, was not addressed, the manoeuvre was not terminated by control input and application of engine thrust and flight attitude was not stabilised.

The simultaneous information by air traffic control about other aircraft and the instruction to change frequencies was very likely also a distraction from the announcement of the simulated engine failure and the initiated reduction in engine thrust. It has to be assumed that the radio messages in the pilots’ headset acoustically overlaid the internal communication (the announcement of the simulated engine failure) and also reduced the usually simultaneous internal communication to a minimum. In the assumption that the pilots perceived the radio messages concerning them and wanted to understand the content, additional distraction during the initial climb or the simulated emergency procedure, respectively, must be assumed.

Engine Failure

The operator's procedures stipulated that take-off with simulated engine failure should be reported to the tower beforehand. This was not the case with the accident flight. The pilots did not take the airplane taking off ahead of them with the clearance for a take-off with simulated engine failure as an opportunity to catch up on this or talk about it in the cockpit.
According to the CVR recording, up until take-off, the two pilots did not talk about a planned simulated engine failure.
The PF's instruction after take-off "gear up, damper on" corresponded with the procedure for a normal take-off and climb with both engines. The following announcement of the PM about the simulated engine failure was a break in the process. The PF acknowledged it right away and instructed "gear up". The instruction "damper on" only 3 seconds later in a yawing condition, without having controlled the airplane yaw-free and trimmed and having reached an altitude higher than about 1,500 ft AGL, could be an indication that the PF did not immediately realise the simulated engine failure. The instruction also contradicted the content of the conducted emergency briefing for take-off. It is likely that he simply reacted to the beginning yawing condition with aileron inputs and stabilised the attitude around the roll axis. It is very likely that the beginning yawing condition was not noticed. The climb attitude of about 18° nose up could have been a contributory factor since it did not allow for any ground view forward as well as the slight cloud cover which also could not serve as attitude reference.

The presumed activation of the yaw damper by the PM with the word "jawohl (yes)" was at the time and with the uncoordinated flight attitude basically wrong. Prior to this, the PM should have checked if the flight attitude is stabilised yaw-free, trimmed the rudder and requested the PF's instruction for it, respectively, before activating the yaw damper would have been the logical step.
In a proficiency check scenario, the following usually would have occurred: temporarily stabilise the flight attitude with rudder and aileron, continue climb, then increase the reduced engine thrust and activate the yaw damper in twin-engine operation and continue the flight.

As the yaw damper was activated, it is highly likely that once the servo actuator with its limited force pulled on the rudder and simultaneously moved the rudder pedal, the PF realised the situation. This and/or the fact that the airplane continued to roll to the right in spite of the full aileron deflection to the left, most likely resulted in the expletive “fuck”. In the recording, the lateral acceleration then reduces which allows the conclusion that now full rudder deflection was used, either by the PF or the PM.

Rudder Deflection Unintentionally Limited

The CVR recording of the previous flight contained a conversation about an occurrence which happened during the proficiency check of one of the pilots. During initiation of a simulated engine failure, the necessary large rudder deflection did not occur because the pilot’s foot had contact with air pipes above the rudder pedal and he had assumed that he had pushed the pedal all the way. Due to the insufficient rudder pedal input, the airplane began to yaw and roll; the swift intervention of the examiner stabilised the airplane.
Visual inspection of the legroom of the operator’s fleet showed that there were significant differences concerning the type of wiring and routing of cables and air ducts for heating/air conditioning. Depending on the position of the foot on the pedals, it was possible that a foot protruding over the pedal had contact with wires.

The comparison of the recoded data of this flight with the data of the accident flight allows the assumption that such a problem did not occur during the accident flight.

During the accident flight, yawing and increase in lateral acceleration, respectively, occurred immediately which allows the assumption that pedal input / rudder deflection at the time of the one-sided engine thrust reduction did not occur. By comparison, the flight where the foot hit the air pipe, yawing and the lateral acceleration, respectively, was temporarily controlled up until the moment where that pedal input against the air pipe was no longer sufficient to compensate the increasing asymmetry of the engine thrust.

Flight Data Analysis

The scientific analysis of the flight data showed that about 4 seconds after the right engine thrust reduction, stall at the vertical tail occurred followed immediately by the wing, which could not be recovered.

