

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	15 February 2013
Location:	Berlin-Schönefeld Airport
Aircraft:	Airplane
Manufacturer / Model:	Embraer / EMB-500
Injuries to Persons:	None
Damage:	Aircraft severely damaged
Other Damage:	Aerodrome equipment
State File Number:	BFU CX001-13

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.

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Abbreviations

AAL	Above Aerodrome Level
AFCS	Automatic Flight Control System
AFM	Airplane Flight Manual
AGL	Above Ground Level
AMSL	Above Mean Sea Level
ANAC	Agência Nacional de Aviação Civil
AOA	Angle of Attack
AOC	Air Operator Certificate
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
BCAA	Belgian Civil Aviation Authority Directorat-General de l'Aviation Civile
BFU	Bundesstelle für Flugunfalluntersuchung German Federal Bureau of Aircraft Accident Investigation
CAS	Crew Alerting System
CENIPA	Centro de Investigação e Prevenção de Acidentes Aeronáuticos
CMC	Central Maintenance Computer
CVDR	Cockpit Voice Data Recorder
DFS	Deutsche Flugsicherung German air navigation service provider
DWD	Deutscher Wetterdienst German Meteorological Service
FL	Flight Level
hPa	Hectopascal
IAS	Indicated Air Speed
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions

KIAS	Knots Indicated Air Speed
MLM	Maximum Landing Mass
MTOM	Maximum Take Off Mass
NM	Nautical Mile
NTSB	National Transportation Safety Board
OAT	Outside Air Temperature
OM	Operations Manual
PFD	Primary Flight Display
PIC	Pilot in Command
QRH	Quick Reference Handbook
SAT	Static Air Temperature
SOP	Standard Operating Procedures
SPA	Stick Pusher Actuator
SWPS	Stall Warning and Protection System
TAT	Total Air Temperature
V_{AC}	Approach Climb Speed
V_{FE}	Maximum Flap extended Speed
V_{FS}	Final Segment Speed
VMC	Visual Meteorological Conditions
V_{REF}	Landing Reference Speed

Synopsis

On 15 February 2013 at 0912 hrs¹ the German Federal Bureau of Aircraft Accident Investigation (BFU) was notified by Berlin-Schönefeld Airport that an air accident involving a twin-engine business jet Embraer EMB-500 had occurred in which the aircraft had been severely damaged. An investigation team consisting of three BFU staff members was dispatched to the accident site. In accordance with ICAO Annex 13 the investigation authorities of Belgium, as State of Registry and State of the Operator, and Brazil, as State of Design and State of Manufacture, were notified and supported the BFU in the investigation.

The airplane banked during the flare phase of the final approach to runway 07L of Berlin-Schönefeld Airport, impacted the ground, and came to a stop at the right edge of the runway. The two pilots and the passenger remained uninjured.

The causes of the air accident were:

- The crew conducted the approach under known icing conditions and did not activate the wing and horizontal stabilizer de-ice system, which was contrary to the Standard Operating Procedures (SOP).
- Due to ice accretion on wings and horizontal stabilizer and infringement of the required approach speed the aircraft entered an abnormal flight attitude during the flare phase and crashed.

Contributing Factor:

- The crew had insufficient knowledge of the connection between the ice protection system and the Stall Warning Protection System (SWPS).

The German Federal Bureau of Aircraft Accident Investigation has issued four safety recommendations as a result of the Investigation. The addressees of the safety recommendations are the Belgian, the Brazilian, and the European civil aviation authorities as well as the Deutsche Flugsicherung.

¹ All times local, unless otherwise stated.

1. Factual Information

1.1 History of the Flight

At 0738 hrs the airplane had taken off from Kortrijk-Welvelgem Airport, Belgium, to a commercial flight to Berlin-Schönefeld Airport, Germany. The Pilot in Command (PIC), the co-pilot and one passenger were on board. The co-pilot was Pilot Flying (PF) during this flight.

According to the Cockpit Voice Data Recorder (CVDR) the pilots had checked the Stall Warning and Protection System (SWPS) prior to engine start-up, among other things, as required by the commensurate procedures, and determined its proper function.

The CVDR showed that at 0742 hrs, while the airplane was at Flight Level (FL) 70 in climb, the engine anti-ice systems of both engines were activated for 46 seconds. Forty seconds later the autopilot was activated. At about 0813 hrs the airplane was at FL390. The recorded conversations of the pilots showed that after about 0823 hrs they had tried several times to receive ATIS of the destination aerodrome on the respective radio frequency. Until leaving cruise level at 0833 hrs, approximately 140 NM from destination, they had not been successful. Two minutes after the beginning of the descent, the PIC explained to the co-pilot that due to the observed traffic he assumed that at the destination aerodrome runway 25R would probably be in use. About five minutes later, the crew received the clearance for RUDAK 5S arrival to runway 07L via radio transmission. Subsequently, the crew began to prepare the navigation system for the approach. At about 0842 hrs, at 76 NM from destination, the PIC started to listen to ATIS, but was interrupted by descent instructions, and the request to change frequencies. At 0843:36 hrs after the frequency change to Bremen Radar the controller said: "[...], Bremen identified. Hello, proceed direct twelve miles final for runway zero seven left Schönefeld."

The co-pilot asked while the airplane was passing FL200 during descent: "Descent checklist?" the PIC asked her to wait and then listened to ATIS Information Z and made notes. In regard to the weather the following information was given, among others: "[...] moderate icing reported below 3,000 feet [...]". The operational flight plan included hand-written entries for the weather data of the ATIS Information Z and for the approach a Final Segment Speed V_{FS} of 130 kt and a Landing Reference Speed V_{REF} of 96 kt. According to the CVDR data at that time the Outside Air Temperature (OAT) was about -18°C. Subsequently, the PIC gave the co-pilot the

following information: cloud cover, cloud base 1,400 ft, visibility 4,800 m in mist and barometric air pressure (QNH) 1,018 hPa. At 0847 hrs the two pilots conducted a two-minute approach briefing. Details of the approach and go-around procedures were discussed.

At 0850:12 hrs the co-pilot asked again, while the airplane was passing FL97 during descent: "Descent checklist?" The PIC answered "stand by". Approximately half a minute later the controller radioed the crew: "[...] descend altitude four thousand feet on QNH one zero one eight." This was confirmed. Subsequently, the pilots completed the checklist. The PIC said: "Landing speeds?" the co-pilot answered with the words: "Set by me." The PIC asked: "Icing conditions?" the co-pilot answered: "Negative, no visible moisture."

At 0851:12 hrs the PIC added: "below ten thousand, de signs gaan aan en temperature is no negative. Ik ga nog wat wachten [...] voor de anti-ice (below ten thousand, signs are on and temperature is not negative [...] I am going to wait a little with the anti-ice)." At that time the CVDR recorded an OAT of -1°C.

At 0853:58 hrs the flaps were extended to position one.

At 0854:11 hrs the controller instructed the crew to use a heading of 050° and issued the clearance to descend to 3,000 ft AMSL and fly to the ILS Yankee approach of runway 07L. The PIC requested the co-pilot to keep speed high with the words: „hou wel nog wat speed want ATC gaat dat niet graag zien als ge alles gaat ophouden achter ons he (keep some speed because ATC won't like it if you will slow down everything behind us)."

According to the radar data at 0855 hrs the aircraft intercepted the extended runway centre line of runway 07L at 3,000 ft AMSL about 13 NM from the threshold. The controller radioed the crew: "[...] maintain speed a hundred and seventy knots or greater to four miles final" and the PIC answered: "Actually we have a hundred and seventy-five Madam, and we will maintain it until four miles final". Subsequently, the PIC said to the co-pilot: "zie je, ze hebben dat niet graag he, ge houdt alles op achter ons he (you see, they don't like that, you slow down everyone behind us)." The PIC said: "ik ga er 175 inzetten als je het goed vindt" (I'm going to set 175 if you agree)" which the co-pilot answered in the affirmative. Then the PIC selected a speed of 175 kt on the Automatic Flight Control System (AFCS).

At 0855:32 hrs the PIC said: "ja, de motoren er bij want het is negatief terug ze hadden het gezegd he, moderate Icing below three thousand (yes, adding the

engines because it is negative again, they have said it, moderate icing below three thousand)" and activated the engine anti-ice system of both engines. According to the CVDR, OAT was about -1.5°C . The selection on the AFCS was reduced to 170 KIAS. At that time the aircraft was flying at 3,000 ft AMSL at about the upper limit of the clouds. At 0857:05 hrs the co-pilot said: "on the glide, gear down", then the landing gear was extended, the airplane began to descend, and entered the clouds.

At 0857:25 hrs the controller said: "[...] wind one zero zero degrees four knots, now zero niner zero degrees seven knots, runway zero seven left, cleared to land. Vacate the runway to the right." The PIC answered: "Cleared to land and we will vacate to the right [...]."

