

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	30 September 2015
Location:	Saarbrücken
Aircraft:	Airplane
Manufacturer / Model:	Bombardier Inc./DHC-8-402
Injuries to Persons:	None
Damage:	Aircraft severely damaged
Other Damage:	None
State File Number:	BFU 15-1354-AX

Factual Information

During take-off from runway 09 at Saarbrücken Airport the landing gear retracted in the rotation phase. The airplane came to a stop approximately 425 m prior to the end of the runway. It rested on the fuselage and was severely damaged. Persons were not injured.

History of the Flight

On the day of the accident, the crew of four was deployed for flights from Luxembourg (LUX) via Saarbrücken (SCN) to Hamburg (HAM) and back again via Saarbrücken to Luxembourg with a Bombardier DHC-8-402.

The crew stated that they had met at about 0530 hrs for pre-flight preparations. The flights up until the take-off in Saarbrücken had occurred without incident. All in all the working atmosphere had been good and relaxed and they had been ahead of schedule.

Saarbrücken was the destination airport for 14 passengers. The remaining 16 passengers' destination airport was Luxembourg.

According to the Cockpit Voice Recorder (CVR), the Flight Data Recorder (FDR), and the radio communication recordings, the engine start-up clearance was issued at 1009:47 hrs² approximately 25 minutes ahead of schedule. At 1015:03 hrs while taxiing on taxiway C take-off clearance was issued. The Into Position Check was conducted at 1015:33 hrs on runway 09. The Pilot in Command (PIC) was Pilot Flying (PF) and the co-pilot Pilot Non Flying (PNF). The plan was to conduct take-off with reduced engine thrust (81%). During take-off the following callouts were made:

1016:24	PF	take off, my controls
1016:25	PNF	your controls
1016:27	PNF	spoiler is closed
1016:30	PNF	autofeather armed
1016:33	PF	looks like spring
1016:35	PNF	yeah, power is checked
1016:36	PNF	80 knots
1016:37	PF	checked
1016:40	PNF	V ₁ , rotate
1016:42	Background	click sound, probably gear lever UP
1016:43	PNF	upps, sorry

During the rotation phase with approximately 127 KIAS and a nose-up attitude of approximately 5°, the landing gear retracted. At 1016:44 hrs the airplane's tail had the first ground contact (tailstrike). The tailstrike warning light illuminated. Approximately 875 m after the initial ground contact the airplane came to a stop after it had bounced three times and skidded on the fuselage.

1 All times local, unless otherwise stated.

2 The times of the CVR recording were determined by means of radio transmission times

The cabin crew stated that due to smoke and fume development in the cabin the airplane was evacuated right away. All passengers and the crew were uninjured and left the severely damaged airplane without help.

Personnel Information

Pilot in Command

The 45-year-old PIC held an Airline Transport Pilot's Licence (ATPL (A)) issued in Luxembourg in accordance with Part-FCL. The licence listed the type rating as PIC on DHC8 and the instrument rating; each valid until 29 February 2016.

His class 1 medical certificate was last issued on 30 June 2015 and valid until 5 July 2016.

He had a total flying experience of about 11,927 hours; of which 3,649 hours were on the type. In the last 90 days prior to the incident he had flown about 98 hours on the type.

Co-pilot

The 27-year-old co-pilot held a Commercial Pilot's Licence (CPL(A)) issued in Luxembourg in accordance with Part-FCL. The licence listed the type rating as co-pilot on DHC8 and the instrument rating; each valid until 31 July 2016. In addition, the night flight qualification and Multi Crew Cooperation (MCC) training were listed.

Her class 1 medical certificate was last issued on 30 January 2015 and valid until 2 February 2016.

She had a total flying experience of about 3,295 hours. She had been PNF during approximately 1,200 flights and had been flying on the DHC8 for about 1,483 hours. During approximately 580 flights she had been PNF. In the last 90 days she had flown about 161 hours on the type.

The day of the accident was the first day of flight duty after a 16-day vacation period.