Weather

The meteorological conditions did not restrict the mission. During the take-off run, tail-wind prevailed which did not influence the accident due to the high airspeed already achieved. Wake turbulence due to a previously departed airplane could be ruled out as well, because of the time distance and the wind direction and strength.

It is very probable that the slight cloud cover did not provide any reference when looking out of the cockpit in climb with about 18° nose up, to determine yaw conditions without checking the compass.

Procedures

Due to different causes, engine failures occur time and again. Therefore, corresponding emergency procedures have to be trained and performed also during proficiency checks.

Nowadays, training and proficiency checks should be performed in simulators whenever possible.[15] For the type involved, there were no EASA qualified simulators worldwide and thus the operator involved conducted the proficiency checks still with aircraft.

One item of the examination protocol was the engine failure after reaching V_2. Such an engine failure occurs during initial climb, in low altitude which leaves little room for error and offers only limited temporal and spatial safety margins for intervention and correction. In the past, accidents occurred during training and checkflights when system failures and emergency situations were simulated as realistically as possible. Simulations of system failures or emergency situations in an aircraft instead of a simulator can only be conducted by accepting risks. Thus, it is very important that prior to a training flight or proficiency check, the process, the procedures, the task distribution in the cockpit, the termination criteria for manoeuvres and the possible recovery is discussed and briefed in the cockpit again shortly before the simulation. When training procedures, flight safety is to be rated higher for all manoeuvres than the realism of the simulated emergency.

The operator was aware of the possible risks of simulated engine failures during training and proficiency checks. They had formulated specifications for the briefing of flight crews, for meteorological minima and safety margins concerning minimum altitude and

[15] Appendix 9 Regulation (EU) No. 1178/2011, Information 02/22 Referat L3 - Examiner of the LBA “use of flight simulator training devices (FSTD) for practical examinations and checks in accordance with Part-FCL”

airspeed. In addition, independent of the occurrence, they saw the need for the construction of their own simulator for training purposes.

Radio Communications

The tower should be notified about simulated engine failures. Had this taken place, the tower crew could have been aware of the possibly increased work load in the cockpit after take-off and might have delayed the radio message which overlaid the entire communication in the cockpit during the emergency procedure.

On the day of the occurrence, radio communications were remarkable. The tower frequency was busy almost the entire time, due to the number of aircraft, the ground coordination, the IFR departures and take-off clearances, the additional information about the weather, bird strike risk and air traffic in the vicinity. This certainly resulted in communications stress in the cockpits and by the completion of checklist items to continuous breaks in the communication.

Conclusions

The accident, loss of control of the airplane, was the result of an untimely or significantly too low rudder deflection to correct the asymmetric thrust after initiation of a simulated engine failure. The large yaw angle resulted in a stall of the vertical tail and on the wing and an uncontrolled roll of the airplane.

It was not possible to determine without doubt the reason for the untimely or significantly too low rudder deflection.

Safety Recommendations

Safety Actions

Based on the accident and the findings of the investigation, the operator of the aircraft involved has initiated the following actions:

- All pilots of the operator were informed by means of a Flight Operation Memo and in the scope of a safety briefing about possible impairments of the pedals with incorrect foot position.
- All pilots were informed about the necessity of complete briefings and the adherence to MCC during training and proficiency checks.
- The procedure for a simulated engine failure after take-off was checked, amended and included into the OM SPO Part B. For the procedure, clear termination criteria were stipulated.
- The FTD 2/FNPT II MCC under construction shall be used as support for the training of engine failures after take-off.
- All aircraft of the operator shall have Avcon Fins to increase flight attitude stability, if required they will be refitted.