At 0857:41 hrs as the airplane was at about 2,250 ft AMSL the co-pilot asked: "mag ik naar 130 gaan (can I go to 130)?" The PIC answered: "nog niet he, tot 4 mijl [...] we zitten nog niet op 4 mijl he, we zitten nog op 6,3. Ge moet uw 170 houden tot 4 mijl. Ge hebt daar tijd genoeg om uw flaps naar buiten. Geen probleem (You must remain at 170 until 4 miles. Then you still have enough time to position the flaps. No problem)".² Subsequently, the PIC began to complete the approach checklist with the items external lights, fuel crossfeed, and altimeter setting. At the checkpoint "icing conditions?" the PIC said "[...] dat staat hier nog aan (it is still on)".

According to the radar data, the airplane was about 4 NM from the runway threshold when the PIC said to the co-pilot at 0858:30 hrs: "okay, begin nu dan maar stillekes te reduceren (okay, you can start to reduce now)". According to the CVDR data, at that time the aircraft passed 1,470 ft AAL and began to reduce speed. Five seconds later the PIC added: "slightly ground contact".

At 0858:44 hrs the co-pilot said: "Ahm, four nautical miles, flaps two". Speed was 163 KIAS. The PIC acknowledged the instruction and extended the flaps to position two. Eleven seconds later the co-pilot said: "Autopilot disconnect". The autopilot was disengaged and then the PIC said: "Okay, dat mag af, visual runway, alles mag af (Okay, that can be set off, runway in sight, everything can be set off)". Afterwards the engine anti-ice systems 1 and 2 and the windshield anti-ice systems 1 and 2 were shut off. At that time, the airplane had an altitude of about 1,000 ft AAL and a speed of 151 KIAS.

² According to the CVDR, between 0853 hrs and 0858 hrs the PIC had requested the co-pilot nine times to keep high speed.

At 0859:13 hrs the co-pilot asked the PIC to fully extend the flaps: „will je hem op four F zetten alsjeblief? (can you set it to 4F please)" According to the CVDR at that time altitude was about 800 ft AAL. At the same time, the co-pilot set the speed on the AFCS to 96 KIAS. According to the CVDR, at 0859:29 hrs the flaps were fully extended, altitude was approximately 640 ft AAL, and the continually reducing airspeed 121 KIAS. Fifteen seconds later, at 0859:44 hrs, the CVDR recorded the synthetic announcement "five hundred". At the time, the speed of the aircraft was about 114 KIAS and almost remained at that level for the next 30 seconds. The PIC said: "landing checklist voor de zekerheid, de yaw damper is [...], gear down three greens, flaps are full, landing clearance update" Then he radioed the controller: "[...] just to confirm cleared to land?" During this radio transmission, at an altitude of about 250 ft AAL, speed began to decrease again.

At 0900:17 hrs the synthetic announcement "Minimums, Minimums" was recorded, immediately afterwards the PIC radioed the controller again: "[...] just to confirm cleared to land?" This was acknowledged as the airplane passed 162 ft AAL with a speed of 106 KIAS.

At about 0900:24 hrs, at a speed of 102 KIAS, pitch attitude had exceeded 0° and continued to increase. The recorded glideslope deviation showed that in this phase the airplane began to deviate downward. The speed decreased during the following nine seconds to about 90 KIAS, the pitch angle increased to about +6°. The recorded Angle of Attack (AOA) on the left sensor increased to 17.2° and the one on the right to 15.8°. At about 0900:33 hrs at approx. 30 ft AAL, the airplane began to roll left and, within two seconds, reached a bank angle of 30°. Simultaneously with the roll, normal acceleration decreased from approximately 1 g to approximately 0.8 g. At the beginning of the roll, the CVDR recorded the exclamation "Oh, oh" of both pilots and two seconds later impact noises. Then the CVDR recording ended.

The pilots stated that during the flare above the threshold the left wing had suddenly dropped and touched the runway. Subsequently, the airplane rolled right and the right main landing gear had come down hard. The landing gear fractured and the aircraft slid along the runway toward the right runway edge and came to a stop there.

The PIC stated that at the beginning of the ILS approach the airplane had been at 3,000 ft AMSL above the clouds. During the descent, as the airplane was entering the clouds from above, he had switched on the engine anti-ice and the windshield anti-ice systems. Once the airplane had been below the clouds he had visually inspected the outer third of the left wing, visible to him. At that time he had not seen any ice accretion. Subsequently, he had switched off the engine anti-ice and windshield anti-ice systems. Once the airplane had cleared the clouds he had told the co-pilot he had ground in sight. The PIC stated that his reason for not activating the wing and horizontal stabilizer de-ice system was that he had not seen any ice accretion and further explained that the activation of the system would result in significant limitations of aircraft performance and there are discussions among pilots whereby the system should only be activated at ice accretion of at least 0.25 inch.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Third Party
Fatal			--
Serious			--
Minor / None	2	1	

1.3 Damage to Aircraft

The aircraft was severely damaged.

1.4 Other damage

The aircraft impact caused damages to the runway surface and runway lighting.

1.5 Personnel Information

1.5.1 Pilot in Command

The 48-year-old pilot held a Commercial Pilot's License (CPL-A) initially issued by the Belgian Civil Aviation Authority (BCAA) on 15 February 2000 and valid until 20 October 2013. His license carried the following entries: Single-Engine Piston (SEP) land valid until 30 June 2014, BE90/99/100/200 valid until 31 August 2013, EMB500 valid until 30 June 2013, Instrument Rating (IR(A)) valid until 30 June 2013, Class Rating Instructor (CRI(A)) valid until 31 January 2016 and Flight Instructor (FI(A)) valid until 31 December 2013.

His class 1 medical certificate was issued on 19 October 2012, and was valid until 13 November 2013. The limitation VNL, correction for defective near vision, was listed.

He had a total flying experience of approximately 4,500 hours, of which 800 hours were flown on type. On enquiry by the BFU he stated that he had conducted about 400 landings on type; 30 of which in the last 90 days.

Prior to reporting for duty he had had a rest period of more than 36 hours.

1.5.2 Co-pilot

The 22-year-old co-pilot held a Commercial Pilot's License (CPL-A) initially issued by the BCAA on 12 August 2011 and valid until 12 August 2016 with the ratings Multi-Engine Piston (MEP) land, valid until 31 May 2013, EMB500, valid until 30 November 2013, and IR(A) valid until 30 November 2013.

Her class 1 medical certificate was issued on 27 April 2012 and valid until 11 May 2013. The limitation VDL, correction for defective distant vision, was listed.

She stated she had a total flying experience of about 260 hours; 32 hours of which on type. Within the last 90 days prior to the accident she had conducted 22 flights. In the last 30 days she had flown 29 hours. On type she had conducted about 20 landings all of them within the last 90 days.

On 3 November 2012 the pilot had her last licence skill test in the simulator during her type rating training.

Prior to reporting for duty she had had a rest period of 14 days.

1.6 Aircraft Information

The airplane EMB-500 is a twin-jet, low-wing aircraft in all-metal construction, with T-tail configuration and six seats. The aircraft was certified in accordance with FAR and CS 23 for single-pilot operation.

The aircraft had a valid Belgian certificate of registration and was operated by a Belgian business aviation operator.

Manufacturer:	Embraer
Type:	EMB-500
Manufacturer's Serial Number (MSN):	50000196
MTOM:	4,750 kg
MLM:	4,430 kg
Engines:	Pratt & Whitney Canada PW617F-E

According to the CVDR, at the time of the accident the aircraft mass was 4,190 kg.

Total operating time of the aircraft was approximately 562 hours and 534 cycles.

According to the Aircraft Maintenance Release to Service on 14 February 2013 it was last subject to a 600-hour inspection.

1.6.1 Ice and Rain Protection System

For ice protection the aircraft was equipped with a thermal engine anti-ice system for the engine inlet cowls and a pneumatic wing and horizontal stabilizer de-ice system for the wing leading edges and the horizontal stabilizer in the form of inflatable de-ice boots. The de-ice boots on wings and horizontal stabilizer had spanwise running inflatable cells and were of silver-grey colour.

