Investigation Report

Identification

Type of Occurrence: Accident
Date: 14 December 2017
Location: Near Waldburg
Aircraft: Airplane
Manufacturer / Model: Cessna Aircraft Company / C510 Mustang
Injuries to Persons: Three persons fatally injured
Damage: Aircraft destroyed
Other Damage: Damage to forest
State File Number: BFU 17-1604-CX

Factual Information

During intercept of the instrument approach ILS RWY 24 for a landing at night during snowfall and in icing conditions at Friedrichshafen Airport the airplane suddenly lost altitude, collided with trees, and crashed into a forest.
History of the Flight

On the morning of the day of the accident, two pilots of an Austrian operator flew with the C510 Mustang involved from Friedrichshafen Airport to Egelsbach Airfield. Take-off was at 0851 hrs\(^1\). On board was also a passenger. At 1743 hrs the crew, and the same passenger, took off for the return flight in accordance with Instrument Flight Rules (IFR) to Friedrichshafen. The flight route to the south took them along Mannheim, Stuttgart, and Mengen-Hohenengen. The maximum flight altitude was Flight Level (FL) 210. At 1759 hrs, north-west of Stuttgart, Center Langen instructed the crew to descend to FL 170. At 1801 hrs, west of Stuttgart toward the way-point HEUSE, Center Langen issued the instruction to descend to FL 150. At 1803 hrs the crew was instructed to change frequency to Swiss Radar, who instructed the crew to descend to FL 110. At 1805 hrs the crew established radio contact with Zurich Arrival. By giving vectors, Zurich Arrival guided the airplane to the announced ILS RWY 24 Friedrichshafen. At about 1806 hrs a heading of 140° and descent to FL 90 was instructed. At about 1810 hrs Zurich Arrival instructed the crew to further descend to 6,000 ft AMSL. At about 1811 hrs they were instructed to descend to 5,000 ft AMSL and at 1812 hrs to turn right to 150° and further descend to 4,000 ft AMSL.

At 1813:28 Zurich Arrival instructed: [...] right heading two one five, cleared for the ILS approach two four, report established. The crew acknowledged correctly.

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\(^1\) All times local, unless otherwise stated.
Then the radar controller noticed that, in 4,000 ft AMSL, during intercept, the aircraft slightly overshot the localizer with about 240 KIAS and reached a high rate of descent. He repeatedly called the aircraft, but the crew did not respond any more.

Witnesses near Waldburg saw and heard an airplane in low altitude. One witness heard the accident and saw a short but intense fire in a forest about 1.5 km west of Waldburg. He called the rescue personnel.

At about 1814 hrs the airplane had contact with objects in a forest west of Waldburg. Then it flew with high speed and a flat angle in another forest approximately 1,000 m away. The three occupants suffered fatal injuries and the aircraft was destroyed.

**Personnel Information**

**Pilot in Command**

The 45-year-old Pilot in Command (PIC) held an Austrian Commercial Pilot Licence (CPL(A)) issued in accordance with Part-FCL, including ATPL(A)\(^2\) theory and MCC\(^3\), initially issued in 2009. The licence listed the type ratings as PIC for C510, EMB 500/505 (MPO\(^4\)), SEP\(^5\) (Land), TMG\(^6\), Night (A), and Instrument Rating (IR) and Flight Instructor (FI) rating. All ratings were valid.

His class 1 medical certificate, without restrictions, was last issued on 12 October 2017 and valid until 18 October 2018.

According to his pilot log book he had a total flying experience of about 2,816 hours, of which about 1,953 hours were flown in accordance with Instrument Flight Rules (IFR) and about 246 hours at night. According to the operator the pilot had a flying experience of about 2,000 hours on C510.

The last Operator Proficiency Check (OPC) was documented on 4 October 2017 during a simulator session; the last Line Check (LPC) on 30 March 2017. On 23 March 2017 the pilot had completed an e-course based Upset Prevention and Recovery Training (UPRT). According to the flight duty and rest period record, in 2017 he had approached Friedrichshafen Airport a total of 58 times.
The day of the accident was the fourth day of flight duty after eleven days off-duty time. On the evening of 13 December 2017 at 2148 hrs he landed with the aircraft involved at Friedrichshafen Airport after an extended flying duty. According to the technical flight log he had been Pilot Flying (PF) during the accident flight.

Representatives of the operator and colleagues of the pilot praised his flying skills and prudence.

Co-pilot

The 49-year-old co-pilot held an Austrian Commercial Pilot Licence (CPL(A)) issued in accordance with Part-FCL, including ATPL(A) theory and MCC, initially issued in 2008. The licence listed the type rating C510 as co-pilot valid until 31 July 2018.

His class 1 medical certificate, with the restriction VDL (correction for defective distant vision) was last issued on 24 August 2017 and valid until 23 September 2018.

According to the operator, the co-pilot had a total flying experience of about 800 hours. On 24 July 2017 he had completed a 14-day EASA initial pilot course C510 including 20 hours simulator flight training. According to his C510 type rating checkflight protocol of 24 July 2017 he had a total flying experience as PIC of 371 hours. According to his flight duty and rest period record he had a flying experience of about 140 hours after acquiring the C510 type rating. The operator stated that the co-pilot was still in the supervision phase after acquiring his type rating. The respective supervision records were supposedly on board of the accident airplane.

On 29 July 2017 the pilot had completed an e-course based UPRT. According to the flight duty and rest period record, he had approached Friedrichshafen Airport a total of 15 times since he started working for this operator in July 2017.

The day of the accident was the first day of flight duty after eight days off duty.

Neither representatives of the operator nor colleagues could say anything about his flying skills or behaviour.

Aircraft Information

General

The C510 Mustang of Cessna Aircraft Company is a so-called Very Light Jet (VLJ) in all-metal construction for up to six persons. In 2006 the type certificate was issued in accordance with CS 23/FAR 23. Production ended in 2017. Up until then 471
C510 Mustang were produced. The airplane is a low-wing aircraft with T-tail configuration and equipped with two PW 615F-A engines manufactured by Pratt & Whitney Canada Inc. The cockpit is equipped with dual controls. Flight control occurs conventional via wire cables to the control surfaces. For the actuation of the landing gear and the brakes a hydraulic system is used. Maximum take-off mass is 3,921 kg. The airplane is certified for single-pilot operation and flights in icing conditions.