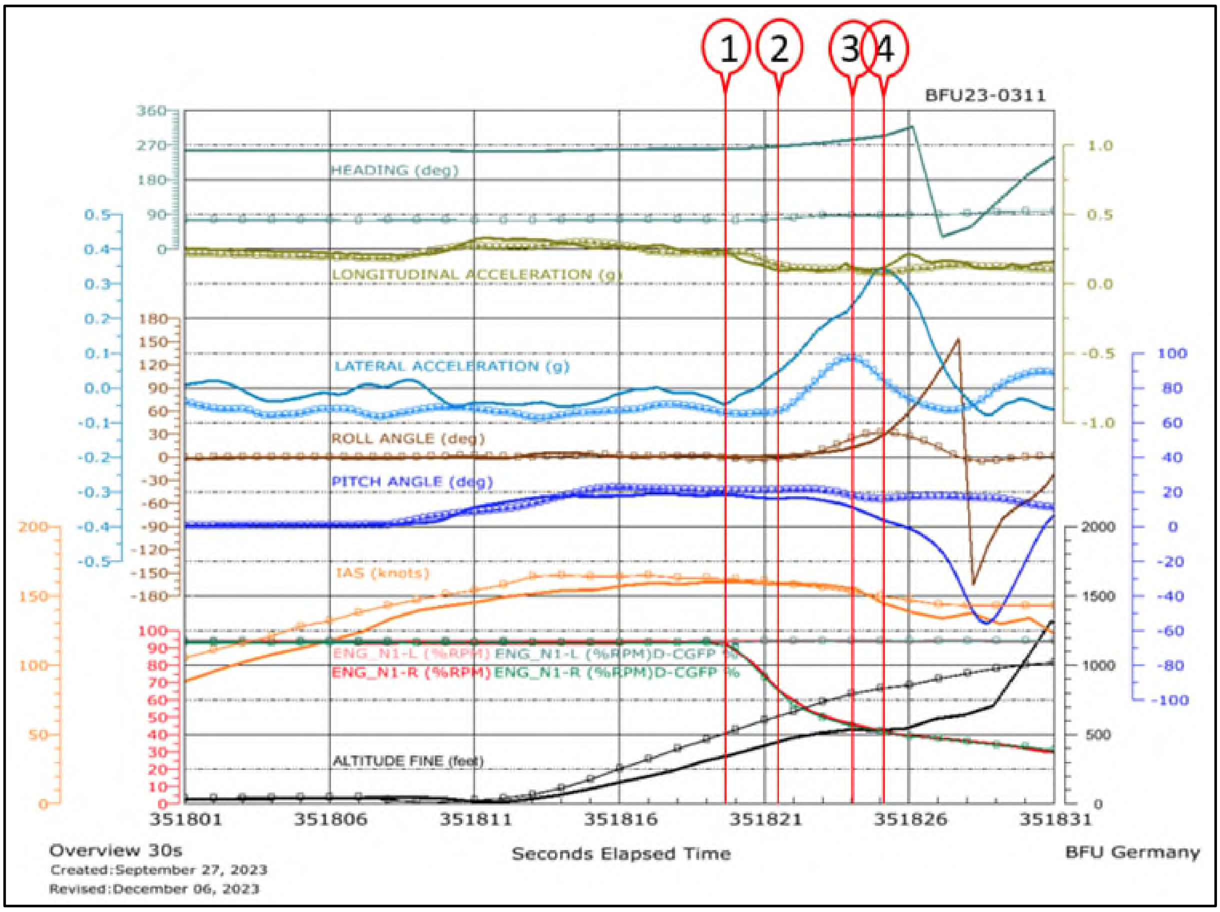
Based on the performed and planned actions, the BFU will not issue any safety recommendations addressed to the operator.

Investigator in charge:	Axel Rokohl
Field Investigation:	Dietmar Nehmsch, Ekkehart Schubert, Axel Rokohl
Assistance:	Martin Beckert, Holm Bielfeldt, George Blau, Michel Buchwald

Braunschweig, 14 May 2024

Appendices

Appendix 1: Comparison accident flight data (solid lines) with take-off on 11 May 2023 with temporary insufficient rudder deflection and roll (thin lines with boxes per data point)



1: Engine thrust is reduced in both aircraft

Aircraft involved yaws immediately

Comparison aircraft keeps the lateral acceleration constant for about 2 seconds, i. e. pedal input / rudder deflection is sufficient.

The roll is controlled in both aircraft.