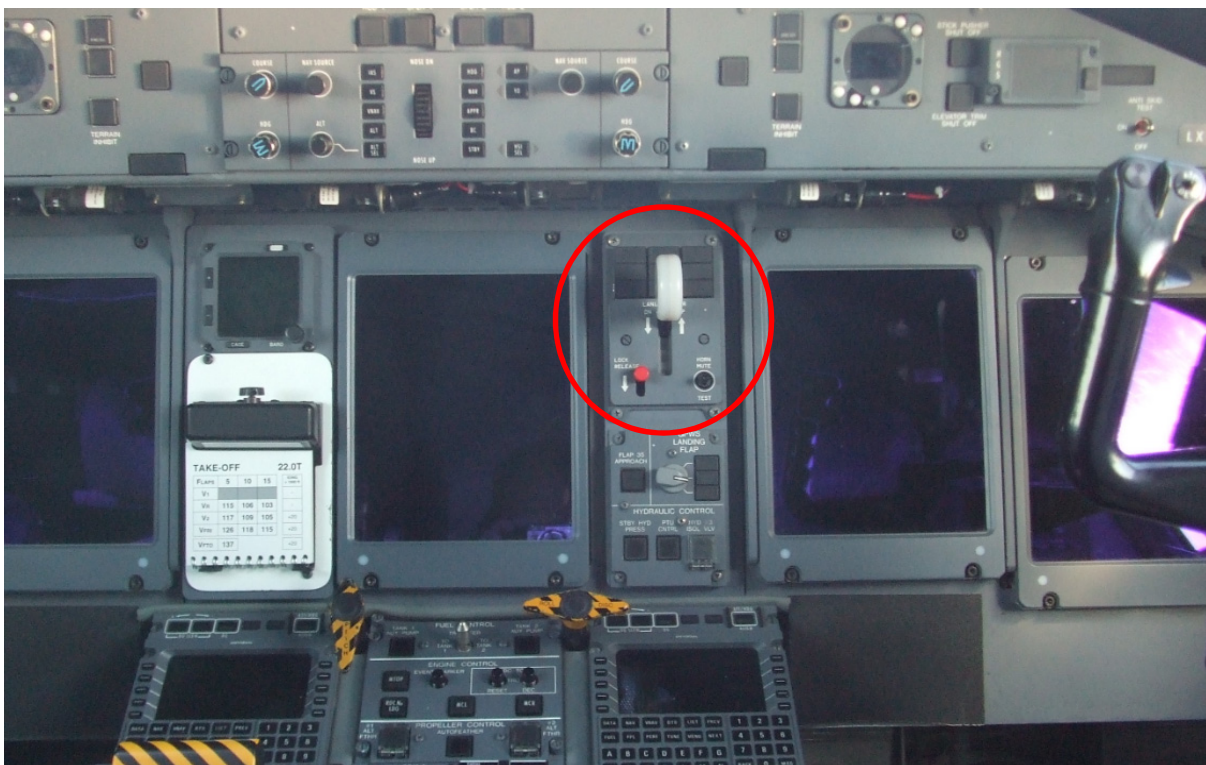
Aircraft Information

The DHC-8-402 manufactured by Bombardier Inc. is a twin-engine turboprop transport aircraft in all-metal construction. The type certificate was issued in 1995. The airplane is a high-wing aircraft with T-tail configuration and equipped with two

PW 150A engines manufactured by Pratt & Whitney Canada Inc. Maximum take-off mass is 28,990 kg.

The aircraft type is equipped with an electronically controlled hydraulic retractable tri-cycle landing gear with twin tyres. The main landing gear are retracted aft into the engine nacelles mounted below the wings. The nose wheel retracts forward into the fuselage nose. A so-called Proximity Sensor Electronics Unit (PSEU) controls and monitors the retraction and extension process in combination with Weight-on-Wheels (WOW) sensors. The landing gear selector lever for the retraction and extension process is located in the cockpit area to the right of the centre. Indication lights indicate the positions of the wheel well doors and the landing gear. In order to actuate the landing gear lever the red Lock Release button has to be pushed simultaneously. The landing gear lever illuminates amber after its actuation until the position of the landing gear corresponds with the position of the lever (UP or DN).

The design of the landing gear selector unit, the landing gear lever, the lock release button, and the indication dates from the '70s and was first used for the aircraft type de Havilland Canada DHC-7 (Dash 7).



Position landing gear lever, lock release and indication lights in the cockpit

Photo: BFU

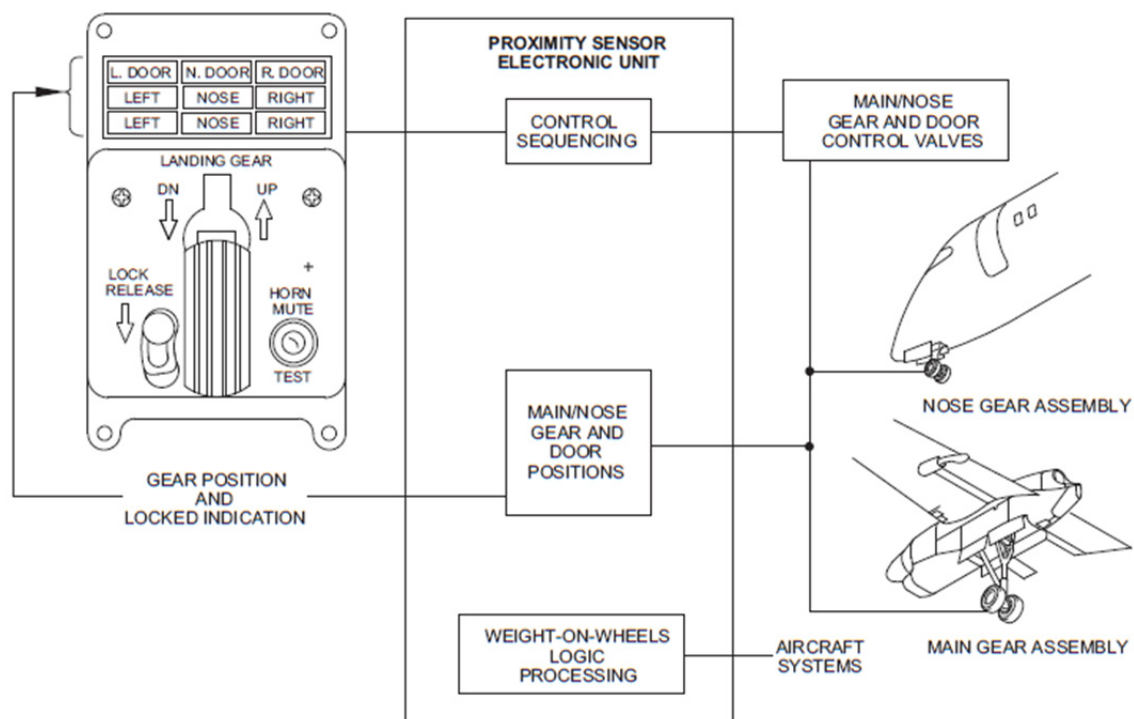
The V_{LO} (Landing gear operation) is 200 kt and the V_{LE} (Landing gear extended) 215 kt.

Schematic description of the manufacturer (Excerpt 12.13 (ATA 32) Landing Gear):

Retraction Sequence

When the landing gear selector lever is selected to the UP position, hydraulic pressure from No. 2 system is applied to the retract side of the system (Figure 12.13-19). This opens the nose gear forward doors and retracts the nose gear, it also opens the main gear aft doors and retracts the main gear. The aft nose gear doors are mechanically linked and close with the retracting nose gear. After nose gear retraction, the forward nose gear doors close hydraulically. The forward main gear doors are mechanically linked and close with the retracting main gear. After main gear retraction, the aft main gear doors close hydraulically.

The advisory light sequence during retraction starts with the LEFT, NOSE and RIGHT red unsafe lights and the amber selector handle light coming on. At the same time, the green LEFT, NOSE and RIGHT lights go off to show the gear is not locked down. The amber door advisory lights come on to show the hydraulically operated gear doors are open. When the landing gear is retracted and locked in the up position, the amber selector handle light and red advisory lights go out. Finally, the amber gear door advisory lights go out to show all the hydraulic gear doors have closed. No advisory lights should be on if the gear is up correctly. The main and nose gear are held in the up position mechanically with uplocks, and hydraulic pressure is removed from the system.