Avionics

It is equipped with an integrated Garmin G-1000 avionic system. The system has three monitors which display the flight instruments, the engine and system monitoring and includes the flight control, navigation, and communications systems. Part of the G-1000 is a caution and warning system including the Engine Indication and Crew Alerting System (EICAS).

![Garmin G-1000 cockpit and panels](source: Cessna)

The Garmin G-1000 comprises the Automatic Flight Control System (AFCS) which ensures a flight path and automatic attitude control. The AFCS includes the following
basic functions: Flight Director, Autopilot, Yaw Damper, and Manual Electric Pitch Trim. A total of four flight-control servos are actuated.

The essential functions are redundantly designed. The Flight Director (FD) control is limited to: Pitch ±20°, Vertical Acceleration 0.1g, Bank Angle 30°, Bank Rate 5°/second. The maximum bank angle the FD applies during intercept of the localizer in LOC mode is 25°. If the FD is engaged roll hold mode (ROL) is always active. It automatically reduces a bank angle of more than 30° back to 30°, among other things.

Fig. 3: Schematic graph of the Garmin G-1000 Integration in the C510

Source: Cessna
In addition to the Garmin G-1000 avionic, the aircraft is equipped with standby emergency instruments including artificial horizon, speed indicator, and altimeter.

Anti-icing

During test flights and certification of the C510, flights in icing conditions were conducted or simulated. According to the manufacturer’s record regarding natural icing and Ice Contaminated Tailplane Stalls (ICTS) there were no limitations and deviations from the certification requirements. The Cessna C510 uses the common anti-ice and de-ice systems. The engine inlet cowls are heated with bleed air. The wings and the tail section are equipped with pneumatic de-ice boots. Die cockpit windows, the sensors for the dynamic and static pressure, the stall warning sensor, the angle of attack sensor and the T2 engine sensors are heated electrically.

![Diagram of anti-icing systems](image)

**Fig. 4:** Anti-icing at the C510  
Source: Cessna

In the Operation Manual Chapter 10 Ice and Rain Protection the manufacturer recommends the following procedures: *Engine anti-ice should be selected ON anytime the indicated ram air temperature RAT is +10°C or below, and visible moisture in any form is present. WING/STAB DEICE should be selected as soon as ice is observed to accrue anywhere on the airplane.*

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7 Cessna Aircraft Company, FT510-9 Test Results Natural Icing / Ice Contaminated Tailplane Stalls (ICTS)
The switch for the wing and tail section de-icing in the cockpit has three positions: Off, Auto and Manual. The de-ice boots on the wings and at the tail section are electronically filled with compressed air, if the switch is either in Manual or Auto.

If the pilot puts the switch in Manual all de-ice boots are simultaneously filled until the spring-loaded switch is released. After the switch is released it skips into Auto. The automatic de-ice cycle then starts after two minutes.

The automatic de-ice cycle starts whenever the switch is in Auto. A timer regulates a de-ice cycle every two minutes up until the switch is either in the position Off or in Manual.

![Diagram of de-ice cycle](image)

**Fig. 5:** Description of the automatic de-ice cycle  
Source: Cessna

Except during take-off, approach or landing, in icing conditions a minimum flying speed of 160 KIAS is recommended in order to prevent ice accretion behind the de-ice boots, on the lower surface of the wings, and on the horizontal stabiliser. When the de-ice boots are activated the stall warning is automatically set to high.
Data of the Airplane Involved

The technical documentation of the aircraft involved (CESCOM 10 – Aircraft Status Report, CESCOM 20 – Projected Maintenance Due, CESCOM 100 - Long Range Projected Maintenance, Master AD/SI Report, Aircraft Maintenance Program C510 of the operator) was made available to the BFU for evaluation purposes. The aircraft had the manufacturer's serial number 510-0049, year of manufacture 2007, and was registered in Austria. The latest Airworthiness Review Certificate (ARC) was issued on 8 May 2017 and valid until 8 May 2018. The last Release to Service was issued on 5 December 2017 at a total operating time of 3,606:43 hours after the air condition had been maintained. Since then no dysfunctions had been recorded in the aircraft log book. The pilots, who had flown the aircraft since, stated that there had been no problems or system malfunctions. At the time of the accident total operating time was about 3,633 hours. The aircraft had been maintained by a maintenance organisation, certified in accordance with EASA Part 145, at Linz Airport.

According to the last weight report of 28 April 2016 the basic empty weight was about 2,442 kg / 5,385 lbs. On the morning of the day of the accident at Friedrichshafen Airport the airplane was refuelled with 800 l Jet A1 fuel. According to the entry in the aircraft log book at take-off at Friedrichshafen Airport 2,100 lbs fuel were on board; at take-off in Egelsbach there still remained 1,500 lbs. With three persons\(^8\) on board and considering fuel consumption for about 30 minutes flying time, the mass at the time of the accident was about 3,195 kg / 7,043 lbs. According to the calculations of

\(^8\) Standard mass according to the Operation Manual Part A, Chapter 8 of the operator: flight crew 85 kg and passenger 104 kg.
the manufacturer, at take-off at Egelsbach Airfield and during the entire flight centre of gravity was within the prescribed limits. Minimum final approach speed (Vref) with anti-ice on and flaps 15° was 105 KIAS for 7,000 lbs and 115 KIAS, respectively, for landing with ice on wing leading edge and for 7,500 lbs 109 KIAS and 119 KIAS, respectively.

Meteorological Information

The BFU charged the Deutsche Wetterdienst (German meteorological service provider, DWD) with the compilation of a weather expertise.