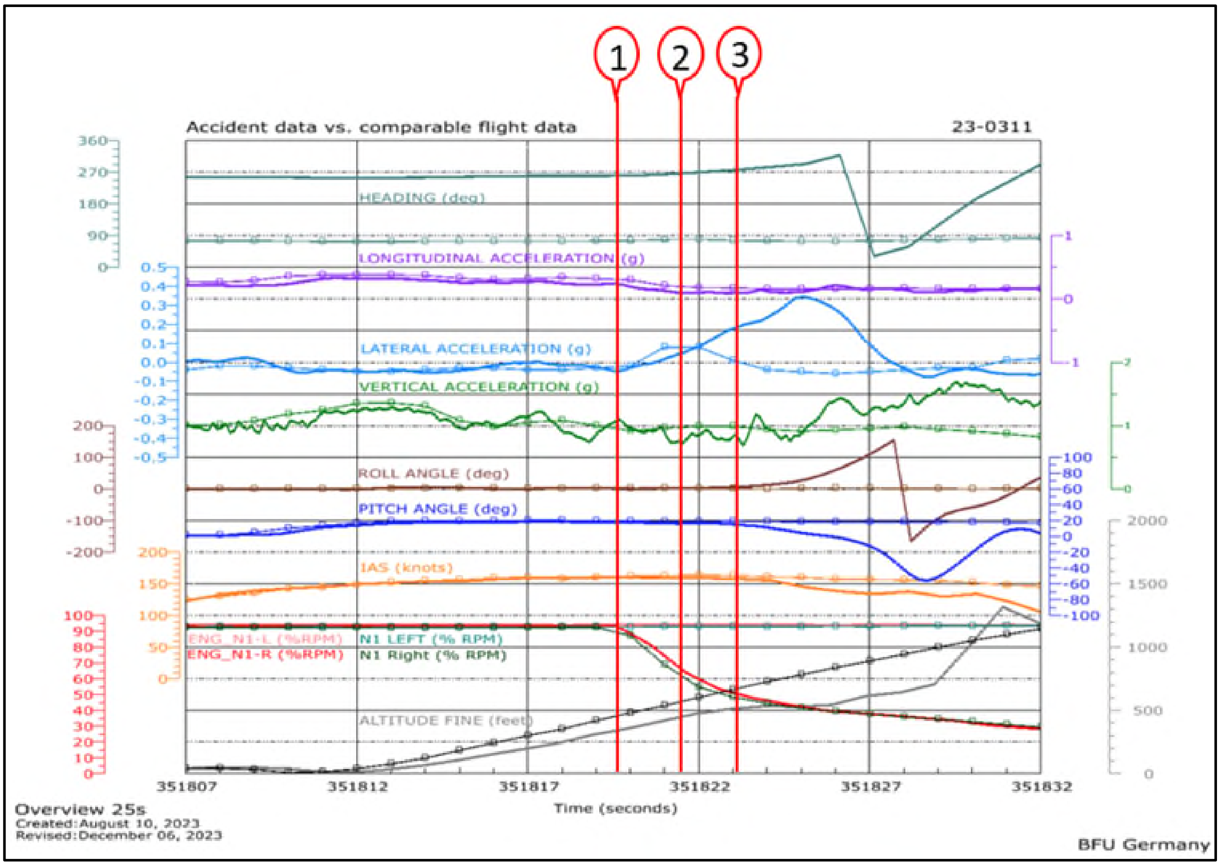
2: The comparison aircraft is in yaw condition as well, rudder deflection is no longer sufficient to compensate further one-sided thrust reduction

3: At the comparison aircraft, yaw is actively controlled by full pedal input / rudder deflection

4: Aircraft involved, expletive “fuck” and the beginning of the yaw reduction, the airplane continues to roll

Comparison aircraft, after the yaw is reduced the roll angle reduces towards neutral

Appendix 2: Comparison accident data (solid line) with the successful single-engine operation (thin line with boxes per data point)