The aircraft type was certified in accordance with Part 25 Airworthiness Standards: Transport Category Airplanes. Certification specifications for the retractable landing gear are stipulated in Sec. 25.729 and CS 25.729 - Retracting Mechanism. These in-

clude stipulations for indications and warnings for the avoidance of landings without extended landing gear. Stipulations regarding the risk to retract the landing gear on the ground are not included. The manufacturer and the European Aviation Safety Agency (EASA) stated that so far they have no information concerning similar accidents with the DHC-8-402.

The airplane involved, manufacturer's serial number 4420, year of manufacture 2012, had a certificate of registration issued in Luxembourg. The latest Airworthiness Review Certificate (ARC) was issued on 21 October 2014 valid until 30 October 2015. Total operating hours were about 7,131 hours. Take-off mass at Saarbrücken Airport was approximately 21,700 kg. The commensurate V_1 (take-off decision speed) was 112 kt and V_R (rotation speed) 115 kt.

Meteorological Information

At the time of the take-off the valid aviation routine weather report (METAR) of

0950 hrs of Saarbrücken Airport read:

Wind: 070°/15 kt, TEMPO 060°/15G25kt
Visibility: More than 10 km
Clouds: No clouds below 5,000 ft (CAVOK)
Temperature: 10°C
Dewpoint: 4 °C
Barometric air pressure (QNH): 1,030 hPa

Radio Communications

Radio communications between the crew and Saarbrücken Tower were recorded and made available to the BFU for evaluation.

Aerodrome Information

Saarbrücken Airport (EDDR) is located 4 Nautical Miles (NM) south-east of Saarbrücken City. Aerodrome elevation is 1,058 ft AMSL.

The airport has one asphalt runway of 1,990 m length and 45 m width and a grass strip which is 545 m long and 50 m wide. Both are oriented 086°/266°. Three taxiways (A, B, C) lead from the apron to the asphalt runway.

Flight Recorder

The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were seized by and read out at the BFU (excerpt FDR - data of the take-off run see appendix).

FDR:

Manufacturer: Universal Avionics
Type: SSFDR
Part Number: 1606 – 00 - 01
Serial Number: 550
Recording: 260 Parameter, 500 Hours

CVR:

Manufacturer: Universal Avionics
Part Number: 1607 – 00 - 00
Serial Number: 442
Recording: Four mono data, 120 minutes

The recorders were undamaged. All recorded parameters were readable. Both recorders stopped recording at 1016:50 hrs prior to the airplane's standstill.

The inertia switch (Part No 3LO-881/5.5), which cuts the power supply in case of an accident with high acceleration values (> 5.5 g), was removed and examined at the manufacturer's on 3 December 2015 in the presence of the US National Transportation Safety Board (NTSB). Function test and examination did not reveal any defects.

In the past, several air accident investigations (e.g. BFU 3X010-13, NTSB CEN13FA192, TSB A09A0016, and TSB A07A0134) determined that due to installed inertia switches the recorders had shut off early. Due to missing information for the accident investigation the TSB wrote:

The European Organization for Civil Aviation Equipment (EUROCAE) document ED112, Minimum Operational Performance Specification for Crash Protected Air-

borne Recorder Systems issued in March 2003 states that negative acceleration sensors (g-switches) shall not be used because their response is not considered to be reliable. In addition, the UK Air Accidents Investigation Branch (AAIB) issued Safety Recommendation 2008-074 which states: It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency review the certification requirements for automatically stopping flight recorders within 10 minutes after a crash impact, with a view to including a specific reference prohibiting the use of 'g' switches as a means of compliance as recommended in ED112 issued by EUROCAE Working Group 50.

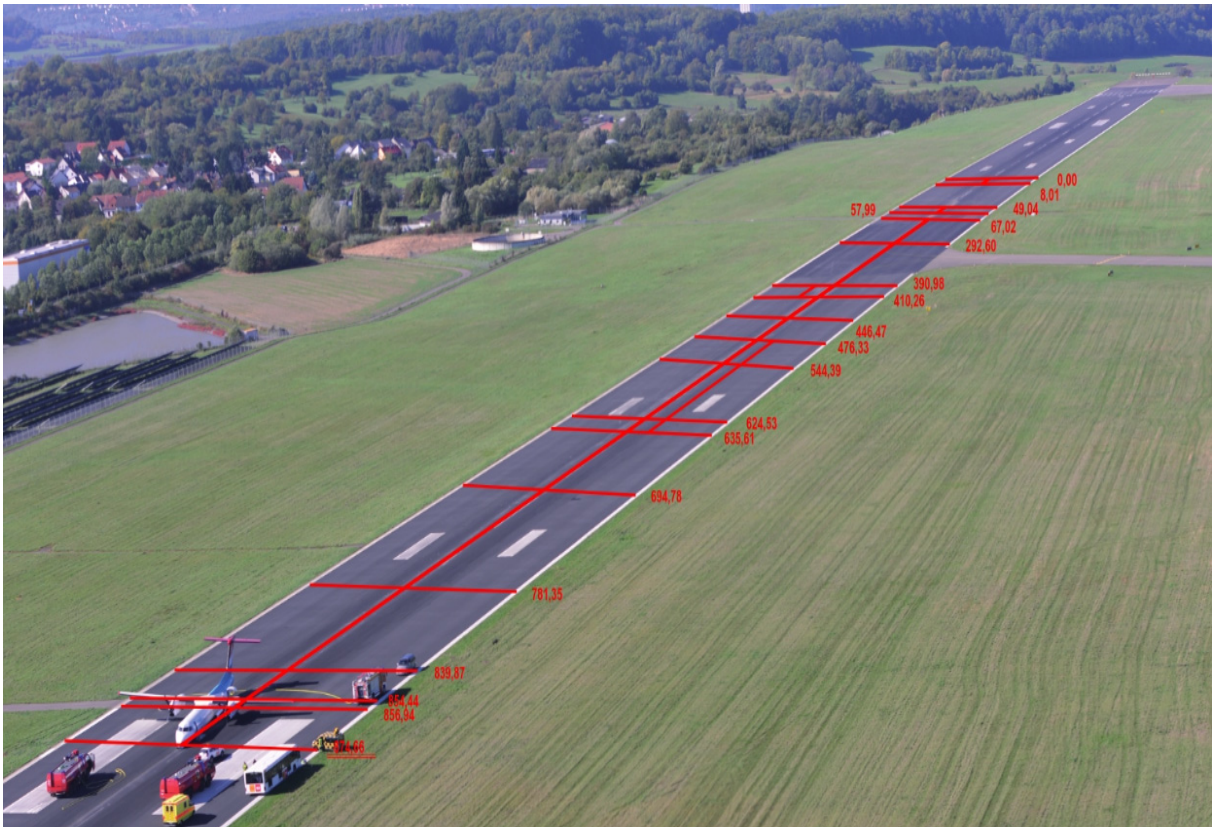
Based on the determinations and discussions regarding the examination of the inertia switch the manufacturer came to the following conclusion:

To this end, Inertia Switch is committed to updating their g-switch product line to incorporate time-delay features that would continue to supply power to the system for a predetermined interval following a switch activation. Preliminary designs for this change are already in progress.

Wreckage and Impact Information

The airplane bounced three times and skidded for a distance of approximately 807 m. It then came to rest approximately in the centre of the runway, abreast the PAPI of runway 27.





Overview skid marks and final position of the airplane

Drawing and Photo: Airport

The airplane rested upright on the fuselage. The main landing gear was completely retracted and the wheel well doors at the engine cowlings closed. The nose landing gear was retracted. The front nose landing gear doors were open and damaged. The landing gear selector lever in the cockpit was in the position “UP”, i.e. retracted. The propeller blades of the left propeller were shortened by approximately 40 cm and the ones of the right by about 1 cm. Commensurate propeller impact marks were found on the runway. The entire length of the left lateral fin below the fuselage was abraded by about 3 cm. The fuselage’s bottom surface was scratched, dented and completely abraded, respectively, from about 2 m aft of the nose landing gear until the aft baggage compartment.



Damage on the fuselage's bottom surface (in flight direction)

Photo: BFU

Approximately 1,630 kg fuel were on board the airplane. No fuel leaked from the airplane.

After the salvage operation the airplane was jacked up and the function of the retractable landing gear checked. The test was repeated several times and neither test showed any malfunction of the landing gear, the operation controls or indications.

It was determined that the landing gear will retract if the nose landing gear is airborne (Weight-on-Wheel switches -> air) but the main landing gears are still on the ground (WOW switches -> ground). The manufacturer stated that this corresponded with the design logic.

Fire

There was no evidence of fire during the take-off run or after the accident.

Organisations and their Procedures

The operator had been approved by the Direction de l'Aviation Civile, Luxembourg.

The operator had made stipulations in the Operation Manual (OM) regarding procedures for crew cooperation during take-off, among others.

Part A Chapter 8.3.20 General Cockpit Procedures of the OM stipulated:

300 Co-operation between crew members

Since crews are constantly changing, it is necessary to facilitate the teamwork by strict adherence to the [...] Standard Operating Procedures, as prescribed in OM Part A and B.

[...] crew members shall use standardized verbal callouts during each phase of flight. Standard callouts are used to improve crosscheck, coordination and mutual crew member awareness and are typically used to:

Give command, delegate a task; Acknowledge a command or confirm receipt of an information; Challenge and respond to checklist items; Call a change of an indication Identify a specific event; Identify exceedances. [...]

Part A Chapter 8.3.22 Cockpit Procedures of the OM stipulated:

100 General

Take-off must only be performed under such conditions that it can be either safely discontinued or continued should an engine fail.

The actual figures for V_1 , V_R , V_2 shall be determined by both pilots individually and then be compared.

These speeds shall be called out distinctly by the PNF. Callouts and procedures are contained in OM Part B for the respective aeroplane types.

Standard take-off procedures as laid down in the operational documentation of OM Part B are based on operational capabilities of the respective aeroplane and noise abatement procedures.

Monitoring and cross-checking of the flight instruments during take-off and climb-out (especially in IMC or darkness) is a "must" for the following reasons:

take-off during darkness but in good visibility has led to accidents because the PF took his reference outside the cockpit only and perceived the take-off acceleration as a positive rate of climb.

take-off and climb-out procedures require considerable nose-high attitude. Should the artificial horizon of the PF fail in such a phase without being readily noticed, the aeroplane might come immediately into a very dangerous situation.

Since some instruments react slowly, only a continuous monitoring and cross-checking of all available flight instruments (especially the artificial horizon, IAS, rate of climb indicators and altimeter) provides the correct information for a particular situation. The PNF must help the PF to perform this difficult task and shall therefore restrict other cockpit work to the bare minimum required during take-off and the initial climb-out phase.

Part B of the OM stipulated operating procedures for the DHC-8-402. Chapter 2 contained checklists for normal procedures, describing texts, lists and callouts.

600 Take off roll callouts

CAPTAIN	COPILOT
After line-up, checks heading / elevation and announces: "RUNWAY HEADING AND ELEVATION CHECKED"	
	Replies: "CHECKED"
Just before advancing the power levers announces: "TAKEOFF, YOUR / MY CONTROLS"	
	Replies: "YOUR / MY CONTROLS"
Advances slowly the power levers to RATING detent.	
PF	PNF
	Observes spoiler advisory lights go out, PFCS indication on MFD show spoilers retracted and announces: "SPOILERS CLOSED"
	Checks A/F ARM annunciation on ED and announces: "AUTOFEATHER ARMED"
	Checks torque matching the torque bugs. Verifies normal engine indications and announces: "POWER CHECKED"
	At 80 KIAS announces: "80 KNOTS"
Replies: "CHECKED"	

The cross-check of the engine instruments during the takeoff roll is performed by the PNF.