The DWD came to the following conclusion:

The information for 14 December 2017 at 15 and 18 UTC available for pre-flight preparation shows that at the flight route Egelsbach (EDFE) to Friedrichshafen (EDNY) significant weather phenomena mainly in the form of showers with rain and snow and individual thunder storms had to be expected. In addition, the Significant Weather Chart (SWC) forecast for 15 UTC south of the Danube a large precipitation area with rain and/or snow. In the Advanced Diagnosis and Warning system for aircraft Icing Environments (ADWICE) forecast icing conditions were expected for the entire flight route, which were forecast specially in the first part of the route until about the Neckar and in the destination area as regionally moderate to intense. The altitude wind forecasts allow the expectation of moderate strong wind from western direction. According to the Terminal Aerodrome Forecast (TAF) of EDNY, for the planned time of landing no larger limitations during the instrument landing had to be expected. In addition, there were no warnings of the flight weather service of the DWD suggesting larger effects on the flight.

The prevailing weather conditions at the flight route EDFE-EDNY were for the first part of the route close to the forecast. The observed weather conditions at the second half of the flight route differed significantly from the forecast since the frontal weather conditions extended farther north [...].

In summary, on 14 December 2017 at about 1715 UTC at the accident site near Ravensburg the following flight weather conditions prevailed. Meteorological visibility was about 9 km and according to the precipitation radar measurement moderate rain prevailed. The main cloud base was at approximately 3,100 ft AMSL. Freezing level was between 3,500 and 4,000 ft AMSL. Surface wind velocity was south-west with 10 to 15 knots. At the accident site there was probably slight turbulence, temporarily with
moderate intensity. Ground air temperature was about 4°C. An aerodrome warning for EDNY had been published, warning of gusty south-west wind.

At about 1649 UTC, the aircraft [...] reached the precipitation area above the southern Odenwald during climb at an altitude of approximately FL140. The precipitation area moved from south-west to north-east, i.e. mainly towards the aircraft. About 4 minutes later, at approximately 1653 UTC, at FL210 the aircraft left the precipitation area. The stated altitude corresponded [...] with a temperature span of -23 to -40°C. Precipitation intensity along the flight route was slight. [...] It is highly likely that at most slight icing occurred in the stated temperature span and slight convection.

![Fig. 7: Precipitation radar image with flight path C510 at 1645 UTC](source: DWD)

On the subsequent route segment without precipitation [...] icing at cruise level (FL210) was most unlikely since the temperature was clearly below -20°C.

At about 1705 UTC the airplane [...] entered the precipitation area above the south-west of Germany. At the time it was in slight descent at about FL150. The radiosonde measurement of Payerne representative for this area determined a temperature of about -20°C for this altitude. [...] in sheet cloud with precipitation on the ground in a temperature span between 0 and -40°C slight to moderate icing was extremely prob-
able. In general, precipitation increases the probability and intensity of icing. In the beginning precipitation intensity was slight.

In the further course of the descent the accident airplane crossed at about 1709 UTC at FL100 the Danube. At that altitude air temperature was approximately -10°C. [...] on the subsequent route segment precipitation decreased temporarily.

Finally at about 1712 UTC at approximately FL070 the airplane [...] reached the area where precipitation changed from slight to moderate. At that altitude air temperature had increased to about -5°C. Once the cloud area was reached [...] presence of severe icing conditions had to be expected.

![Fig. 8: Precipitation radar image at the time of the accident at about 1715 UTC](source: DWD)

The ceiling at 1720 UTC is the lowest during the time span considered between 16 and 18 UTC. In the area Friedrichshafen the very humid air reached from FL100 to about 3,500 ft AMSL and was therefore about 6,500 ft thick. [...]

These two facts - the thick very humid air and the unstable humid air - and the temperature span between 0 and -10°C at this altitude area increased the probability of severe icing. [...] 

After analysis of the compiled findings for this last route segment, which, from a meteorological point of view, started at about 1712 UTC with the entry of the area of
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moderate precipitation intensity, it is highly likely that on 14 December 2017 during the relevant time at FL050 to FL090 moderate to severe and/or severe icing conditions prevailed.

According to the aviation routine weather report (METAR) of 1750 hrs of Friedrichshafen Airport (ATIS Yankee), valid at the time of the approach, the following weather conditions prevailed: visibility of more than 9,999 m, slight rain, wind from 200° with 8 kt, scattered clouds (SCT) at 1,700 ft, overcast (OVC) at 2,500 ft, temperature 5°C, dewpoint 1°C, and barometric air pressure (QNH) was 1,001 hPa.

In the Friedrichshafen area sun set was at 1629 hrs.

The captain of a transport aircraft told the BFU that he had observed severe icing at his aircraft between FL 150 and FL 70 during the approach to Stuttgart at about 1800 hrs. In a short time 2 to 3 cm ice accretion had formed on the ice indicator on the windshield. Between 1757 hrs and 1804 hrs the accident aircraft passed Stuttgart airspace in descent from FL 210 to FL 170.

Approximately 10 minutes prior to the accident, another airplane, also a C510, of the company involved landed at Friedrichshafen. This PIC told the BFU that between FL 70 and FL 50 it had been pretty windy and "auch etwas bockig (also somewhat turbulent)". During the descent on ILS 24 the wind had perceptibly lessened and the flying been easy to handle. Slight icing had appeared during descent from 7,000 ft AMSL. Only a slight strip of ice had appeared on the wing leading edge. He did not use the de-ice boots. During the approach there had been snow and sleet. But the airplane had already been clear of clouds at about 3,500 ft AMSL and the runway lighting in sight early on.

About 45 minutes after the accident a Beechcraft 1900 airplane landed at Friedrichshafen. The de-icing personnel at Friedrichshafen stated that the nose, the wings, and the tail section of this airplane had been covered with massive layers of clear ice. The pilot described the icing as moderate. Prior to the next take-off the aircraft had to be de-iced with de-icing fluid of about 70° for an unusually long period of time. Four times as much de-icing fluid, 400 l, had been needed.

Aids to Navigation

Friedrichshafen Airport is equipped with several instrument approach procedures for the approach directions 06 and 24. The instrument approach procedure ILS/LOC 24
requires an approach to the Final Approach Fix (FAF) ETREM at 4,000 ft AMSL with a heading of 238°.

![Fig. 9: ILS 24 Approach profile](Source: AIP)

Radio Communications

Radio transmissions were recorded. The transmissions with Center Langen und Swiss Radar were made available to the BFU as transcripts for investigation purposes. Radio transmissions with Zurich Arrival were also available as audio recording.

The crew never mentioned any technical problems or flight operations limitations during the entire radio transmissions.