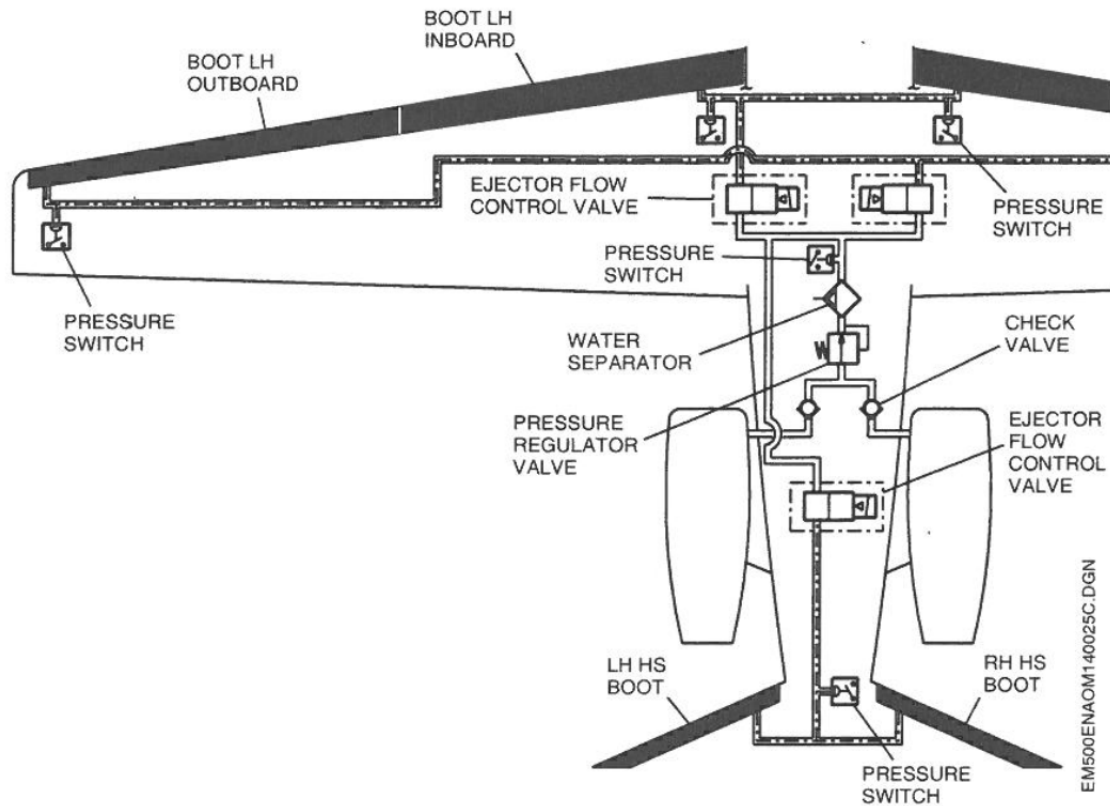


Image 1: Wing and horizontal stabilizer de-ice system

Source: Embraer

It was also equipped with an electrical windshield and air data heating system (pitot, static port and AOA vane heater). The panel for the systems is located at the right of the left control column.

On the lower left of the Primary Flight Display (PFD) the temperature is indicated as Total Air Temperature (TAT) or as Static Air Temperature (SAT).



Image 2: Ice protection / heating panel

Source: BFU

1.6.2 Stall Warning and Protection System

The airplane was equipped with a Stall Warning and Protection System (SWPS) which, depending on AOA and Mach number, shall warn if the AOA becomes too great and, if appropriate, actively reduce the AOA. Therefore the SWPS should strengthen the situational awareness of the pilots and actively help to prevent stalling the airplane. The main components are: the SWPS computer, two AOA sensors, and the Stick Pusher Actuator (SPA).

The pilots are warned by the acoustically generated announcement "Stall". The yellow and red range of the speed indication on the Primary Flight Display (PFD) serves as low speed awareness.

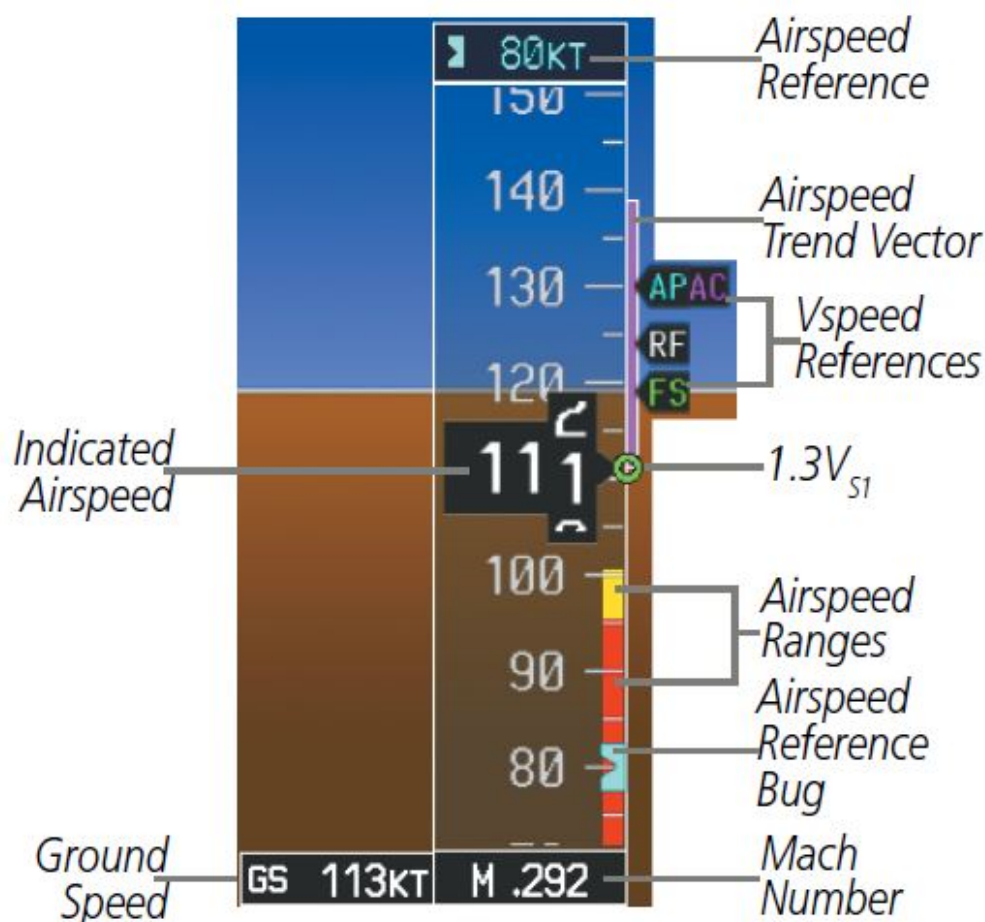


Image 3: Air speed indicator

Source: Garmin

Depending on the configuration of the aircraft, the upper end of the red range matches the speed which corresponds with the AOA for the acoustic stall warning

In addition to the warning, the SWPS can, via a Stick Pusher Actuator (SPA), actively interfere with the elevator control in order to reduce the AOA of the aircraft.

According to the aircraft manufacturer for the configuration landing gear extended, flaps fully extended (4F), ice protection switched off, the acoustic warning "Stall" is generated when AOA is 21°. When 28.4° are reached the SPA is triggered. The same configuration, but with wing and horizontal stabilizer de-ice system activated the stall warning is generated at 9.5° and the SPA triggered at 15.5°. The AOA is the

mean value of the measured values of both AOA sensors under consideration of the rate of AOA change.

According to the Airplane Flight Manual (AFM), prior to each flight the pilots had to check the SWPS. The control column had to be pulled and the stall protection push switch on the right instrument panel held down until the acoustic warning "stall, stall" is announced three times and the stick pusher triggered.

1.6.3 Airplane Flight Manual

The AFM issued on 3 July 2009 Revision 5, approved by the Brazilian aviation authority, Agência Nacional de Aviação Civil (ANAC), was carried on board.

AFM Section 2 Limitations listed the maximum speeds for different flap positions.

Maximum Flap extended speed (V_{FE})

<i>Flaps 1</i>	<i>200 KIAS</i>
<i>Flaps 2</i>	<i>160 KIAS</i>
<i>Flaps 3</i>	<i>160 KIAS</i>
<i>Flaps FULL</i>	<i>145 KIAS</i>
<i>Maximum Landing Gear Operation Speed</i>	<i>180 KIAS</i>
<i>Maximum Landing Gear Extended Speed</i>	<i>275 KIAS</i>

Chapter *Operation in Icing Conditions* stipulated:

Crew must activate the ice protection system when icing conditions exist or are anticipated as follows:

If SAT (TAT in flight) is between 5 °C and 10 °C with visible moisture:

<i>ENG1 and ENG2 switches</i>	<i>ON</i>
<i>WINGSTAB switch</i>	<i>OFF</i>
<i>WSHLD1 and WSHLD2</i>	<i>OFF</i>

At the first sign of ice formation or if SAT (TAT in flight) is below 5 °C with visible moisture:

<i>WSHLD1 and WSHLD2</i>	<i>ON</i>
<i>ENG1 and ENG2 switches</i>	<i>ON</i>
<i>WINGSTAB switch</i>	<i>ON</i>

The phrase "visible moisture in any form" was described as clouds, fog with visibility of one mile or less, rain, snow, sleet or ice crystals.

AFM Section 2 specified the minimum control airspeed (V_{MC}) for landing in icing conditions with 97 KIAS.

AFM Section 3 Normal Procedures Operation in Icing Conditions stipulated the minimum flying speed during approach:



Image 4: AFM - Normal Procedures - Operation in Icing Conditions

Source: Embraer

1.6.4 Quick Reference Handbook

For a landing with *WINGSTAB OFF* and *ENGINE ICE PROTECTION OFF/ON*, *ZERO SLOPE*, *NO WIND*, *FLAPS FULL* and a mass of 4,200 kg the following speeds were required:

V_{REF} 98 KIAS
 V_{AC} 103 KIAS
 V_{FS} 122 KIAS

For a landing with *WINGSTAB ON* and *ENGINE ICE PROTECTION OFF/ON*, *ZERO SLOPE*, *NO WIND*, *FLAPS FULL* and a mass of 4,200 kg the following speeds were required:

V_{REF} 121 KIAS

V_{AC} 121 KIAS

V_{FS} 140 KIAS

1.6.5 Pilot Operating Handbook

The Pilot Operating Handbook (POH) included general recommendations of the aircraft manufacturer; among others for the conduct of an ILS approach.