700 Take off callouts

PF	PNF
	At V_1 announces: "V ₁ "
	At V_R announces: "ROTATE"
Rotates to 8° to achieve lift off. After lift off continues to a minimum pitch attitude of 10° to achieve V_{FTO} .	When positive climb is indicated on the flight instruments announces: "POSITIVE CLIMB"
Requests: "GEAR UP"	
Climbs with V_{FTO} .	Selects landing gear up and replies: "GEAR UP SELECTED"
	Checks gear up, no lights and announces: "GEAR UP AND LOCKED"
For FMS departure, requests: "SELECT LNAV"	
	Presses NAV, checks LNAV on FMA and announces: "LNAV SELECTED"
Requests: "SELECT INDICATED AIRSPEED, SET V_{FTO} "	
	Selects IAS, sets V_{FTO} , checks on FMA and announces: "INDICATED AIRSPEED SELECTED, V_{FTO} SET"

The PNF monitors flight instruments and flight path.

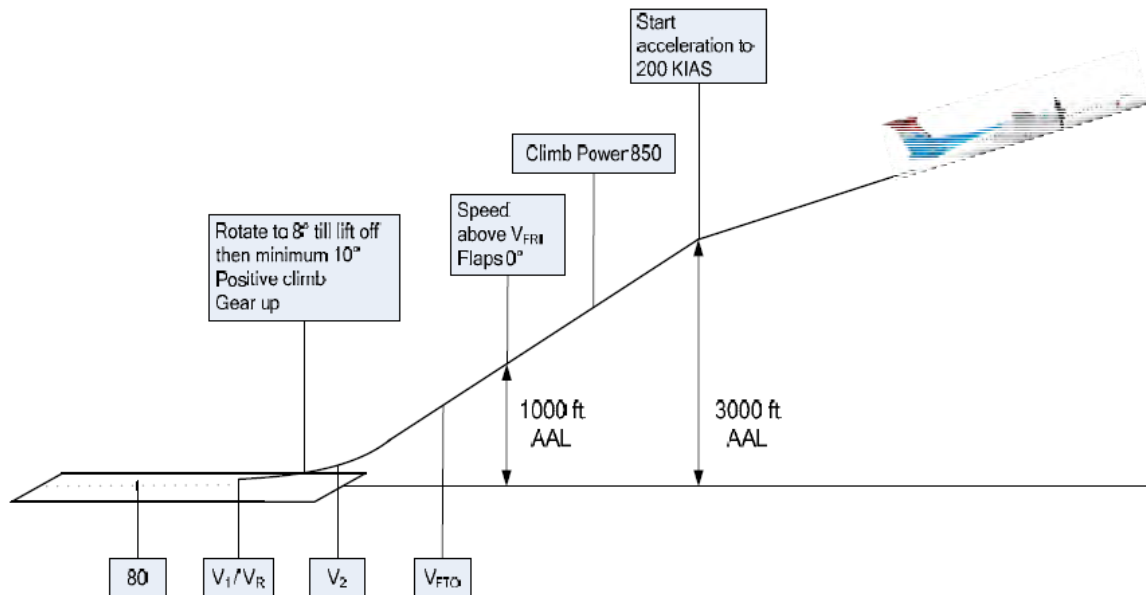
NOTE:

"POSITIVE CLIMB" will be announced when the flight instruments clearly indicate that the airplane is climbing (VSI, altimeter). This is particularly important when taking off in low visibility or low ceiling weather conditions.

900 Normal take off profile

The following profile summarize the major actions performed by the crew.

Callouts and additional actions to be performed by the crew are not detailed in the profile.



Chapter 3.5 Engine Failure in Take-off stipulated: [...] *The gear must be retracted as soon as a positive rate of climb is established.* [...]

Additional Information

Due to the accident 30 flights from the last 3 months prior to the accident were randomly selected. Their Quick Access Recorder (QAR) data was examined regarding the retraction of the landing gear using the Operational Flight Data Monitoring Program (OFDM). In addition, 10 take-offs from runway 09 at Saarbrücken Airport were examined. Furthermore, all flights (29) of the co-pilot since 5 August 2015 as PNF were examined. In all cases the time of the pitch application for rotation, the rate of climb, and the radar height were examined. The examination of the flights determined no indication that the landing gear lever was actuated too early.

In addition, crews of the operator flying the type in question were interviewed and asked if they were familiar with the retracting logic of the landing gear. All interviewees assumed that the landing gear cannot be retracted on the ground. They were not aware that the landing gear may retract even if only the nose landing gear is airborne.

In the flight simulator the company is using the early actuation of the landing gear lever to the UP position was re-enacted with different speeds (prior V_1 , after V_1 , prior V_R , after V_R) and lifted nose. The landing gear never retracted during the take-off run and the tail never had ground contact. Each time normal take-off was possible.

Air Accidents with Retractable Landing Gears

According to the US Federal Aviation Authority (FAA) 1,878 accidents involving retractable landing gears occurred in the USA between 2002 and 2006; 1,777 of them had no technical causes. The better part of these accidents occurred due to retracted landing gears during landing. It was rather rare that the landing gear was retracted too early during the take-off run. According to the FAA Advisory Circular (AC 20-34D) issued in 1980, in 1979 106 accidents occurred involving retractable landing gears, of which 2.8% occurred due to early retraction during take-off. Human factors as cause were determined in 63% of the accidents.