At 1813:41 hrs radio communications ended. Based on the audio recording, representatives of the operator identified the co-pilot as the pilot conducting the radio transmissions.

Aerodrome Information

Friedrichshafen Airport is located at the Bodensee (Lake Constance), east of the city centre of Friedrichshafen. Aerodrome elevation is 1,368 ft AMSL.

The airport has one asphalt runway with the orientation 060°/240° (06/24). It has a length of 2,356 m and a width of 45 m.

Flight Recorder

The airplane was not equipped with a Flight Data Recorder or a Cockpit Voice Recorder. There were no legal requirements for such equipment to be fitted.

The flight path from Egelsbach to Friedrichshafen was recorded by the radar of the air traffic service provider. Radar recordings of the German and Swiss air traffic con-
trol units and the Bundeswehr (German Armed Forces) were made available to the BFU for evaluation purposes.

The aircraft broadcast position and flight data (e.g. roll angle, ground speed, true air-speed, indicated airspeed, barometric altitude, altitude selected altitude) via the Automatic Dependent Surveillance – Broadcast (ADS-B). The Swiss air traffic control unit recorded this data in different time intervals.

Fig. 10: Excerpt ADS-B data until the end of the transmission  
Source: SkyGuide

On the Multi-Function Display (MFD), central display in the cockpit, the Garmin G-1000 can save flight parameters to a SD memory card. At the accident site a total of four SD memory cards were found. They were mechanically damaged; two were ruptured. In spite of several attempts, contact to other safety investigation authorities, and laboratories it was not possible for the BFU to read-out the memory cards.

The two engines were equipped with Full Authority Digital Electronic Control (FADEC). The FADECs save engine parameters as snapshots whenever an error occurs or threshold values are exceeded. Both FADECs were sent to the engine manufacturer in Canada. They were read-out under supervision of the Transportation Safety Board of Canada (TSB). It was determined that during the accident the FADEC of the right engine had recorded an error (Loss of Interpowerplant Communications). At the time of the error engine N2 was 70% (high idle speed) and anti-ice was on. The left engine had not triggered any storage in the FADEC. The engine manufacturer stated that during the analysis of the FADECs no indications for malfunctions of the two engines during the accident flight were found. Comparing the
recorded parameters of the last Power Assurance Test of the engines on 18 November 2017 with the parameters of the snapshot at the time of the accident the engine manufacturer assumes that at the time of the accident bleedair for the de-ice boots of the airplane was used.

The BFU charged the responsible air traffic service provider to find out whether other aircraft had been in the vicinity of the accident airplane. It was determined that no other aircraft, which could have caused e.g. wake turbulences, had been in the vicinity.

Due to the accident the radar data recordings of the airplane involved of the last six approaches to Friedrichshafen prior to the accident were requested. These showed that the approaches during intercept to the localizer were flown with 220 to 240 kt ground speed and each time the extended runway centre line was overshot.

Wreckage and Impact Information

The airplane had contact with objects in the area west of Waldburg, in a forest called Frankenberg, at about 2,450 ft AMSL. The left wing tip and parts of the rudder were found in this forest.

The accident site, near Sieberatsreute, was about 1,000 m south-west of the location where the airplane had contact with objects. The traces show a flat entry into the forest. The airplane caused a crash aisle of about 130 m which had the direction of about 240°. Several trees had been cut off and uprooted along this crash aisle. The terrain in the area of the accident site had an elevation of approximately 2,300 ft AMSL.
The airplane was destroyed during the path through the forest. Wreckage parts were distributed over an area of approximately 130 m by 50 m. Remarkable was that numerous wreckage parts lay reversed left to right, i.e. e.g. parts of the right aircraft side were found left of the accident trace and vice versa (see Appendix: Wreckage Distribution).

At the beginning of the crash aisle individual trees had caught fire. The smell of fuel was noticeable at the entire accident site.

After the accident site had been documented the wreckage was salvaged and transported to BFU facilities in Braunschweig for further investigation.

With the support of an expert of the aircraft manufacturer the wreckage was displayed laid out and investigated. It was determined that all control surfaces were present and all control surface joints had been severed by overload. All control rods and control cables from the cockpit controls to the control surfaces were examined and analysed. It was determined that at the time of the accident landing gear and flaps had been retracted. The speed brakes had also been retracted. The trim tabs on the aileron and rudder were in neutral positions. The investigation of the wreckage parts did not reveal any technical deficiencies prior to the accident.
Medical and Pathological Information

A postmortem examination was performed on the two pilots and the passenger. No evidence was found of any health impairments of the pilots. All three persons died of severe multiple trauma. The toxicological examination determined that neither of the two pilots suffered from impairments due to medications, drugs, or alcohol.

Fire

At the accident site, at the beginning of the crash aisle, several trees showed signs of fire. The central part of the wing, including a part of the right wing and the retracted right main landing gear, had burnt.

Witnesses saw a blaze in the forest which went out again after a short time.

Survival Aspects

Due to the destruction of the fuselage during entry of the forest the accident was non-survivable.

The Emergency Locater Transmitter (ELT) had deployed. The antenna had been torn off and the ELT signal was not received by air navigation services or satellite.

Witnesses observed the accident and notified emergency services by telephone. The first rescue personnel reached the accident site within a few minutes after notification.

Organisational and Management Information

According to the application for change of registration dated 16 January 2017 and the proof of transfer of operator dated 12 January 2017, two companies (A and B) were operator of the aircraft involved.

The two pilots were employed at company (A), who marketed and conducted the flights. The company was based in Bregenz, Austria. The focal point of the company was the marketing of flights with two C510 aircraft from Friedrichshafen Airport. The PIC involved was the managing director of this company and called "head pilot". Since 2 June 2017 this company no longer held an Air Operator Certificate (AOC).

The second company (B), based in Vienna, Austria, was responsible for the aeronautical scope in order to conduct passenger transport flights. It was a certified operator
and aeronautical owner of the aircraft involved. This company managed the pilots' files, the flight duty and rest period records, and the technical documentation of the aircraft. The PIC was listed in the crew list of the Operation Manual (OM) dated 19 July 2017. He had the intra-company rating to conduct line check flights. The co-pilot was not listed in the crew list.