It was recommended to initially conduct the descent with 170 KIAS and retracted flaps. The checklist shall be completed at the same time. At a distance of approximately 15 NM to the threshold the flaps should be put in position 1 and the speed reduced to 150 KIAS. As soon as the glideslope indication was "alive" the landing gear should be extended, the speed reduced to 130 KIAS, and the flaps put in position 2. Once the glideslope (1 Dot) is reached flaps should be put in landing configuration and speed reduced to V_{REF} . When passing the outer marker the altitude and heading for a go-around procedure should be selected at the AFCS, the approach be flown with V_{REF} and the Before Landing Checklist completed.

1.7 Meteorological Information

1.7.1 Meteorological Pre-Flight Preparation

A so-called Crew Briefing Information Package was made available to the BFU. It had been prepared by a company, who had been commissioned by the operator, and contained the documentation for the pre-flight preparation of the pilots including the weather data. It included the Wind/Temperature Prognostic Chart for FL390, the Vertical Cross Section Chart for the flight route, and the Significant Weather Prognostic Chart. For the destination aerodrome Berlin-Schönefeld the package contained the METAR of 0500 UTC and the forecast of 0500 UTC.

1.7.2 Weather Condition at the Time of the Accident

The accident occurred at daylight.

According to the aviation routine weather report (METAR) of 0750 UTC the following weather conditions prevailed at Berlin-Schönefeld Airport:

Wind: 090° / 7 kt
 Visibility: 4,800 m / mist
 Clouds: 5-7 oktas at 1,400 ft AAL
 Temperature: 0°C
 Dewpoint: -2°C
 Barometric air pressure (QNH): 1,018 hPa

Relative air humidity was given with 86.4%.

The DWD stated that there were no weather warnings or SIGMET. The prevailing closed stratus clouds had been supercooled and therefore "eisträchtigt (carrying ice)".

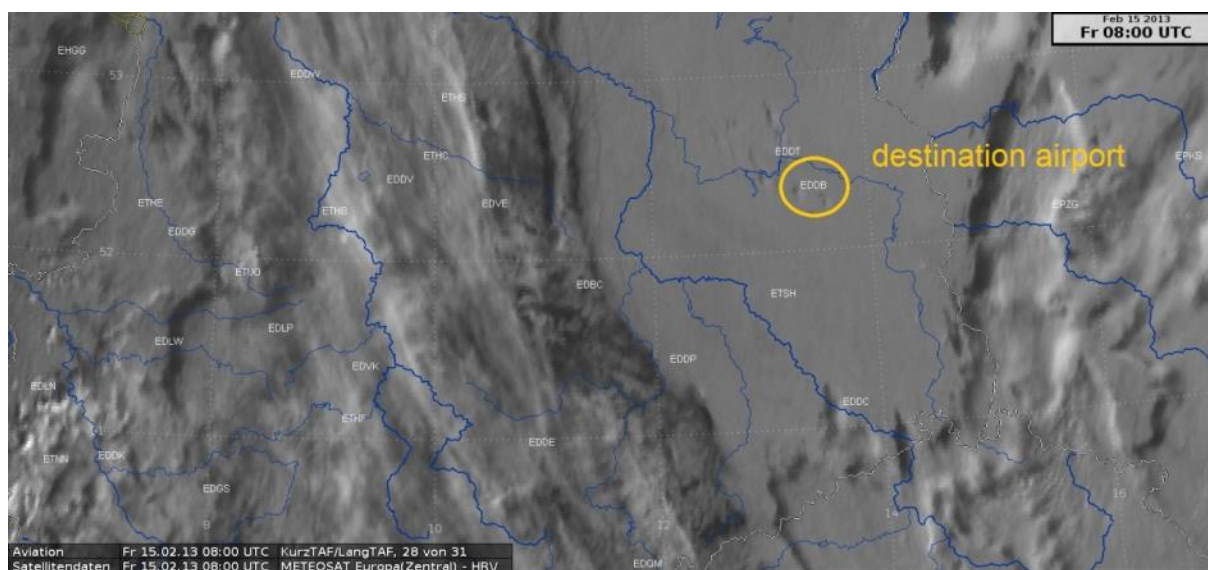


Image 5: Satellite image at the day of the accident at 0800 UTC

Source: Deutscher Wetterdienst

The area forecast for low level flights (GAMET) forecast moderate icing conditions below FL60. The Low Level Significant Chart forecast moderate icing conditions, locally up to FL160.

1.7.3 In-Flight Icing

Depending on the temperature and size of the water droplets in the air, aircraft structural icing can appear in different forms. Large, supercooled water droplets do not freeze completely on impact with the aircraft structure but spread as liquid and then freeze as clear ice. Small, supercooled water droplets result immediately in rime on impact with the cold aircraft structure. Rime consists of ice crystals with enclosed air and has a milky-white appearance. With regard to wings rime accretion starts in the area of the stagnation point. There also is a mixed form of clear ice and rime.



Image 6: Detail of the ice accretion at the wing leading edge

Source: Aviation Supervision Office

1.8 Aids to Navigation

Not applicable.

1.9 Radio Communications

The radio communications conducted in English were recorded by the air traffic service provider and made available to the BFU.

1.10 Aerodrome Information

Berlin-Schönefeld Airport has one runway with the orientation 069°/249°. The asphalt runway with the marking 07L/25R was 3,600 m long and 45 m wide.

At the time of the accident runway 07L was in use. Threshold elevation of runway 07L is 146 ft AMSL. Landing Distance Available (LDA) is 3,300 m.

According to the Aeronautical Information Publication (AIP), the designated operational coverage of the ATIS frequency was 60 NM at FL200.

1.11 Flight Recorders

1.11.1 Radar Data Recording

The flight of the aircraft was recorded by the radar equipment of the air traffic service provider and made available to the BFU as radar plot.

The recording of the surface movement radar at Berlin-Schönefeld Airport was also made available to the BFU.

1.11.2 In-Flight Data Recording

In accordance with aviation regulations it was not required to equip the aircraft with a FDR or CVR. However, the airplane was equipped with a Cockpit Voice Data Recorder (CVDR) to record flight parameters, conversations and sounds. The BFU seized and read out the CVDR.

Manufacturer: L3 Communications

Type: FA2100

The CVDR had recorded 530 parameters and 120 minutes of audio data.

The pilots talked either in English or in Dutch. An air safety investigator of the Belgian Air Accident Investigation Unit prepared a transcript and translation of the CVR recordings at the BFU facilities in Braunschweig.

The aircraft manufacturer stated that the difference of the left and right AOA sensor measurements of up to 3.4° during the accident flight was basically caused by aerodynamic effects, such as e.g. sideslip. The aircraft manufacturer stated further that this was normal and did not result in the interference of other aircraft systems.

The aircraft was equipped with a CVDR impact switch which discontinues the recording if certain acceleration values are exceeded, in order to not override any accident data. At impact the impact switch had been triggered.

1.12 Wreckage and Impact Information

The traces on the asphalt of runway 07L and on the left wing of the aircraft showed that the airplane's left wing tip had initially had ground contact about 7 m prior to the displaced threshold, which is marked with a white bar, and about 4 m left of the runway centre line. Rubber deposits were found about 4 m behind the threshold from the nose landing gear wheel and another 6 m farther from the right main landing gear wheel.

The airplane had come to a stop about 447 m from the threshold beyond the right runway edge marking but still on the asphalt area.



Image 7: Overview accident site, viewing direction north-east

Source: Police/BFU

The outer 2 m of the left wing were bent upwards by about 10°. The lower surface of the wing, the left aileron, and the outer rear end of the left flap showed scratch marks and deformations.

The right flap was deformed. The right main landing gear had fractured and folded back. Parts of the landing gear had penetrated the upper surface of the wing. The wheel of the right main landing gear was destroyed. About 20% of the wheel rim and parts of the flap track and carriage had been abraded.

Some representatives of the aviation supervision office arrived at the site a few minutes after the accident. They photographed an ice accretion of up to 10 mm at the nose, the entire length of both wing leading edges, the leading edges of the horizontal stabilizer, and the front end of the landing gear components. Three hours after the accident as the BFU investigation team was examining the wreckage the ice accretion was still visible.



Image 8: Ice accretion about 50 minutes after the accident

Source: Aviation Supervision Office

The ice accretion was about 4 cm wide, had a milky, rough, crystalline appearance and a slightly concave form with strongly developed feathering at the upper and lower edges. In addition, the upper and lower surfaces of the two wings showed a

lamellar ice accretion. There was no ice accretion on the left wing, where the impact had caused a bend.



Image 9: Ice accretion

Source: Aviation Supervision Office/BFU

During the investigation of the aircraft a photo was taken of the view from the left-hand pilot seat toward the left wing. In order to understand the PIC's statement, a photo with a similar viewing direction, documenting the ice accretion on the left wing leading edge approximately 60 minutes after the accident, was inserted (Image 10).



