

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	2 February 2010
Location:	Munich
Aircraft:	Airplane
Manufacturer / Model:	Cessna / Cessna 425
Injuries to Persons:	None
Damage:	Aircraft severely damaged
Other Damage:	None
Information Source:	Investigation by BFU
State File Number:	BFU 3X004-10

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

AMSL	Above Mean Sea Level
BFU	German Federal Bureau of Aircraft Accident Investigation
CPL	Commercial Pilot Licence
CRI	Class Rating Instructor
CRM	Crew Resource Management
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
hPa	Hectopascal
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IR	Instrument Rating
ITT	Interstage Turbine Temperature
JAR-FCL	Joint Aviation Requirements - Flight Crew Licensing
KIAS	Knots Indicated Airspeed
LBA	Luftfahrt-Bundesamt
MCC	Multi Crew Coordination
NM	Nautical Mile
OM-A	Operation Manual Part A
OPS 1	Commission Regulation - Commercial Transportation by Aeroplane
PF	Pilot Flying
PIC	Pilot in Command
POH	Pilot's Operating Handbook
RPM	Revolutions per Minute
SEP	Single-Engine Piston Aeroplane
V _{MCA}	Minimum Control Speed

V_{YSE}

Best rate of climb, airspeed with critical engine inoperative (Blue Line Speed)

Synopsis

On 2 February 2010 employees of Munich Airport notified the German Federal Bureau of Aircraft Accident Investigation (BFU) at 0215 hrs¹ that a few minutes earlier an air accident with a Cessna 425 had occurred. Two BFU staff members immediately travelled to the accident site.

The crew stated that during a positioning flight at night in accordance with Instrument Flight Rules (IFR) from Hanover to Munich problems with the left engine occurred. The engine was shut off and the flight continued to the destination airport. During final approach with one engine inoperable the airplane crashed to the ground left and short of the runway. The occupants remained uninjured; the airplane was severely damaged.

The accident was due to:

- When the left engine was shut off the propeller was not feathered
- During the final approach the speed for an approach with one shut-off engine was lower than stipulated
- The airplane veered to the left during power increase and became uncontrollable due to the lack of rudder effectiveness.

Contributory factors were the non-adherence to checklists during the shut-off of the engine and the poor crew coordination.

¹ All times local, unless otherwise stated.

1. Factual Information

1.1 History of the Flight

The aircraft took off at 0041 hrs from Hanover (EDDV) for a positioning flight to Munich (EDDM) with a crew of two pilots. The intention was to make a subsequent air ambulance flight from Munich to Kiel. During the climb the crew received the instruction for a direct flight to Munich and the clearance for a climb to Flight Level (FL) 230. The radar data showed that the aircraft turned south-east and climbed to FL230 after take-off.

At 0123:45 hrs the crew made radio contact with Munich Radar. About five minutes later, the controller advised the crew that both runways were closed for snow removal, but that the southern runway would re-open in about 25-30 minutes. In response, the crew advised they would reduce the speed somewhat. The crew stated that the temperature in flight altitude had been -40 °C.

At 0133:58 hrs the controller issued descent clearance to FL110. According to crew statements in this phase there were problems with the left engine. A system check indicated that the engine's Interstage Turbine Temperature (ITT) had exceeded 900°C and the torque had reduced to zero. The crew then first worked through the memory items before "beginning with the engine failure checklist". In the presence of the BFU the crew gave their reasons for the shut-off of the engine as being the fast increase of the ITT and the decrease of the torque to zero. The crew could not give any other engine parameters like Ng per cent RPM, propeller RPM, fuel flow, oil pressure or oil temperature.

The co-pilot reported via radio: "... we request to maintain FL150 ... we have engine failure on the left side, call you back." At that time, the radar data showed the aircraft at FL214. As the controller asked at 0138:15 hrs if a frequency change to approach control were possible, the co-pilot answered: "... give us a minute, please, and then we report back, until we have everything secured ...". At 0143:22 hrs the co-pilot advised the controller that the engine had been "secured" and a frequency change was now possible. The crew subsequently reported that, three to five minutes later there had been brief, strong vibrations in the right engine. The crew could not state which actions they had carried out after the descent clearance and during shut-off and securing of the left engine. Both pilots stated that there was no attempt to re-start the left engine.