According to the OM Part A 4.1.4 the minimum crew consisted of a commander/pilot in command qualified in accordance with OM Part A 5.2.1 and a co-pilot qualified in accordance with OM Part A 5.2.3. OM Part B 2.1 Normal Procedures and Duties described crew cooperation, task distribution for Pilot Flying (PF) and Pilot Non Flying (PNF), and the use of checklists.

The OM Part A 8.3.11.2 Icing Conditions stipulated the following:

**Inflight**

*Prior to entering areas with a risk of icing all anti-icing-de-icing equipment shall be switched on.*

*Known areas of severe icing shall be avoided. When severe icing is nevertheless encountered, every effort shall be made in order to find altitudes or areas with less icing, i.e. keep the rate-of-descent-climb high in order to cut down the time spent in these conditions.*

**Approach and Landing**

*When ice has accumulated, stalling speeds are considerably higher than normal and a stall may be entered without warning.*

*Therefore, in such a condition it is recommended to increase the airspeed according to PIC’s discretion, taking into account all relevant factors, in particular the available runway length.*

*Make wider turn […]*

OM Part B 2.1 (e) Noise Abatement and 2.1 (i) Instrument Approach describes approaches and ILS approaches as follows:
Approach

1. Pilots should organize their flight in a way allowing to leave the initial approach fix (IAF) with a speed which permits cruise speed. This speed should be maintained until approx. 12 NM from the threshold. For this part of the approach an indicated airspeed of 210 kt ± 10 kt is recommended as long as performance does not require a lower speed.

2. The subsequent part of the approach until short before the IAF should be flown at a speed of 170 kt ± 10kt. in which should be intercepted at an altitude of not less than 2000 ft. above the touchdown zone (or as published).

3. The aircraft should be shortly before or above the OM, at this time the gear should be down, the flaps in landing position and the safe approach speed should be stabilized.

Figure 18-7. ILS Approach—Normal

NOTE: In gusty wind conditions increase $V_{APP}$ by 1/2 of the gust factor in excess of 5 knots.
<table>
<thead>
<tr>
<th>Phase</th>
<th>PF</th>
<th>PNF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleared for approach</td>
<td>• orders &quot;Approach Check&quot;</td>
<td>• reads &quot;Approach Check&quot;</td>
</tr>
<tr>
<td></td>
<td>• Selects APP mode on Flight Director Mode Selector Panel LOCALIZER, GLIDESLOPE ARMED</td>
<td>CHECKED</td>
</tr>
<tr>
<td>Speed below 180 KIAS</td>
<td>FLAPS APPROACH</td>
<td>• checks speed, selects Flaps APP, when Flap travel has completed: FLAPS APPROACH SET</td>
</tr>
<tr>
<td>Localizer capture</td>
<td>LOCALIZER CAPTUREED</td>
<td>CHECKED</td>
</tr>
<tr>
<td></td>
<td>• reduces speed to 160 - 180 KIAS</td>
<td></td>
</tr>
<tr>
<td>1 dot below Glide path</td>
<td>GEAR DOWN</td>
<td>• checks speed, selects Gear down, when three green indicated: GEAR DOWN</td>
</tr>
<tr>
<td>Established on Glide path</td>
<td>GLIDESLOPE CAPTURED</td>
<td>CHECKED</td>
</tr>
<tr>
<td></td>
<td>• reduces speed to VREF - VREF + 10 SET GO AROUND ALTITUDE BEFORE LANDING</td>
<td></td>
</tr>
<tr>
<td>Passing Outer Marker or equivalent position</td>
<td>OUTER MARKER</td>
<td>• crosschecks Altimeters and QNH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• compares altitude to value on approach chart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• calls out any deviations, and calls out minimum MINIMUS FEET</td>
</tr>
<tr>
<td>Passing 500 ft AGL</td>
<td>500</td>
<td>CHECKED</td>
</tr>
<tr>
<td>100 ft above minimum</td>
<td>APPROACHING MINIMUM</td>
<td>CHECKED</td>
</tr>
<tr>
<td>At minimum</td>
<td>MINIMUM</td>
<td></td>
</tr>
<tr>
<td>Whenever sufficient visual reference is obtained</td>
<td>RUNWAY IN SIGHT or APPROACH LIGHTS IN SIGHT</td>
<td>CHECKED</td>
</tr>
<tr>
<td>If no sufficient visual cues</td>
<td>GO AROUND</td>
<td>• continue with missed approach procedure</td>
</tr>
<tr>
<td></td>
<td>• continue with missed approach procedure</td>
<td></td>
</tr>
</tbody>
</table>
Additional Information

Aircraft Icing in Flight

In-flight aircraft icing is an eminent danger during flights in clouds or precipitation and low temperatures. Air accidents in combination with in-flight icing occur often. In the past this resulted in numerous studies and publications. For example:

- Aircraft Icing Handbook, Civil Aviation Authority New Zealand
- Flight in Icing Conditions Summary, French Civil Aviation Authority (Direction générale de l'aviation civile)
- Aircraft Icing, AOPA Air Safety Foundation
- Flight in Icing Conditions, Federal Aviation Administration, USA
- The Adverse Aerodynamic Effects of Inflight Icing on Airplane Operation, TP185 - Aviation Safety Letter, Transport Canada

A prerequisite for in-flight icing are water droplets (different sizes, from hovering droplets in clouds to precipitation) and low air temperature. Icing can develop in the temperature range from 0°C to -40°C.

There are three different kinds of icing on aircraft: clear ice, rime ice, and mixed ice.

Thickness of the ice accretion and the amount of ice accretion in relation to time are classified as follows (excerpt Flight in Icing Conditions, Chapter 4 (icing severity index)):

- Trace: Ice becomes perceptible and it can barely be seen. The rate of ice accumulation is slightly greater than the rate of sublimation. Trace ice is not hazardous even without use of de-icing/anti-icing equipment, unless the conditions are encountered for an extended period of time (over 1 hour).
- Light: The rate of accumulation of light icing may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of de-icing/anti-icing equipment removes or prevents its accumulation.
- Moderate: The rate of accumulation of moderate icing is such that even short encounters become potentially hazardous and the use of de-icing/anti-icing equipment or a flight diversion is necessary.
- Severe: The rate of accumulation is such that de-icing/anti-icing equipment fails to reduce or control the accumulation. The only thing to do is conduct an immediate flight diversion.
- The rate at which ice builds up depends on the atmospheric conditions, but the shape of the object on which it builds affects both the rate and the severity.
of the ice buildup. Ice tends to build first on parts of the airframe with a low radius of curvature, so it will for example tend to form on the tailplane before the wing, and small protuberances like a temperature probe or door stop may well see the first indication of icing. In severe icing conditions, the ice accretion can become critical within a few minutes.