Image 10: View from the left-hand pilot's seat to the left wing

Source: BFU

The data of the Central Maintenance Computer (CMC) was read out. They contained the Crew Alerting System (CAS) and maintenance messages of the accident flight as well as messages of past flights and incidents. The function of the wing and horizontal stabilizer de-ice system was checked and the time of activation and de-activation determined.

1.13 Medical and Pathological Information

Not applicable.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The three occupants remained uninjured. They disembarked the aircraft unaided via the main door.

1.16 Tests and Research

Not applicable.

1.17 Organisational and Management Information

1.17.1 Air Operator

The operator held an Air Operator Certificate (AOC) issued by the Belgian civil aviation authority (BCAA) for the conduct of non-scheduled passenger and cargo air services. They had a total of 24 aircraft of 11 different aircraft types; 2 turboprop Beechcraft BE200; 22 jets of different manufacturers, of which 2 were Embraer EMB-500.

The operator's Operations Manual (OM) stipulated Standard Operating Procedures (SOP) which had to be applied during daily operations. Among other things, requirements for the application of checklists, standard phraseology between crew members and task distribution between pilots were made.

According to Chapter 2.3.9 Descent it was the task of the PNF to obtain ATIS of the destination aerodrome well before the Top of Descent (ToD) in order to prepare the approach briefing.

Chapter 2.3.10 Approach of the OM stipulates that the approach checklist should be completed prior to the beginning of the approach. Once the crew received the descent clearance to a QNH or QFE altitude completion of the approach checklist should begin.

Chapter 2.3.10.1 described criteria for a stabilised approach:

All approaches should be stabilized by 1.000 feet AAL in IMC and by 500 feet AAL in VMC.

An approach is considered stabilized when all of the following criteria are met:

- *The aircraft is on the correct flight path.*
- *Only small changes in heading/pitch are required to maintain the correct flight path.*
- *The aircraft is in landing configuration; [...].*
- *The IAS is not more than VREF+20 knots and not less than VREF.*
- *The thrust is appropriate for the aircraft configuration.*
- *Descent rate is less than 1.000 fpm; [...].*
- *All checklists have been completed.*

ILS approaches should be flown within one dot deviation of both glide slope and localizer.

[...]

Note 1: It is unlikely to achieve a stabilized approach if the approach speed is in excess of 160 kts by 4 NM.

Note 2: If ATC requires a higher approach speed, adapt your configuration accordingly in order to achieve a stable approach or advise ATC that you are not able to comply with the speed restriction imposed.

The operator stated that a few months after the accident the remaining airplane of this type was sold, so that this particular aircraft type is no longer part of the fleet.

1.17.2 Air Traffic Control

In order to ensure the required separation and smooth traffic, air traffic control applies means such as heading instructions to shorten or lengthen approach paths or higher approach speeds up until 4 NM prior to the threshold.

In this case the CVDR recording showed that at the time the EMB-500 was 4 NM from the intended touch-down point a Boeing 737-800 was on approach 5 NM behind.

The air traffic service provider stated that controllers generally instructed approach speeds of 160 - 170 KIAS because pilots could easily adhere to them.

The Manual of Operations Air Traffic Services (MO-ATS) of the air traffic service provider Chapter Approach Area Control Procedures - Speed Control. - stipulated, among other things:

471.41

[...] Between 12 NM and about 4 NM from touchdown instructed speeds should not be lower than 150 kt IAS.

The International Civil Aviation Organization (ICAO) had stipulated five different approach categories for aircraft. Category A: airplanes with a final approach speed of 70 - 110 kt (mostly small single engine airplanes). Category B: small multi-engine airplanes with final approach speeds of 85 - 130 kt. Category C: most transport aircraft with final approach speeds of 115 - 160 kt. Category D: some jets with final approach speeds of 130 - 185 kt. Category E: is the highest and includes airplanes with final approach speeds of 155 - 230 kt (some military aircraft).

1.18 Additional Information

1.18.1 Ice Protection Systems

Ice protection systems are generally divided into two categories: anti-ice systems and de-ice systems. Anti-ice systems prevent the formation of ice accretion. De-ice systems remove already formed ice accretions.

The following methods are predominantly applied for ice protections systems:

- Thermal by means of hot air or electrical heat
- Mechanical pneumatic (de-ice boots)
- Chemical (liquid de-icing)

Whereas the wing and horizontal stabilizer leading edges of transport aircraft are heated mostly with hot air or electrically and therefore meet the requirements for anti-icing and de-icing, smaller General Aviation aircraft are mostly equipped with de-ice boots, which have to be considered as mere de-icing systems.

The inflation of the de-ice boots blows the ice accretion apart and the air stream removes the ice pieces.

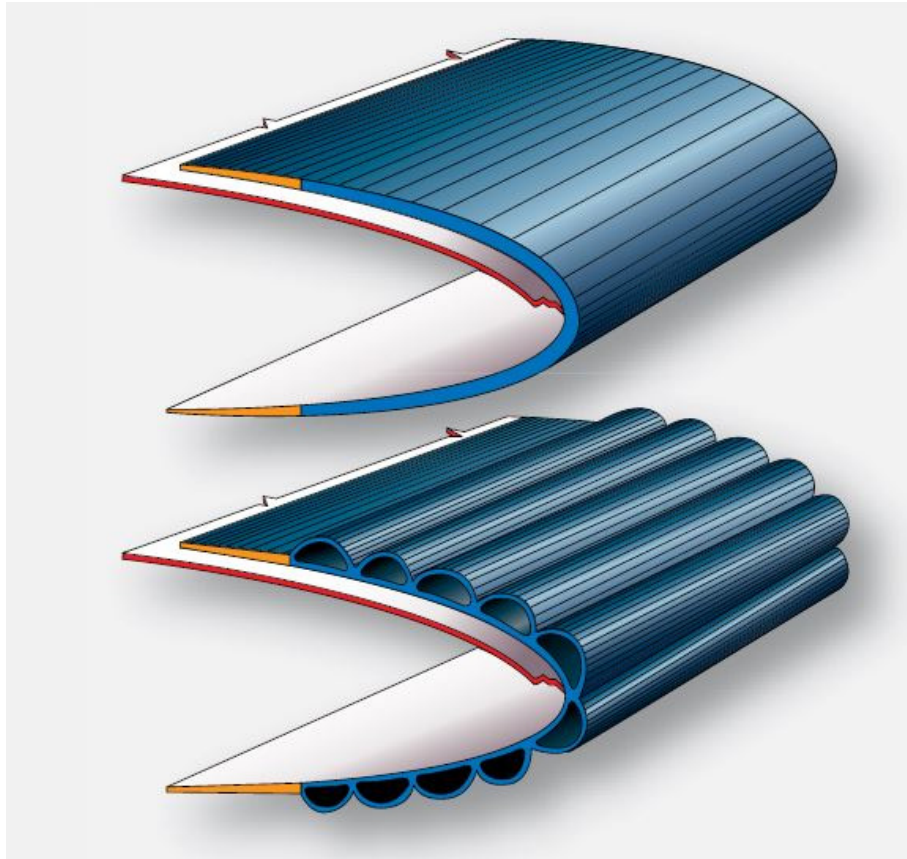


Image 11: Cross section of the de-ice boots

Source: FAA AMT Airframe Handbook

The aircraft type Beechcraft King Air or the Super King Air, which the PIC flew besides the EMB-5500, is equipped with de-ice boots on the wings and horizontal stabilizer.

1.18.2 Analysis of Data of Previous Flights with this Aircraft

The BFU analysed CVDR data of previous flights regarding the use of the engine anti-ice system and the wing and horizontal stabilizer de-ice system. The respective flight phase and the OAT during the use and the duration of the use were considered. Between 30 October 2012 and the accident the analysis showed 22 flights where the engine anti-ice system was temporarily switched on. During 8 of the 22 flights the

wing and horizontal stabilizer de-ice system was also switched on. During 6 of the remaining 14 flights the OAT was less than 5°C.

1.18.3 Result of the Investigation of a Similar Accident

On 8 December 2014 an accident occurred in Gaithersburg, Maryland, USA, involving the aircraft type in question, where the airplane entered aerodynamic stall in icing conditions. At impact the pilot, the two passengers, and three other persons were fatally injured. The aircraft was destroyed.

In June 2016 the NTSB (NTSB/AAR-16/01) issued the investigation report and comes to the following conclusion:

The National Transportation Safety Board determines that the probable cause of this accident was the pilot's conduct of an approach in structural icing conditions without turning on the aircraft's wing and horizontal stabilizer deice system, leading to ice accumulation on those surfaces, and without using the appropriate landing performance speeds for the weather conditions and airplane weight, as indicated in the airplane's standard operating procedures, which together resulted in an aerodynamic stall at an altitude at which recovery was not possible.

The NTSB discussed three possible scenarios in their investigation report which may have resulted in the pilot not activating the wing and horizontal stabilizer de-ice system:

- The pilot was concerned about the landing distance
- The pilot forgot to activate the de-ice system
- The pilot did not correctly assess the effect ice accretion has on the performance of an aircraft.