After changing frequency to Munich Approach Control the crew was advised that runway 26L was available. The co-pilot declared emergency at 0143:48 hrs, about 25 NM away from the airport of destination, mentioning again the failure of the left engine. The controller responded by asking the crew what assistance they would require, and asked if a ten-mile approach would be acceptable. This was affirmed. At 0149:28 hrs the controller gave clearance for an ILS approach to runway 26L. At that time the radar data showed the airplane in FL78 flying with a ground speed of 210 kt to the south-east.

The aircraft turned right towards the final approach and at 0151:53 hrs it reached the extended runway centre line about 17 NM prior to the runway threshold in 5,400 ft AMSL with a ground speed of 120 kt. At 0154:12 hrs the controller said: "... observe you a quarter mile south of the centre line." According to the radar data the aircraft was in 5,000 ft AMSL with a ground speed of 90 kt at that time. The co-pilot answered: "Ja, we are intercepting...". Twenty seconds later the controller gave clearance to land on runway 26L. Up until about 0157:30 hrs the ground speed varied between 80 and 90 kt. From 0157:43 hrs on, within about 80 seconds, the speed increased from 100 kt to 120 kt. Thereby, the airplane had come within 5.5 NM of the threshold of runway 26L. Up until 0200:53 hrs the airplane flew with a ground speed of 100 - 110 kt. At 0201:32 hrs ground speed decreased to 80 kt. At that time, the airplane was in 1,900 ft AMSL and about 1.5 NM away from the threshold. Up until the last radar recording at 0202:27 hrs the ground speed remained at 80 kt.

The crew stated the approach was flown with Blue Line Speed. During the final approach the aircraft veered slightly to the left and tended to sink below the glidepath. Approximately 3 NM from the threshold the approach lights had become visible and the flaps and the landing gear were extended. Then the airplane veered to the left and sank below the glidepath. The co-pilot stated a decision for a go-around was made. When an attempt was made to increase power from the right engine, no additional power was available. The aircraft had lost speed and to counteract it the elevator control horn was pushed.

Prior to the landing, rescue and fire fighting vehicles were positioned at readiness in the vicinity of the airport's southern fire station. The weather was described as very windy with a light snow flurry. The fire fighters subsequently reported they had seen two white landing lights and the dim outline of an approaching aircraft. The aircraft's bank attitude was seen to alter a number of times. Shortly before landing, the landing lights suddenly disappeared and the aircraft was no longer visible.

The aircraft impacted the ground about 100 metres prior to the threshold of runway 26L. The crew turned off all the electrical systems and left the aircraft unaided.

During the initial interviews by BFU and police the co-pilot repeatedly talked about a go-around the crew had intended and he had, therefore, pushed the power lever for the right engine forward. In later statements he stated that the engine power was to be increased.

A few days after the accident, the BFU asked both pilots for a detailed written statement concerning the course of events. The BFU received documents with a short description of the accident in note form. The statements of the two pilots were almost identical in content and format.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Third Party
Fatal			
Serious			
Minor / None	2		

1.3 Damage to Aircraft

The aircraft was severely damaged.

1.4 Other damage

None

1.5 Personnel Information

1.5.1 Pilot in Command (PIC)

The 38-year-old pilot held an Commercial Pilot's Licence (CPL(A)) initially issued on 12 July 2000 in accordance with ICAO regulations and valid until 13 July 2014. His licence included the ratings for C406/425 (PIC and IR) valid to 31 August 2010 and PA31/42 (PIC and IR) valid to 15 May 2010. In combination with the revalidation of his licence the pilot had submitted a written statement dated 22 January 2010 in which the operator confirmed that he had a flying experience of at least 500 hours as

pilot in flight operations with two pilots according to JAR-FCL 1.250 (b) (3) and in accordance with EU OPS on multi-engine aircraft with one pilot certified in accordance with JAR/FAR 23 to the LBA and therefore the requirements for MCC training were met. Subsequently, the LBA issued a commercial pilot's licence in accordance with JAR-FCL German on 1 February 2010 valid until 1 February 2015; section XIII Notes ATPL Theory Credit carried the entry MCC.