Aircraft icing can cause a number of limitations and risks for the conduct of the flight (Excerpt from Flight in Icing Conditions, Chapter 3. Aerodynamics degradation):

- Ice causes: a reduction of lift, a reduction of stall angle, an increase in drag, a modification of longitudinal and lateral stability
- Even a small amount of roughness on airfoil leading edge can deteriorate stall characteristics
- Flow separation caused by ice can also cause a loss of effectiveness (or a command inversion) of control surfaces (ailerons and elevators)

Moderate to severe ice accrual creates entirely new, unpredictable aerodynamic flow over the wings and tail. Airfoil shape, aerodynamic flow, the relationship of forces and design logic are all subject to random changes unique to the specific ice encounter.

In addition to the well-known risk of unexpected stall due to too low speed with ice accretion on the wings, in the most recent past Icing Contaminated Tail Stall (ICTS) or un-commanded roll about the longitudinal axis came into focus during air accident investigations. A short description of these risks are in Chapter 7, Flight in Icing Conditions (Aircraft operation: effect of ice on aircraft):

- Icing Contaminated Tail Stall (ICTS)

[...] If tail-plane is contaminated by icing, the stall characteristics are degraded and this maneuver may increase the tail-plane angle of attack beyond tail-plane ice contaminated stall angle of attack. Once the tail-plane is stalled, the tail-plane downward force is reduced and the aircraft will pitch nose down. Considering that this phenomenon may typically happen during approach, the low altitude could annul the effects of any recovery action.

- Icing contaminated roll upset

[...] It is a little known and infrequently occurring flight hazard potentially affecting airplanes of all sizes. Roll upset can result from severe icing conditions without the usual symptoms of ice or perceived aerodynamic stall. In some conditions ice accretion on the wing leading edge may form a separation bubble; with the increase of the an-
gle of attack such bubble could extend backward up to the aileron. In this condition an aileron hinge moment reversal could cause the aileron to deflect towards the separation bubble (Aileron “snatch”) in aircraft with unpowered control. Aileron "snatch" is a descriptive term that results from an unbalance of aerodynamic forces, at an AOA that may be less than that of the wing stall, that tends to deflect the ailerons away from their neutral position.

One of many recommendations regarding flight in icing conditions: Disengage the autopilot and hand-fly the aeroplane. The autopilot may mask important handling cues, or may self-disconnect and present unusual attitudes or control conditions.  

Summary CAA NZ:

[...] Accident investigators and ice experts believe that autopilot use and pilot training also contribute to icing upsets and accidents, and must be addressed along with boot operating procedures.

The first challenge is to get flight crews to activate de-ice systems early. A lot of the inflight, ice-related accidents and incidents are so vicious, it has become fairly apparent that they occur when de-icing systems are not used. In most of these incidents, the FAA suspect the flight crews were comfortable with some level of accretion and intended to delay the activation of their de-icing systems until they gauged that the ice had reached [the AFM] recommend thickness. [...]

Loss of Control in Flight

Loss of Control (LoC) is one of the main contributing factors in fatal air accidents world-wide.

LoC events and accidents can have a multitude of causes. These range from system and components failure, to meteorological challenges, wake turbulences, operating errors of the flight management system, control input errors, misunderstandings, loss of situational awareness to distraction within the crew.

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9 DGAC, 7.3.2 Avoidance of Roll Upset / Cessna C510 Emergency/Abnormal Procedures: Severe Icing Encounter

10 Aircraft Icing Handbook, Chapter 6.3.3 Pneumatic De-Ice Boots
Due to the frequency and severity of LoC accidents in the past, International Air Transport Association (IATA) and NASA Flight Research Center have published studies and other publications regarding this topic. In addition to statistics, recommendations for the avoidance of LoC events were made.

2015 IATA came to the following conclusion:11

[…] In Loss of Control In-Flight (LOC-I) accidents, as with most accident categories, the investigation usually reveals a multitude of factors leading up to a loss of control. Very often the trigger that initiates a LOC-I accident sequence is an external environmental factor, predominantly meteorological but potentially traffic related in the form of wake turbulence. Human performance deficiencies, including improper, inadequate or absent training, automation and flight mode confusion, distraction the ‘startle’ factor and loss of situational awareness frequently compounded the initial upset and precluded an effective recovery until it was too late.

The analysis found that pilots often missed or ignored readily available indications that could have alerted them to an impending upset or LOC-I event. These included icing conditions, flight control system malfunctions and turbulence. Ultimately, the failure to recognize these precursors to loss of control led to inadvertent or in some cases even deliberate pilot-induced upsets and LOC-I accidents. […]

NASA came to the conclusion:12

[…] Human-induced causal factors are a stronger contributor to loss of control accidents when compared to environmentally-induced and systems-induced causal factors. For near-term impacts on human-induced loss of control, mitigation strategies should focus on loss of control prevention and recovery training. […] Avoidance and
detection of loss of control events are more important strategies when compared to recovery based mitigations, however, development of recovery-based mitigations are also required in order to ensure complete coverage when “breaking the chain” of events in a loss of control scenario. […] 

In order to avoid LoC accidents, pilots shall complete an Upset Prevention and Recovery training. In this training they are learning to prevent the loss of normal flight attitude early enough and to recognise it (Upset Prevention) and to recover a stabilised flight attitude before loss of control occurs (Recovery Training). Among others, the Advisory Circular No: 120-111 of the FAA and the Opinion 06/2017 Loss of control prevention and recovery training of EASA described content and procedures.