As a result, the NTSB issued a total of three safety recommendations. It was recommended that the Federal Aviation Administration (FAA) and the General Aviation Manufacturers Association (GAMA) develop a system which automatically warns pilots that the ice protection system should be activated.

To the National Business Aviation Association (NBAA) it was recommended to develop improved training programs with the focal point risk management during winter flight operations and the use of ice protection systems.

1.18.4 Qualification Requirements for EMB-500 Pilots

The BFU had the Flight Standardization Board Report of the FAA dated 15 September 2010 and the Operational Evaluation Board Report of EASA dated 23 January 12 and of 17 October 2013 (after the accident) available, which included the pilot training requirements of the aviation authorities.

These documents showed that the EMB-500 was classified as ICAO approach category B. Described were, among other things, training specifications, check flights, and flying under supervision. In addition, the requirements for the Initial Type Rating Training in regard to *Training Areas of Special Emphasis (TASE)*, which had to be completed in the theoretical and practical training phases, were listed.

Part of the Training Areas of Special Emphasis (TASE) were operation in icing conditions and the stall warning and stick pusher system.

1.19 Useful or Effective Investigation Techniques

Not applicable.

2. Analysis

2.1 Accident / General

The recorded data shows that about 16 seconds prior to impact the pitch angle began to increase, speed continued to decrease, and the airplane dipped below the ILS glideslope. Approximately two seconds prior to impact the airplane suddenly rolled left by approximately 15° per second.

The sudden roll movement with subsequent loss of altitude at an AOA, where normally the aircraft should still fly, is characteristic for stall behaviour with icy aircraft structure (rime). The leading edges of wings and horizontal stabilizer and all other fronts of the aircraft showed ice accretion. The documented ice accretion showed characteristics of rime and clear ice. Rime and the double horn structure of the ice accretion influence the aerodynamic characteristics of a profile very strongly. The determined lamellar ice accretion on the upper and lower surfaces of the wings (runback ice) show that it consisted of a mixture of rime and clear ice.

Due to the low altitude, the flat impact angle, and the relatively low speed the occupants remained uninjured; only the aircraft was damaged.

The investigation revealed no indications of malfunctions of the ice protection system, the SWPS or any other technical irregularities of the aircraft.

2.2 Individual Actions

In the ten minutes of cruise flight prior to reaching the Top of Descent the crew had tried several times in vain to listen to ATIS of the destination aerodrome.

The CVDR recordings and the hand-written notes of the PIC in the operational flight plan prove unambiguously that by listening to ATIS he had been informed about the weather conditions during the approach and at the destination aerodrome. Still, during the preparation of the aircraft for the approach V_{AC} , V_{FS} and V_{REF} values were set at the FMS, which did not take into consideration the reported icing conditions in the vicinity of the airport. During completion of the descent checklist the PIC asked: "landing speeds?" the co-pilot answered "set by me" without explicitly stating the speed values. The PIC did not ask either. The co-pilot's answer "negative, no visible moisture" to the PIC's question regarding icing conditions shows that the pilots checked in this phase.

At 0855 hrs descent to 3,000 ft, the initial approach altitude for the ILS approach, ended and the crew received the instruction to adhere to a speed of at least 170 kt. The PIC accepted the high speed, agreed to the adherence, and selected 175 kt at the AFCS control unit. In general, with an aircraft of this type it is possible to reduce speed by 10-20 kt per NM during the approach. In this case the excess speed was reduced by approximately 17 kt per NM. The acceptance of the high speed resulted in a late landing configuration and also in an increased work load of the pilots during the final approach phase. The requested value of at least 170 KIAS at a distance of 4 NM to the threshold was above the requirements in the operator's OM for a stabilised approach. The BFU is of the opinion that the PIC, who had listened to the traffic situation via radio, wanted to fulfil the wish of air traffic services. It is highly likely that he was convinced that, contrary to the stipulations in the OM, landing with increased approach speed would be successful.

The PIC stated that he had switched on the engine and windshield anti-ice systems when the aircraft had entered the clouds from above. His words: "ja, de motoren er bij want het is negatief terug ze hadden het gezegd he, moderate Icing below three thousand (yes, adding the engines because it is negative again, they have said it, moderate icing below three thousand)" prove that he had monitored the temperature indication on the PFD and was aware of the prevailing icing conditions. Even though the conditions (temperature below 5°C and visible moisture) were met, the PIC did not switch on the wing and horizontal stabilizer de-ice system.

Approximately two minutes prior to the accident, during final approach at about 2,000 ft, the PIC began with the completion of the approach checklist. The Standard Operating Procedures stipulated to complete this checklist at the beginning of the approach, when the altimeters are set to QNH. The BFU is of the opinion that it is highly likely that the PIC's remark "[...] dat staat hier nog aan (it is still on)" when completing the item "icing conditions?" refers to the still engaged engine anti-ice systems 1 and 2.

The recorded conversations of the pilots and the flight data show that about two minutes prior to the accident, at a distance of about 4 NM to the runway, speed was reduced in order to configure the airplane for landing. In this phase the co-pilot disengaged the autopilot.

The PIC stated that as the airplane was passing downward through the clouds, he had checked the part of the left wing, about the outer third, which he could see from his point of view, for ice accretion and not seen any. However, it is not plausible that

the ice accretion determined during the investigation appeared only after leaving the clouds. The PIC's statement, that he had conducted a visual check of the left wing, cannot be confirmed with the CVDR recording of this flight phase. The BFU is of the opinion that with only a fleeting look at the wing it is possible that he could have overlooked the milky-white ice accretion on the silver-grey de-ice boots. It cannot be ruled out, that he did not take a look at all. The recorded data show, that the engine anti-ice system was switched off.

Approximately one and a half minute prior to the accident, at a speed of 134 KIAS, the co-pilot asked the PIC to fully extend the flaps and selected a V_{REF} of 96 KIAS. Once the flaps had fully extended the altitude was about 640 ft AAL.

It is highly likely that triggered by the synthetic announcement (Five Hundred) at 0859:44 hrs, the PIC realised that immediately prior to landing not all checklists had been completed and said: "landing checklist voor de zekerheid, de yaw damper is [...], gear down three greens, flaps are full, landing clearance update". He asked via radio about the landing clearance, even though it had been issued about three minutes earlier. The BFU is of the opinion that the reason for it was very likely that the PIC had forgotten the landing clearance due to the many tasks which still had to be coped with prior to landing. During the PIC's radio transmission with the controller, at an altitude of about 250 ft AAL, the co-pilot reduced the speed of the aircraft further.

When, at an altitude of 200 ft, the synthetic announcement "Minimums, minimums" sounded the PIC was still in communication with the controller regarding the landing clearance.

About 15 seconds prior to the accident, at approximately 150 ft AGL, the co-pilot began to flare the airplane and continuously increased the AOA. In this phase the airplane began to deviate downward from the ILS glideslope. Neither of the two pilots mentioned this. The co-pilot was looking out the window and concentrated on reducing the speed to the value intended for overflying the threshold. The BFU is of the opinion that this shows that the PIC concentrated on the communication with the controller and was distracted from monitoring the co-pilot.

In this phase the airspeed dropped below the V_{MC} for icing conditions, stipulated in the AFM, and below the V_{REF} the pilots had selected.

Aerodynamic stall was the result of the continuously increasing AOA. Up until the impact, the sudden roll movement and the descent could no longer be recovered.

2.3 Specific Conditions

Based on visibility and the altitude of the cloud base instrument meteorological conditions prevailed within the control zone.

The data and statements show that the upper limit of the cloud cover was at approximately 3,000 ft AMSL and the cloud base at 1,400 ft AAL. For about three minutes the airplane had been in this cloud layer. During this time period distinct ice accretion had formed at the leading edges of both wings and the horizontal stabilizer and the fronts of other components. This ice accretion was still verifiable several hours after the accident.

The instruction of the controller to maintain speeds of more than 170 kt up to 4 NM prior to touch-down should ensure traffic flow and separation between the different aircraft. Due to the PIC accepting the speed instruction of the controller configuration for landing occurred very late.

The BFU is of the opinion that the CVDR recording indicates that the work relationship between the very experienced PIC and the co-pilot, who was at the beginning of her flying career, resembled more a relationship between flight instructor and student pilot. The recordings also show that the co-pilot had been highly stressed during the approach, especially during the part where she flew the airplane manually.

2.4 Defences

In the scope of this investigation, the term "defences" or "safety mechanism" means technical systems, actions, procedures and institutions which shall minimise the effects of technical and human errors to protect flight safety.

Standard Operating Procedures and Checklists

Standard operating procedures are part of the defences. They shall protect against errors during the decision making process and help to avoid erroneous actions.

According to the OM-B ATIS should be obtained well before reaching Top of Descent and the approach briefing be conducted. In this case the pilots could not obtain ATIS of Berlin-Schönefeld Airport before leaving cruise level. The reason is that the airplane was well outside the designated operational coverage of the ATIS frequency (60 NM at FL200). Then the reception of ATIS was delayed even further due to the

necessary radio transmission with air traffic services, which the PIC conducted without involving the co-pilot. These factors resulted in the approach briefing being conducted considerably later than stipulated.