In transport aviation similar accidents are rather rare. Examples for early retraction of the landing gear during take-off:

- 1959, Addis Ababa-Lideta Airport, Fokker F27
- 1974, Southend Municipal Airport, DC 6B
- 1985, Hot Springs Airport, SA226TC Metro
- 2006, Buenos Aires Newbury Airport, SA227AC Metro III
- 2010, Tallinn Ülemiste Airport, AN-26B

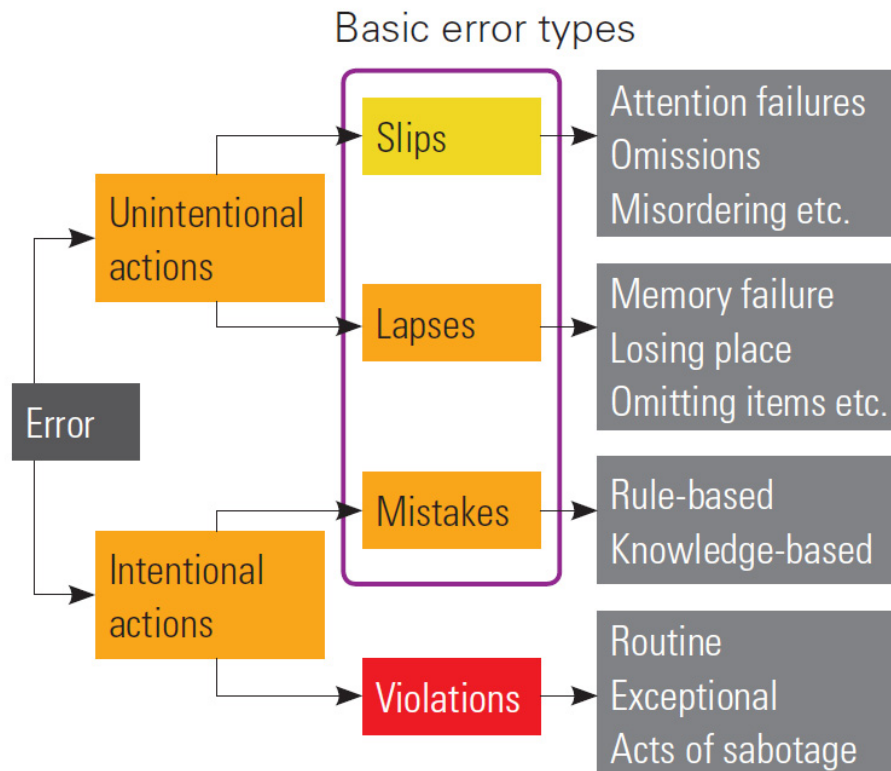
Human Error

In the past in regard to Human Error investigations of air accidents were conducted and studies compiled to increase flight safety. Some are quoted below (excerpts).

Civil Aviation Safety Authority: SMS for Aviation—Human Factors a Practical Guide

Making errors is about as normal as breathing oxygen. (James Reason)

Error is a normal and natural part of everyday life—it is generally accepted that we will make errors daily. In fact, research suggests that we make between three to six errors every waking hour, regardless of the task being performed.



Adapted from Human Error, J. Reason, Cambridge University Press, Cambridge (1992).

Managing error: If you want to find actual solutions for the problems human errors cause, you often need large systemic changes. [...] Another way is for you to build error tolerance into the system—limiting the consequences of errors when they do occur. This involves adopting a broad organisational approach to error management, rather than focusing solely on the individuals making the errors. [...]

For example, the most common types of errors (slips and lapses) involve attention, vigilance and memory problems. Therefore, developing procedures (checklists that act as memory aids), designing human-centred equipment (alarms and warning devices if operationally critical items are forgotten) and training programs to raise awareness of human factors issues, are all common tools.

Health and Safety Executive: Reducing error and influencing behaviour

Accidents can occur through people's involvement with their work. As technical systems have become more reliable, the focus has turned to human causes of accidents. It is estimated that up to 80% of accidents may be attributed, at least in part, to the actions or omissions of people. [...] We all make errors irrespective of how much training and experience we possess or how motivated we are to do it right. Failures are more serious for jobs where the consequences of errors are not

protected. However, errors can occur in all tasks, not just those which are called safety-critical.

Active failures have an immediate consequence and are usually made by front-line people such as drivers, control room staff or machine operators. In a situation where there is no room for error these active failures have an immediate impact on health and safety.

Errors fall into three categories: slips, lapses and mistakes. Slips and lapses occur in very familiar tasks which we can carry out without much need for conscious attention. These tasks are called 'skill-based' and are very vulnerable to errors if our attention is diverted, even momentarily. Driving a car is a typical skill-based task for many of us. Slips and lapses are the errors which are made by even the most experienced, well-trained and highly-motivated people. [...]

Slips are failures in carrying out the actions of a task. They are described as 'actions-not-as-planned'. Examples would be: picking up the wrong component from a mixed box, operating the wrong switch, transposing digits when copying out numbers and misordering steps in a procedure. Typical slips might include: performing an action too soon in a procedure or leaving it too late; omitting a step or series of steps from a task [...]

Everyone can make errors no matter how well trained and motivated they are. Sometimes we are 'set up' by the system to fail. The challenge is to develop error-tolerant systems and to prevent errors from occurring. [...]

Airbus, Flight Operations Briefing Notes, Human Performance - Error Management:

Slips and lapses are failures in the execution of the intended action. Slips are actions that do not go as planned, while lapses are memory failures. For example, operating the flap lever instead of the (intended) gear lever is a slip. Forgetting a checklist item is a lapse. [...]

Slips and lapses typically emerge at the skill-based level. There are several known mechanisms behind slips and lapses. It is known, for example, that mental "programs" which are most commonly used, may take over from very similar programs, which are less frequent or exceptional. [...]

Slips are usually easy to detect quickly and do not have immediate serious consequences due to in-built system protections.

Lapses may be more difficult to detect, and therefore may also be more likely to have consequences. [...]

One common false assumption is that errors and violations are limited to incidents and accidents. Recent data from Flight Operations Monitoring (e.g. LOSA) indicate that errors and violations are quite common in flight operations. According to the University of Texas LOSA database, in around 60% of the flights at least one error or violation was observed, the average per flight being 1.5.

A quarter of the errors and violations were mismanaged or had consequences (an undesired aircraft state or an additional error). The study also indicated that a third of the errors were detected and corrected by the flight crew, 4% were detected but made worse, and over 60% of errors remained undetected. This data should underline the fact that errors are normal in flight operations and that, as such, they are usually not immediately dangerous. [...]