Flight Data Storage

Due to missing objective data or uncleared causes for air accidents with commercially operated aircraft which had been exempt from the obligation to be fitted with flight data and cockpit voice recorders, several investigation authorities issued safety recommendations in this regard. Examples are:

AAIB UNKG-2005-101: The EASA should promote the safety benefits of fitting, as a minimum, CVR equipment to all aircraft operated for the purpose of commercial air transport, regardless of weight or age.

TSB Recommendation A13-0: The Department of Transport should work with industry to remove obstacles to and develop recommended practices for the implementation of flight data monitoring and the installation of lightweight flight recording systems by commercial operators not currently required to carry these systems.

TSB Recommendation A91-13: The Department of Transport expedite legislation for upgrading the flight recorder requirements for Canadian-registered aircraft.

NTSB Safety Recommendation A-06-017: TO THE FEDERAL AVIATION ADMINISTRATION: Require all rotorcraft operating under 14 Code of Federal Regulations Parts 91 and 135 with a transport-category certification to be equipped with a cockpit voice recorder (CVR) and a flight data recorder (FDR). For those transport-category rotorcraft manufactured before October 11, 1991, require a CVR and an FDR or an onboard cockpit image recorder with the capability of recording cockpit audio, crew communications, and aircraft parametric data.
In 2017, EASA issued the Notice of Proposed Amendment (NPA) 2017-03 In-flight recording for light aircraft as part of the legislative procedure (RMT.0271 (MDM.073(a)) & RMT.0272 (MDM.073(b)).

This Notice of Proposed Amendment (NPA) addresses safety and regulatory harmonisation issues related to the need of in-flight recordings for accident investigation and accident prevention purposes. 12 safety recommendations were addressed to the European Aviation Safety Agency (EASA) by 7 safety investigation authorities, recommending an in-flight recording capability for light aircraft models which are outside the scope of the current flight recorder carriage requirements. In addition, new Standards (recently introduced in ICAO Annex 6) require the carriage of lightweight flight recorders for light aeroplanes and light helicopters. [...] This NPA proposes to mandate the carriage of lightweight flight recorders for some categories of light aeroplanes and light helicopters when they are commercially operated and manufactured 3 years after the date of application of the amending regulation. In addition, this NPA proposes to promote the voluntary installation of in-flight recording equipment for all other light aeroplanes and light helicopters and for all balloons. The proposed changes are expected to increase safety with limited economic and social impacts.
Analysis

History of the Flight

The approximately 31-minutes long instrument flight at night from Egelsbach ran south along the route Mannheim, Stuttgart, and Mengen-Hohentengen to Friedrichshafen Airport.

The climb was conducted with more than 200 KIAS up until the maximum altitude of FL 210. The descent until interception of the ILS at Friedrichshafen was flown with about 240 KIAS.

Neither the recorded flight path, nor the flight parameters transmitted via ADS-B, nor the recorded radio communications showed any evidence of problems during the flight or unusual behaviour of the crew or airplane. The recorded flight parameters suggest that it is highly likely that the flight was conducted with the continuous use of the autopilot.

The transmitted flight parameters show a consistent decrease of the rate of descent until the instructed altitude of 4,000 ft AMSL was reached. In the turn towards the localizer the bank angle increased to more than 25°. Therefore, the bank angle exceeded the possible value if the flight director is in APR mode. Later the 30° value of the ROL mode was exceeded as well. Immediately afterwards a very high rate of descent developed. The combination of fast increasing right bank angle and high sink rate within a few seconds allows the conclusion of loss of control while oversteering the autopilot or disengagement of the autopilot.

About 36 seconds elapsed between the unremarkable acknowledgement of the last radio transmission by the co-pilot during the descent until the loss of control during the interception of the localizer.

The facts that contact with objects prior to the accident site itself occurred and that the airplane must have been in a flat descent, allows the conclusion that the crew attempted to recover the aircraft and succeeded in decreasing the rate of descent. The altitude was not sufficient, however. After the airplane had contact with obstacles and lost wing and tail section parts it is probable that loss of control was complete and the course of the flight until the accident site uncontrolled.

Crew

Both pilots held the required licences and ratings. In correspondence with their ratings they were deployed as pilot in command and co-pilot (PIC and COP).
The PIC, in his role as line training captain, was very experienced on type and was flying almost exclusively the C510. His last check flight in the simulator had taken place a few months previously.

The co-pilot had acquired the type rating for the C510 in July. He was still flying under intra-company supervision. Since he had acquired the type rating he had flown about 140 hours on type. It is remarkable, however, that neither the operator nor other pilots could provide information about him. There was also no documentation regarding the supervision.

Both pilots should have been able to fly the aircraft in single-pilot operation. They were surely familiar with the approach to Friedrichshafen because it was the main base of the airplane and they approached Friedrichshafen on a regular basis.

The BFU could not determine what the relationship of the two pilots with each other had been like.

Due to the chronological proximity of the landing of the sister airplane of the operator, it has to be assumed that the crew had heard the approach and landing via the radio and was therefore reassured regarding the weather and possible icing conditions.

Due to the entry in the aircraft log book and the fact that the co-pilot conducted radio transmissions the BFU is of the opinion that the PIC was Pilot Flying (PF) during the accident flight.

Aircraft

In 2006 the aircraft type C510 Mustang received type certification. Production ended in 2017. Up until then 471 C510 Mustang were produced. The accident with the airplane involved was the first fatal accident with this type. The BFU is of the opinion that in regard to construction, complexity of systems and their handling it is a comparatively simple jet. This is also conveyed in the single-pilot certificate of the type. Essential systems, such as the autopilot, are redundant. Simple system failure, e. g. engine, generator, or autopilot, should not result in larger effects or even loss of control. The same is true for unexpected entry into slight to moderate icing conditions. According to the manufacturer’s records regarding in-flight icing and the risk of Ice Contaminated Tailplane Stalls (ICTS) no significant and negative characteristics were determined during testing.

The aircraft involved was registered in Austria and according to the maintenance documentation provided by the operator maintained continuously. The examination of
the wreckage did not determine any technical deficiencies and failures at the controls. In regard to the configuration it was determined that the landing gear, the flaps, and the speed brakes had been retracted at the time of the accident. The analysis of the two engine FADECs by the engine manufacturer showed that at the time of the accident N2 of both engines was about 70% (high idle), anti-ice was switched on, and so was probably de-ice given the reference data of the last Engine Power Assurance Check. It could not be determined as to when anti-ice and de-ice were switched on.