Prior to the approach briefing the PIC had informed the co-pilot about the weather conditions at the destination aerodrome, but neither mentioned temperature and dewpoint nor the reported icing conditions.

During the descent and the approach the crew did not complete any of the stipulated checklists at the required time but significantly later. According to the OM the approach checklist should be completed after the altimeter setting had been changed to QNH or QFE. In this case it only occurred during the final approach at about 1,900 ft. The BFU is of the opinion that this deviation from procedures increased the workload of the crew in general and in particular for the inexperienced co-pilot. During the critical phase of the final approach, the delayed completion of the Before Landing Checklist resulted in the PIC concentrating on his communication with the controller and in the distraction from his other tasks especially monitoring the adherence to the speed parameters by the co-pilot.

Ice Protection System

Part of the preparation of the airplane for landing is to select the correct approach and final approach speeds and V_{REV} . The meteorological data of ATIS (temperature, dewpoint, clouds, visibility and the report about observed moderate icing conditions) made clear that the ice protection system including wing and horizontal stabilizer had to be switched on. With his remark "ja, de motoren er bij want het is negatief terug ze hadden het gezegd he, moderate Icing below three thousand (yes, adding the engines because it is negative again, they have said it, moderate icing below three thousand)" the PIC referred to it again, but only activated the windshield anti-ice and the engine anti-ice system of both engines.

The fact that the crew, despite of icing conditions, did not switch on the wing and horizontal stabilizer de-ice system, had two effects: one the ice accretion on wings and horizontal stabilizer was not removed; second the stall warning and protection system became ineffective.

The BFU is of the opinion that historically the de-ice boots were designed to be a purely reactive system to remove ice accretion. Pilots had to realise and monitor ice accretion in order to then activate the de-ice boots and remove the ice. In the present

case the de-ice system was designed to be used as proactive and not just reactive system, because the activation of it influences the stall warning and the stick pusher (SWPS) as well as the approach planning.

Crew Resource Management

The BFU is of the opinion that the assessment of the CVDR recordings showed deficiencies in regard to the application of crew resource management principles. These deficiencies become noticeable in: cooperation, communication, leadership behaviour, situational awareness, mutual monitoring, and the decision making process.

While the airplane had been in descent to 3,000 ft the PIC had requested nine times within five minutes that the co-pilot maintain a high speed in order to not slow down the following traffic. The BFU is of the opinion that the fact that the co-pilot repeatedly tried to reduce speed indicates that on the one hand she tried to adhere to the SOPs and on the other hand wanted to establish the approach parameters, (speed, flap position, etc.) she had learned during her training and conduct a standard ILS approach. The CVDR recordings did not contain any indications that the pilots had discussed whether the co-pilot had viewed herself capable to conduct the approach, given that she was inexperienced on the type and in regard to flying in icing conditions. The BFU is of the opinion that part of good CRM would have been that the PIC notices and communicates these facts so that a timely decision could be made if a change of pilot flying and pilot non flying or special support during the approach were necessary.

As the airplane was entering the clouds, the pilots should have realised that the wing and horizontal stabilizer de-ice system had to be switched on. Neither of the two pilots mentioned that according to the SOP the requirements were met or had questioned the decision.

In the flare phase both pilots allowed the airspeed to drop below V_{MC} for icing conditions, stipulated in the AFM, and below the V_{REF} the pilots had selected.

Stabilized Approach

Past investigations of various landing accidents determined that a landing accident is often preceded by an unstabilised approach. Criteria for a stabilised approach were developed as aid for pilots to avoid landing accidents. Non-adherence to these criteria at a Safety Gate (1,000 ft in IMC or 500 ft in VMC) should result in the termination of the approach. Operators had established this procedure as standard procedure. The correct flap position and the correct speed were part of these criteria. In the present case the airplane had not been in landing configuration when passing 1,000 ft AAL, and in 500 ft AAL not all criteria for a stabilised approach were met, because the Before Landing Checklist had not yet been completed. According to the stipulations in the OM the pilots should have initiated a go-around at the latest at reaching 500 ft.

The controller's request of the crew to approach with at least 170 KIAS was at the upper limit of the usually given speeds. The BFU is of the opinion that this speed did only insufficiently consider the concrete aircraft type. The Manual of Operations Air Traffic Services (MO-ATS) of the air traffic service provider only contained the provision to give pilots speed values of no less than 150 KIAS. The controller's wording "[...] maintain speed a hundred and seventy knots or greater to four miles final" was more an instruction than a request.

Even though the crew could have declined this request, and according to their SOPs should have, the PIC accepted and the co-pilot did not intervene. The BFU is of the opinion that this behaviour indicates that the pilots did not view this SOP as mandatory.

2.5 Organisational Aspects

FAA and EASA had stipulated special focal points for pilot type rating training. Airplane operation in icing conditions, SWPS warnings, stick pusher, and the interaction with the de-ice system were part of these focal points.

The BFU is of the opinion that the fact, that neither the experienced PIC, having flown in business aviation on different aircraft types for years and being trained as FI and CRI, nor the co-pilot, who had just completed the type rating training, did not use the ice protection system in accordance with the procedures indicates training deficiencies. On enquiry by the BFU the PIC stated that among pilots there are

discussions whereby the system should only be used at an ice accretion of at least 0.25 inch. This explanation demonstrates that his system knowledge was insufficient.

The analysis of CVDR data of previous flights with the operator's airplane showed that during six other flights during the winter months prior to the accident the wing and horizontal stabilizer de-ice system was not switched on, although the meteorological conditions described in the procedures were met. The BFU is of the opinion that this indicates that the knowledge level of other EMB-500 pilots of the operator regarding the wing and horizontal stabilizer de-ice system and the SWPS varies and is partially inadequate. Since the operator no longer operates this aircraft type the BFU refrains from issuing a safety recommendation.

The BFU is of the opinion that the requirements of the aviation authorities should be amended in order to improve the pilots' training of this aircraft type in regard to risk management during winter flight operations and the use of the ice protection system.

3. Conclusions

3.1 Findings

- The pilots held the required licenses and ratings to conduct the flight.
- The investigation revealed no indications of malfunctions of the ice protection system, the SWPS or any other technical irregularities of the aircraft.
- The fact that the airplane was equipped with a CVDR allowed the analysis of valuable data and information and therefore made an essential contribution to the result of the investigation.
- The ATIS informed about moderate icing conditions below 3,000 ft AMSL other pilots had reported.
- Even though according to the AFM the conditions were met the crew did not switch on the wing and horizontal stabilizer de-ice system. Therefore ice accretion was possible and the stall warning and protection system became ineffective.
- At about 3,000 ft the aircraft entered the clouds and approximately three minutes later left them again at about 1,400 ft. Ice accretion formed during this time period.
- The flight crew did not notice the ice accretion.
- The approach speed the air traffic service provider had requested corresponded with the standards stipulated in the MO-ATS, but did not sufficiently take into account the approach classification of the airplane.
- The fact that the PIC accepted the request of the air traffic service provider about an increased approach speed up to 4 NM to the threshold resulted in increased work load of the pilots and made establishing a stabilised approach more difficult.
- When reaching the Safety Gate the conditions for a stabilised approach were not met, but the crew continued the approach which was contrary to the valid SOPs.
- The final approach was conducted with an airspeed which was significantly too low for the prevailing icing conditions.

- An aerodynamic stall occurred during flare and the airplane impacted the ground with a rolling movement.
- Impact initially occurred with the left wing prior to the runway threshold.
- At the time of the aerodynamic stall altitude and speed had been low and therefore the occupants remained uninjured.
- Even though EASA and FAA had stipulated Training Areas of Special Emphasis this accident and the analysis of other flights with the airplane operated by the operator and a comparable accident in the USA showed that pilots have deficits in regard to the use of the ice protection system in combination with the stall warning and protection system.

3.2 Causes

The causes of the air accident were:

Immediate Causes:

- The crew conducted the approach under known icing conditions and did not activate the wing and horizontal stabilizer de-ice system, which was contrary to the Standard Operating Procedures (SOP).
- Due to ice accretion on wings and horizontal stabilizer and infringement of the required approach speed the aircraft entered an abnormal flight attitude during the flare phase and crashed.

Contributing Factor

- The crew had insufficient knowledge of the connection between the ice protection system and the Stall Warning Protection System (SWPS).

4. Safety Recommendations

The BFU issued the following safety recommendations:

BFU SR No. 9/2018

The Belgian aviation authority, *Directorat-General de l'Aviation Civile*, should, as part of their oversight responsibilities, ascertain that the operator takes measures which ensure the consequent adherence to Standard Operating Procedures and the application of the criteria for a stabilised approach.

BFU SR No. 10/2018

The European Aviation Safety Agency (EASA) should, in cooperation with the Brazilian aviation authority *Agência Nacional de Aviação Civil (ANAC)*, ascertain that the aircraft manufacture of the EMB-500 renders the syllabus for the acquisition of the type rating more precisely to the effect that pilots unmistakably understand the importance and operation of the ice protection and the stall warning protection systems of the EMB-500.