Real solutions for human error require systemic improvements in the operation. One way consists of improving working conditions, procedures, and knowledge, in order to reduce the likelihood of error and to improve error detection. Another way is to build more error tolerance into the system, i.e. limit the consequences of errors.

Error Prevention aims at avoiding the error all-together. This is possible only in some specific cases and, almost without exception, requires design-based solutions. [...]
Error Tolerance aims at making the system as tolerant as possible towards error, i.e. minimizing the consequences of errors.

Analysis

History of the Flight

The accident occurred during rotation from Luxembourg to Hamburg and back with two short stopovers in Saarbrücken. The crew stated that until the accident the flights of the day had occurred without incidents. It had been a rather relaxed day without technical problems, no time stress, no traffic problems, or difficult passengers. They had been looking forward to the early end of shift after conclusion of the short flight to Luxembourg.

In Saarbrücken only a few passengers left the airplane and in good time the airplane was ready to depart again. After coordination for an early take-off the crew received engine start-up clearance. During taxi they received take-off clearance. After a short

stop in position at runway 09 acceleration for take-off was begun. The analysis of the recorders and the crew interviews showed that during take-off run, after reaching rotation speed, the landing gear lever was put into position UP and the landing gear retracted during rotation with lifted nose.

Without the support of the main landing gear the tail of the aircraft hit the runway. The recorded data of the FDR and the ground contact of the tail strike warner at about 5° nose up show that the main landing gear folded back and retracted before the airplane had reached the rotation pitch of approximately 8° nose up. Due to the tail strike the tail bounced off the ground. This reduced the pitch instantly even though the pulled control input of the PF still remained. Therefore the pitch was not sufficient to produce enough lift for the airplane to become airborne even though rotation speed had been reached and engine thrust remained unchanged.

Once the PF had realised the occurrence he reduced engine thrust and tried to keep the airplane on the runway and stop it.

The cabin crew stated that during the slide on the runway smoke and acrid metallic smell had developed which caused them to open the doors and evacuate the aircraft immediately after it had come to a standstill.

Crew

Both pilots held the required licences and checks. Both were very experienced on the type and in the respective role as PF or PNF.

For the co-pilot (PNF) the day of the accident had been the first day of work after some weeks' vacation. The pilot in command (PF) had had a 16-hour rest period prior to this shift. Up until the accident both pilots had flown less than five hours. The CVR recordings did not indicate any indications for fatigue.

The crew communicated friendly in English; the communication alluded to flying tasks only. The recordings showed that during engine start-up, taxiing, take-off, etc. the procedures of the operations manual were applied. The commensurate checks (after start, before take-off, into position, etc.) were conducted and the checklists in the so-called challenge and respond procedure completed. The two-hour long CVR recording showed that actions, checks, procedures, etc. were conducted efficiently, competently, and adequately in accordance with the procedures.

Human Error

Each pilot and flight crew is aware that the retractable landing gear of an airplane has to be extended prior to landing and shall not be retracted on the ground.

Nevertheless, accidents involving retractable landing gears occur without technical reasons. The better part of these accidents occurred due to retracted landing gears during landing. It is rather rare that the landing gear was retracted too early during the take-off run.

At the time of the accident, the weather was good, during the three previous flights no technical problems had emerged, there had been no other traffic in Saarbrücken, and due to the few remaining passengers and the fuel on board the aircraft was relatively light, and the atmosphere on board had been rather good. It is probable that the agitation level of the experienced crew was rather low for the short flight to home base (about 15 minutes). Therefore the BFU cannot rule out that the co-pilot's (PNF) concentration during the fourth take-off of the day within less than four hours had been reduced.

The early, not requested, grasp of the landing gear selector lever during the take-off callout procedure came suddenly and unexpectedly for the PF. After the event, the co-pilot could not explain her actions.

Publications on human performance and error management (see page 16 ff) describe such actions as Slip. It is a spurious action which occurs unintentional und unplanned in a correct, known, often trained and repeated course of action. Especially processes which are repeated quite often and therefore generate reduced concentration are susceptible for these kinds of errors.

Additional training and checks take no effect because no one is immune to such errors. In general, error tolerant design, a warning system for the detection of a spurious action, or a technical solution is considered approaches to solving the problem.

Airplane

The airplane was registered and maintained in accordance with the commensurate aeronautical regulations. During the accident it was severely damaged.

After the salvage operation the landing gear was examined and no indications of technical failure determined.

The examination showed that the design of the landing gear selector lever is unusual compared to others in transport aviation. The lock release button has to be pushed

with each actuation. Otherwise the lever is locked. The manufacturer stated that this should prevent the unintentional actuation on the ground, e.g. by hitting it with one's knee. If the lock release button is pushed the landing gear lever can be put into the UP position on the ground. Consequently the landing gear lever would illuminate due to the disagreement of lever position and landing gear position. Other transport aircraft (B737, EMB145, A320, Fokker 50, et.) only have emergency lock override buttons or switches, to override the automatic lock in case of blockade, etc. In normal operation the lock override does not have to be used. An automatic lock prevents the actuation of the lever on the ground until the landing gear sensors report the aircraft airborne.

The investigation also determined that the landing gear retracts in accordance with the control design logic if the cockpit commands it (lever in position UP) and at least one landing gear (nose wheel or main landing gear) is airborne according to the weight on wheels sensors. During rotation with lifted nose this is the case.

The recordings of the CVR and FDR shut off during the second contact with the runway. This was probably due to the impact energy or an acceleration peak. The inertia switch was examined but no malfunctions were found. Therefore, a hard impact has to be assumed. Due to the shut off of the recorders objective data concerning the time of the engine thrust reduction and the actions of the crew until the evacuation of the aircraft were missing.

In this regard the BFU can only associate with the recommendations the European Organisation for Civil Aviation Equipment (EUROCAE) and the British Air Accident Investigation Branch (AAIB) have already issued (see page 8).

Organisational and Management Information

The accident occurred with a commercial air transport aircraft, a full-time cockpit crew of an internationally operating air operator. The selection of the crew, the training, the proficiency checks, and the duty roster corresponded with the accepted standards of the aviation industry.