1: Engine thrust is reduced in both aircraft

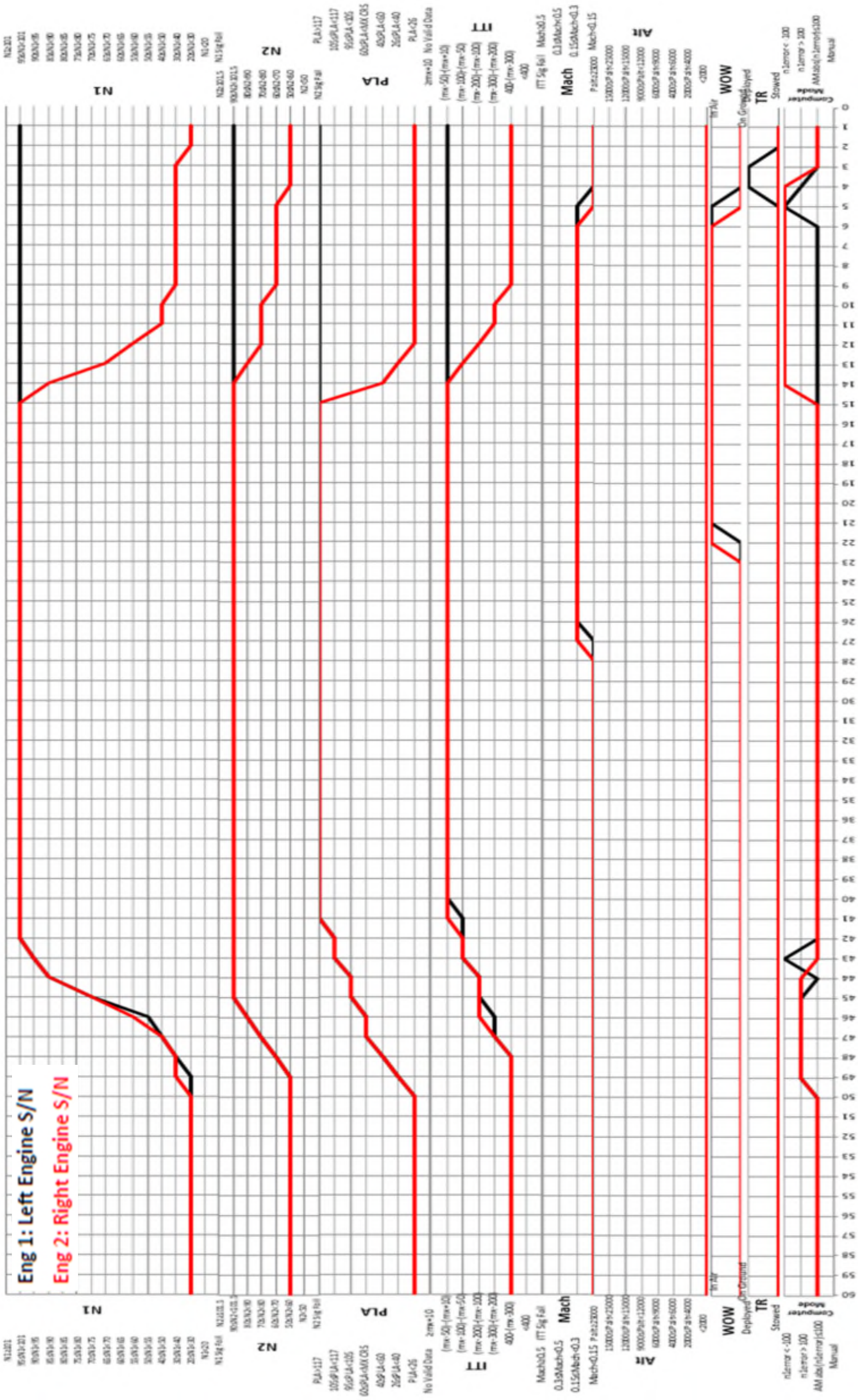
Both aircraft yaw immediately

The roll is controlled in both aircraft.

2: A the comparison aircraft, yaw is controlled and reduced by rudder deflection. Flight attitude is under control

3: With the aircraft involved, the roll cannot be held with the ailerons during the heavy yawing condition

Appendix 3: Recorded data of the electronic engine controller



This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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Bundesstelle für
Flugunfalluntersuchung
Hermann-Blenk-Str. 16
38108 Braunschweig

Phone +49 531 35 48 - 0
FAX +49 531 35 48 - 246

Mail box@bfu-web.de
Internet www.bfu-web.de