The speeds recorded by air navigation services showed that during climb until reaching cruise level and during descent until the accident they were higher than the minimum speed of 160 KIAS recommended for icing conditions. This should ensure that ice could not form behind the de-ice boots, on the lower surfaces of the wings, and the tail section. At the same time, until the accident speed was far above the stall speeds stated in the flight manual and the Vref for the actual mass. Therefore, the BFU rules out stall in bank due to low speed during interception of the localizer. The high approach speed while using the autopilot resulted in overshooting of the extended runway centre line. The recordings of previous approaches to Friedrichshafen showed that this occurred each time due to the high approach speed; it could therefore not have been a surprise to the crew.

Meteorological Conditions

According to the meteorological expert opinion of the DWD the information available for the pre-flight preparation showed significant weather phenomena mainly in form of showers with rain and snow and individual thunder storms for the route Egelsbach - Friedrichshafen. Icing conditions had to be expected for the entire flight route, which were forecast specially in the first part of the route until about the Neckar and in the destination area as regionally moderate to intense. At the time of the intended landing no significant limitations had to be expected at Friedrichshafen Airport for an instrument landing.

The observed weather conditions at the second half of the flight route differed significantly from the forecast, since the frontal weather conditions extended farther north. The observations of other aircraft crews match the change in weather conditions very well.

The airplane entered these frontal weather conditions with precipitation and first slight than later moderate to severe icing conditions during descent from FL 150. Af-
ter about 10 minutes in icing conditions with differing intensity at the time of the accident the airplane was probably at least partially covered with ice.

The accident occurred after sun set in a local precipitation area in the form of rain and snow. At the time of the accident, in the area of the extended runway centre line cloud base was at approximately 3,100 ft AMSL, about 800 ft above ground. According to the observations of other crews, visibility of light below was more than 10 km in spite of the precipitation.

Therefore, the sudden loss of control occurred in clouds, precipitation, and in the dark. If the landing lights had been switched on, snowflakes in the light beam would have prevented the crew from being able to see outside. Therefore, the crew did not have the earth in sight and, up until leaving the cloud in an uncontrolled flight attitude, no optical reference points (lights on the ground or object lights). Using the instruments, the crew should have recognised and recovered the uncontrolled flight attitude.

The slight to moderate turbulence will have increased the crew’s workload during approach.

Organisational and Management Information

The operator was an Austrian commercial air transport operator. Even though this company provided the aeronautical scope for the commercial flights, the BFU is of the opinion, that it did not have much to do with the commercial flight operations of the airplane involved and the sister airplane of the same type.

These two aircraft were marketed, planned, and deployed by a second company. The pilot involved in the accident had been the managing director. This is also reflected in the fact that it was not possible for the BFU to receive information regarding the co-pilot from the operator. The operator did not have any documentation of the continuous supervision of the co-pilot. This second company discontinued flight operations due to the accident.

The flight operations procedures of the operator essentially corresponded with the Aircraft Flight Manual of the type involved. These procedures and additional regulations of the flight operations manual, e.g. regarding flights in icing conditions or crew co-operation, should have ensured safe instrument approach procedures.

The BFU is of the opinion that all subsequently examined approaches were flown with high speeds. This increases the crew’s workload during approach since less
time is available for the configuration of the airplane and the establishment of stability
criteria, etc. The operator stated that at numerous international airports there is no
other option to queueing with the traffic of larger aircraft.

Aircraft Icing and Loss of Control in Flight

In-flight loss of control can have a multitude of causes.

The BFU is of the opinion that in this case technical problems can be ruled out with a
high degree of certainty.

In the present case, it is more likely that the attempt to re-intercept the localizer in
darkness and snowfall resulted in a control error of the PF, possibly due to spatial
disorientation. It is also possible that misunderstandings within the crew occurred or
while activating the autopilot for the approach procedure.

The BFU is of the opinion that due to the frontal weather condition and the most likely
accompanying severe icing conditions immediately prior to the accident it is possible
that aerodynamic forces affected the airplane. The so-called Roll Upset is a scenario
which could have been possible if all factors are considered. The airplane was not
equipped with servo-controlled ailerons; it only had de-ice boots and probably flew
with engaged autopilot. Unexpected decoupling of the autopilot due to high aerody-
namic pulling forces could have resulted in LoC. In the past, such events with other
aircraft types were described in literature.

But any number of other causes could have existed. Due to missing information from
the cockpit, the BFU cannot determine with certainty the possible causes for the sud-
den loss of control.

Flight Data Storage and Recommendations

Due to the destruction of the cockpit, including the SD memory cards of the multi-
function display and the fact that the airplane involved was not equipped with a flight
data recorder or cockpit voice recorder data regarding the accident is missing.

In the past accidents in commercial flight operations occurred which could not be ex-
plained due to missing data. As a result safety investigation authorities issued sever-
al recommendations regarding the fitting of such recorders.

Nowadays the necessary technical solutions exist and the BFU is of the opinion that
the aeronautical requirements for the equipment with flight data or cockpit voice re-
corders, or cockpit recording image systems should be augmented.
Conclusions

The accident was caused by sudden loss of control in clouds at night during intercept of the localizer for the approach to Friedrichshafen Airport.

It is probable that the frontal weather conditions with slight to moderate turbulence, snowfall, and icing conditions played a contributing part.

Due to missing data regarding the events on board saved causes for the loss of control could not be determined.

Safety Recommendations

Safety Actions

The BFU is going to abstain from issuing safety recommendations due to the many safety recommendations already issued and the planned aeronautical changes in regard to equipment with flight data and cockpit voice recorders (RMT.0271 (MDM.073(a)) & RMT.0272 (MDM.073(b)) ‘In-flight recording for light aircraft’ and EASA NPA 2017-03/ CRD to NPA 2017-03/ Opinion No 02/2019).

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Assistance: Philipp Lampert
Braunschweig: 23 September 2019

Appendix

Wreckage distribution at the accident site
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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