The operator had a Flight Operations Manual (FOM) approved by the Luxembourgish supervisory authority. In regard to the take-off the specified callouts, the actions, and responsibilities corresponded with the requirements of the FOM and internationally common procedures.

The analysis of 40 randomly selected flights with the type in question of the operator using the Operational Flight Data Monitoring Program did not reveal any indications of previous incidents where the landing gear was retracted too early.

The BFU is of the opinion that it was neither due to a systemic organisational deficiency in regard to the actuation of the retractable landing gear nor to an erroneous procedure.

Conclusions

The air accident was the result of an early retraction of the retractable landing gear during take-off, which was not prevented by the landing gear selector lever and the retracting control logic.

Contributory factors:

- Reduced concentration level
- A break in the callout process / task sequence on the part of the PNF
- Actuation of the landing gear lever to the UP Position too early
- Control logic design allows retraction of the landing gear with one wheel airborne

Safety Recommendations

Due to the accident the operator had contemplated to implement additional callouts prior to the actuation of the landing gear lever. During several simulator flights the additional callouts were tested. Especially when emergency situations during take-off run were added these callouts resulted in delays and distractions. Therefore the operator refrained from implementing them.

The operator implemented instead a training scenario during recurring crew training and “Lessons Learned” which are meant to increase crew awareness.

In the Operational Flight Data Monitoring Program (OFDM) an event trigger was determined which in the future calls attention to early landing gear retraction in operational flight operations.

The aircraft manufacturer also responsible for the landing gear design has implemented a change in the decision logic of the PSEU for retraction of the landing gear

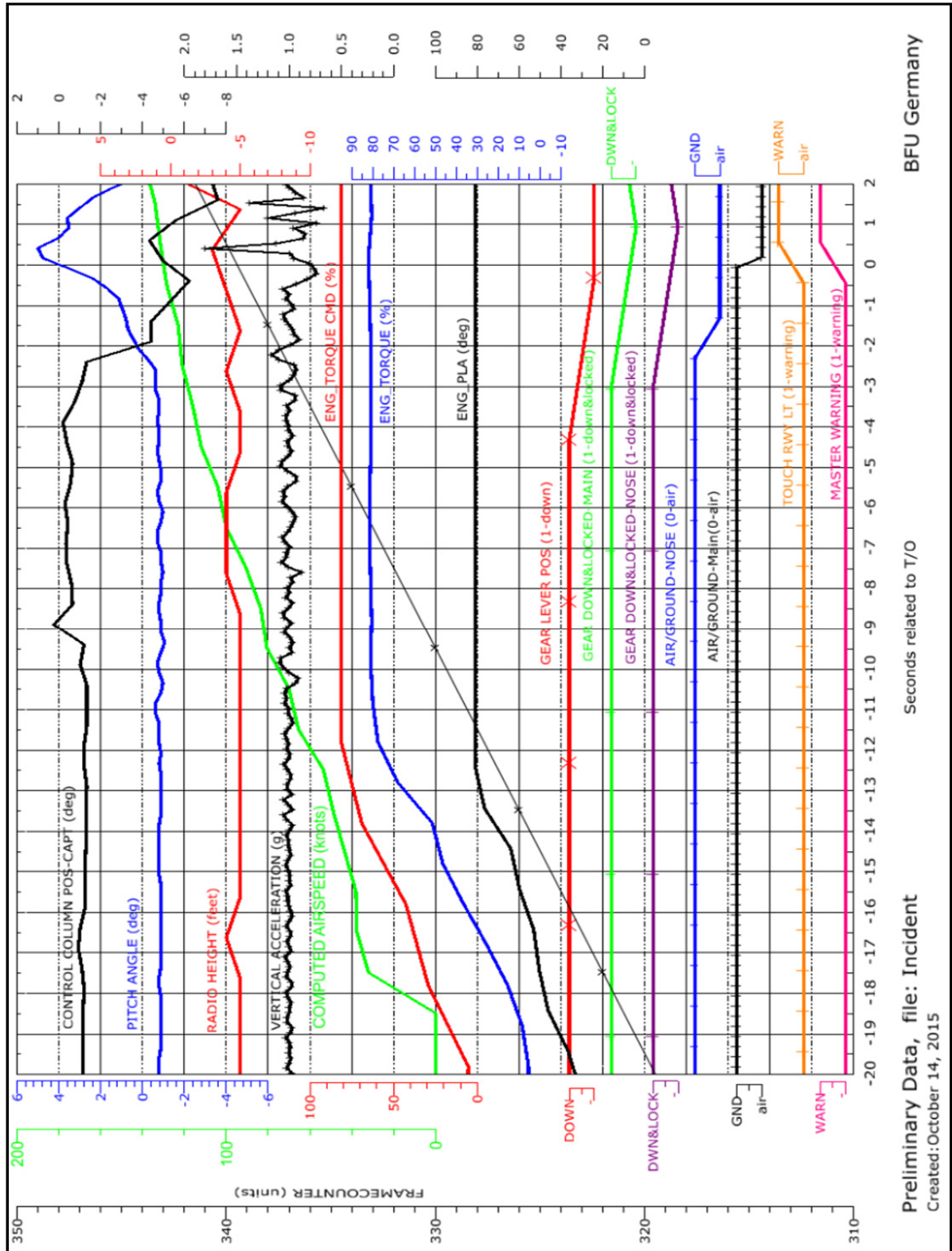
in the scope of an Airworthiness Directive (AD CF-2016-31) by Transport Canada dated 12 October 2016. With the new logic the PSEU retracts the landing gear when all WOW sensors report the aircraft airborne. Compliance period for the AD is 18 months after publication.

Due to these actions the BFU refrained from issuing safety recommendations concerning this matter.

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Field investigation: Thomas Karge, Axel Rokohl
Assistance: Hans-Werner Hempelmann
Braunschweig: 31/10/2016

Appendix

FDR data of the take-off run



BFU Germany

Seconds related to T/O

Preliminary Data, file: Incident
Created: October 14, 2015

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 - FIUUG*) 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.

Published by:

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