BFU SR No. 11/2018

The Brazilian aviation authority *Agência Nacional de Aviação Civil (ANAC)* should, in cooperation with the European Aviation Safety Agency (EASA), ascertain that the aircraft manufacture of the EMB-500 renders the syllabus for the acquisition of the type rating more precisely to the effect that pilots unmistakably understand the importance, function, and operation of the ice protection and the stall warning protection systems of the EMB-500.

The BFU issued the following safety recommendation, due to the results of this investigation and the findings from the investigation into the accident involving a Diamond DA-40 NG on 2 March 2018 (File No. BFU18-0211-3X):

BFU SR No. 12/2018

The Deutsche Flugsicherung (DFS) should amend the Manual of Operations Air Traffic Services (MO-ATS) to the effect that the assignment of a final approach speed takes into account the separation requirements, the approach classification of the respective airplane and the Safety Gates the pilots have to adhere to.

The Manual of Operations Air Traffic Services (MO-ATS) should be amended as follows:

Prior to assigning a speed, the pilot should be asked which speed could be maintained up to which distance to the touch-down point. Single engine turboprop aircraft should not be given any speeds after initiation of the descent.

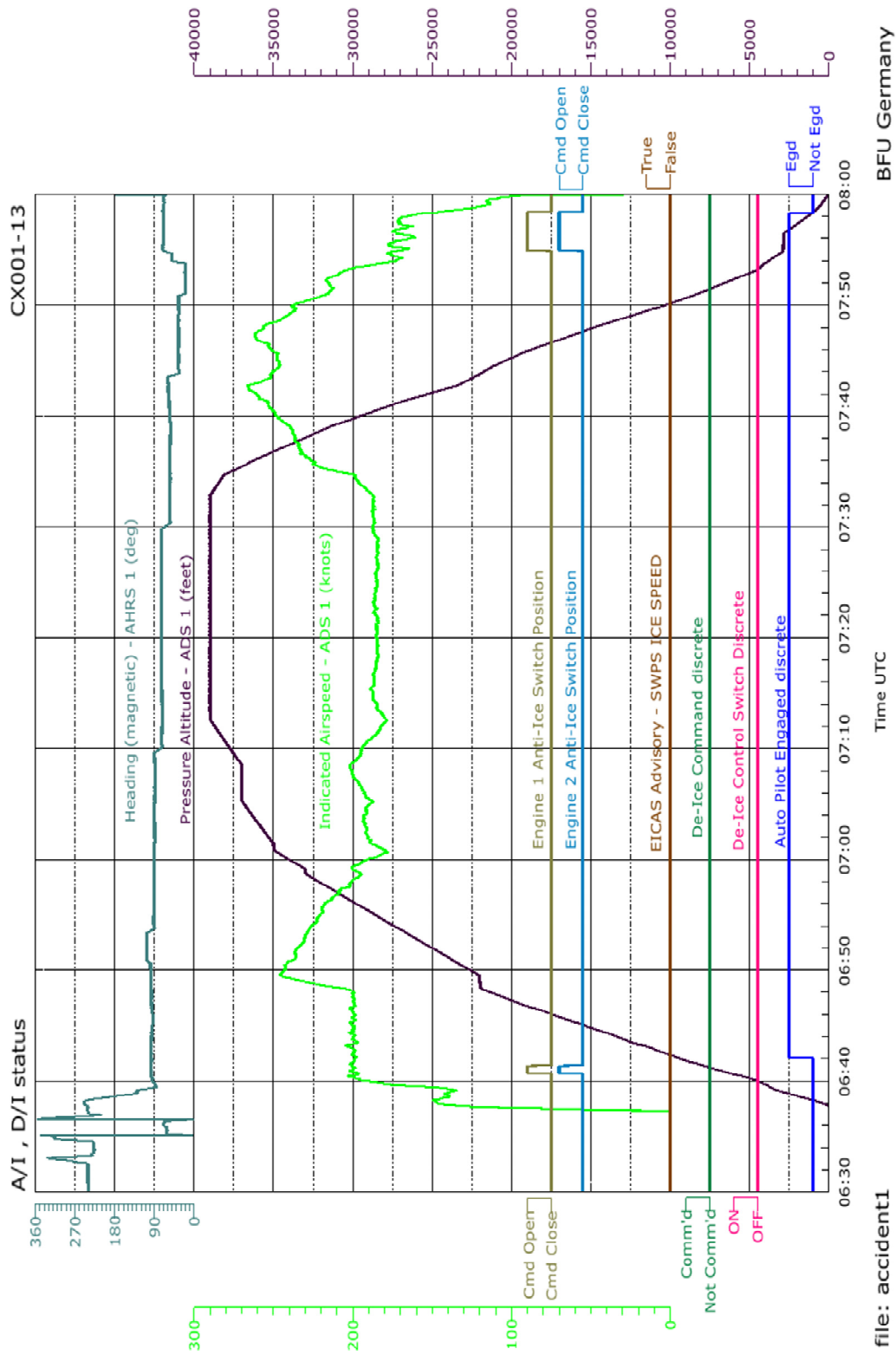
Investigator in charge:	Jens Friedemann
Field investigation:	Uwe Berndt, Thomas Karge, Jens Friedemann
Assistance:	Dieter Ritschel, Hans W. Hempelmann, Philipp Lampert

Braunschweig 17/12/2018

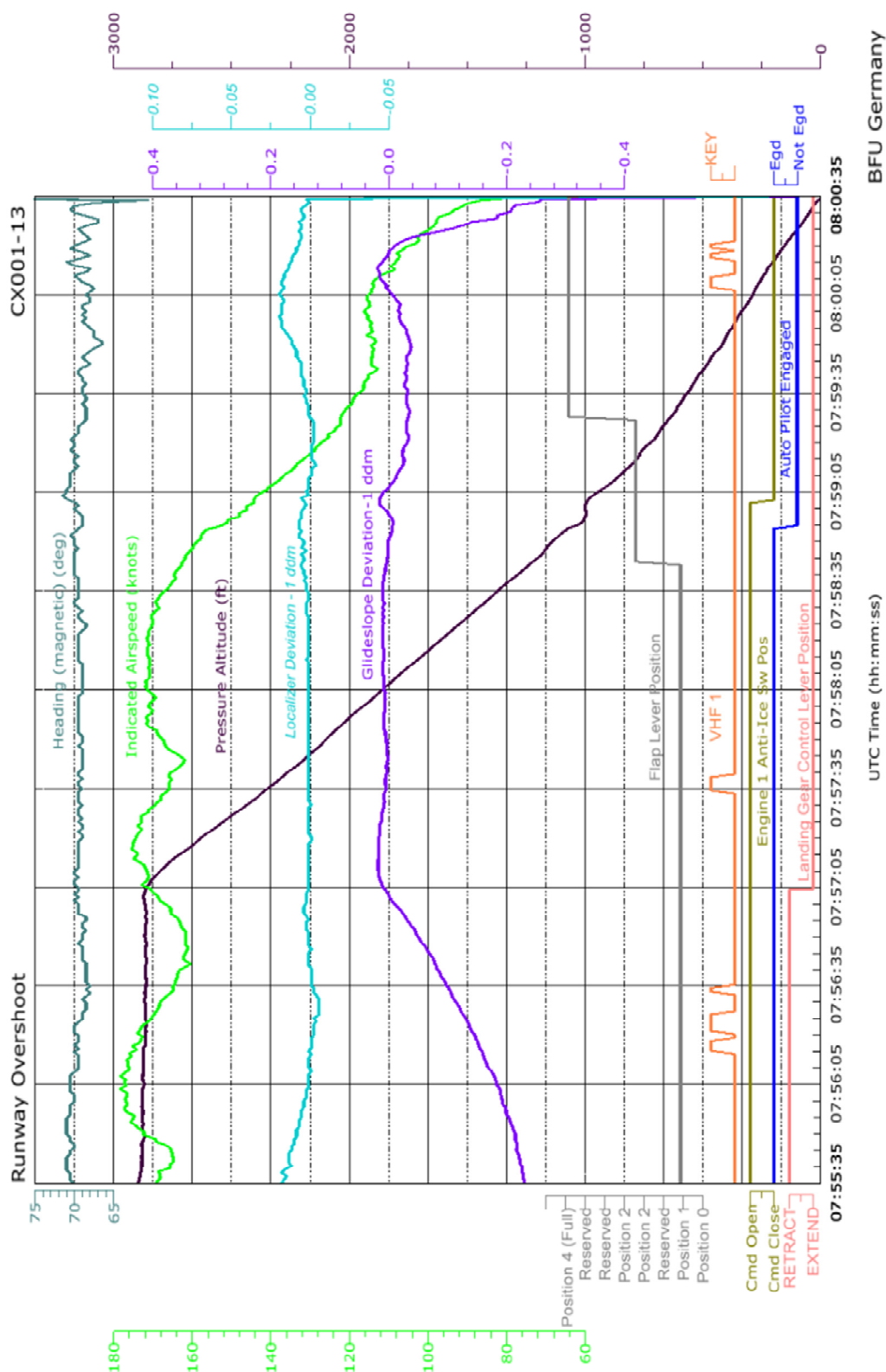
5. Appendix

Excerpt flight data recorder data

Overview entire flight



Final approach



Last phase