His class 1 medical certificate was issued on 14 January 2010 and valid to 17 January 2011.

The pilot had a total flying experience of about 3,600 hours, about 400 hours of which were on the type.

Prior to the accident, the pilot had had a rest period of more than 15 hours. His last flight prior to the accident occurred on 31 January 2010 between 0727 hrs and 1340 hrs.

He had been employed by the operator as a pilot since 2005. According to the OM-A the operator deployed him as PIC on PA-42 and Cessna 425. The flight schedule showed him as PIC for the accident flight.

On 31 August 2009 the pilot had his last check flight on a Cessna 425. The check record attested the qualification according to JAR-FCL 1.240 and JAR-FCL 1.246. The entry of 30 November 2009 showed his last proficiency check according to JAR-FCL 1.245 and JAR-FCL 1.246 on the PA-42. On 6 November 2008 the pilot had completed a proficiency check in the PA42 simulator in accordance with OPS 1.965. The documentation carried the note "Right hand seat introduction". The pilot's file from the Luftfahrt-Bundesamt (German civil aviation authority, LBA) did not show any proof that he had completed a proficiency check according to OPS 1.968 on either pilot's seat.

The documentation of the operator and the pilot's file from the LBA showed that the pilot had attended a two-day CRM initial training in July 2000 and in November 2003. On 14 July 2002, on 25 April 2005, on 11 October 2007, and on 20 October 2008 he had attended a one-day CRM recurrent training. No such proof was made available to the BFU for 2004, 2006, and 2009.

After the pilot had acquired the CPL in 2000 he had flown single-engine aircraft up to 2 t MTOM as PIC; in January 2001 he acquired the rating to fly as co-pilot on Piper PA31T/42. In May 2003 he acquired the rating to fly as PIC on PA31T/42. Up until the accident he flew about 3,100 hours on the type. At the end of 2008 he completed

the training for the Cessna 425 type rating. In January 2009 the type rating was entered into his license.

During the BFU interview the pilot negated the question whether he had experienced an engine failure during his flying career. His experience with such failures was limited to training flights. Engine failure during take-off and the approach with an engine failure and subsequent go-around were part of the check flights the pilot had conducted every six months since 2005 in the PA42 simulator.

In the course of the investigation the BFU conducted several interviews with the pilot. His demeanour was always reserved and insecure.

In addition, the BFU interviewed persons from his work environment like his supervisor and his check pilot. They described him as sometimes insecure in connection with sudden arrogance. They estimated that he was hard-working and a good pilot in a technical sense. He showed shortcomings in interpersonal communication. The witnesses stated that in regard to leadership qualities the pilot much rather allowed himself be guided instead of leading. When he became PIC he all of a sudden had to lead.

The supervisor stated that the PIC was initially reluctant to fly the C 425 in addition to the PA-42. On enquiry by the BFU the pilot's justification was that he was not to receive any monetary compensation for the additional qualification and extra work.

The check pilot stated that during check flights the pilot showed shortcomings in leadership behaviour. For example, this was illustrated by a minor involvement of the other crew member and in stone-walling the respective co-pilot. During the check flights it was noted that the checklists were not always used as stipulated.

His superiors and the check pilot described his attitude towards his work as pilot unanimously as little motivated. This had become apparent in the course of the years, but initially he had been enthusiastic about his profession. His superior stated he had passed this partially negative attitude to younger pilots also. Check pilot and superior said the reason for his demotivation had been that he had tried in vain for years to complete the training to acquire the Air Transport Pilot's Licence (ATPL) and then leave the operator. In the pilot's opinion there was no career perspective for him within the operator and the company was to blame for it. The pilot said his relationship with his superior had been strained for quite some time. Contrary to this, in his estimation, there had been no professional or personal problems between him and the co-pilots.

1.5.2 Co-pilot

The 46-year-old co-pilot and Licensed Aircraft Mechanic held a Commercial Pilot's Licence (CPL (A)) in accordance with JAR-FCL (German), first issued on 25 June 1999 and valid to 29 May 2010. His licence had type ratings for: the C525 (PIC and IR valid to 30 November 2010); C406/425 (PIC and IR valid to 26 April 2010); PA31/42 (PIC and IR valid to 21 November 2010); SE piston (land) (PIC valid to 15 August 2011 and CRI valid to 18 May 2010); also FI PPL (A) valid to 18 May 2010. His class 1 medical certificate was issued on 9 September 2009 and was valid to 13 October 2010.

His total flying experience was about 5,200 hours, of which about 300 hours were on the type in question.

Prior to the accident, the pilot had had a rest period of more than 15 hours. Within the last 72 hours prior to the accident he had conducted four flights. On 1 February 2010 between 0230 hrs and 0450 hrs; on 31 January 2010 between 1805 hrs and 1950 hrs, and during the night of 30 January to 31 January 2010 between 2350 hrs and 0115 hrs.

He had been employed by the operator as a free-lance pilot since 2007. According to the OM-A the operator deployed him as PIC on PA-42 and Cessna 425. He stated that he has also been working as a supervision pilot since 2007.

On 18 September 2009 the co-pilot had his last check flight on a Cessna 425. The check record attested the qualification according to JAR-FCL 1.240 and JAR-FCL 1.246. The entry of 30 November 2009 showed his last proficiency check according to JAR-FCL 1.245 and JAR-FCL 1.246 on the PA-42. The pilot's file from the Luftfahrt-Bundesamt did not show any proof that he had completed a proficiency check according to OPS 1.968 on either pilot's seat. The operator was of the opinion that the co-pilot was rated to fly the aircraft from the right-hand seat because he held CRI and FI ratings.

The pilot had acquired the type rating for the Cessna 525 as co-pilot in 1999 and for the PA31T/42 as PIC in 2000. In August 2002 he acquired the type rating for the Cessna 525 as PIC and on 24 April 2008, while working for the operator, the type rating for the Cessna 425

During the interviews conducted by the BFU the co-pilot seemed to be very self-confident.

He stated he had received in-house and external CRM training. According to his description the procedures and processes taught in those CRM trainings were geared towards air transport and could not really be applied to the "Practice of General Aviation". The operator's documentation showed that the pilot had attended a two-day CRM initial training in December 2006 and a one-day CRM recurrent training on 8 October 2009. There was no proof for any participation in 2007 and 2008.

He stated that so far in his flying career he had not have to deal with a real engine failure. Since 2006 he had conducted check flights every six months in the PA42 simulator which included engine failure during take-off and approach flights with an engine failure and subsequent go-around.

His supervisor and the check pilot stated unanimously that he was very self-confident and eloquent. During check flights it was noted that he often made intuitively correct decisions. His shortcomings became obvious by the involvement of the other crew member in the decision-making process, the crew coordination, the supervision of the other pilot and the standard use of checklists. Prescribed procedures were not always applied.

The supervisor and the check pilot stated that the pilot did not advance the way they had expected. He, too, had tried for some time in vain to acquire the ATPL in order to change to another area of commercial air traffic. The missing success had resulted in a noticeable demotivation.

1.6 Aircraft Information

The Cessna 425 is an all-metal, twin-engine, low-wing airplane. It is equipped with a pressurized cabin and has five passenger seats. The airplane had a length of 10.93 m, a height of 3.84 m and a wingspan of 13.45 m. It is certified in accordance with FAR Part 23 Airworthiness Standard (Normal, Utility, Acrobatic and Commuter Category Airplane). According to the flight manual the aircraft is certified for operation with a minimum crew of one pilot.

Manufacturer:	Cessna
Type:	Cessna 425
Manufacturer's Serial Number (MSN):	425-0222

Year of manufacture:	1985
MTOM:	3,901 kg
Engines:	Pratt & Whitney PT6A-112
Engine No. 1:	Serial No PC-E12343; 7,197 operating hours
Engine No. 2:	Serial No PC-E12441; 5,820 operating hours
Propeller:	McCauley, 4HFR34C762

At the time of the accident, the aircraft had a total flight time of about 5,836 hours and 4,376 landings. The aircraft had a valid German certificate of registration and was operated by a German air operator. The Airworthiness Review Certificate was renewed on 18 November 2009 and valid to 3 December 2010.

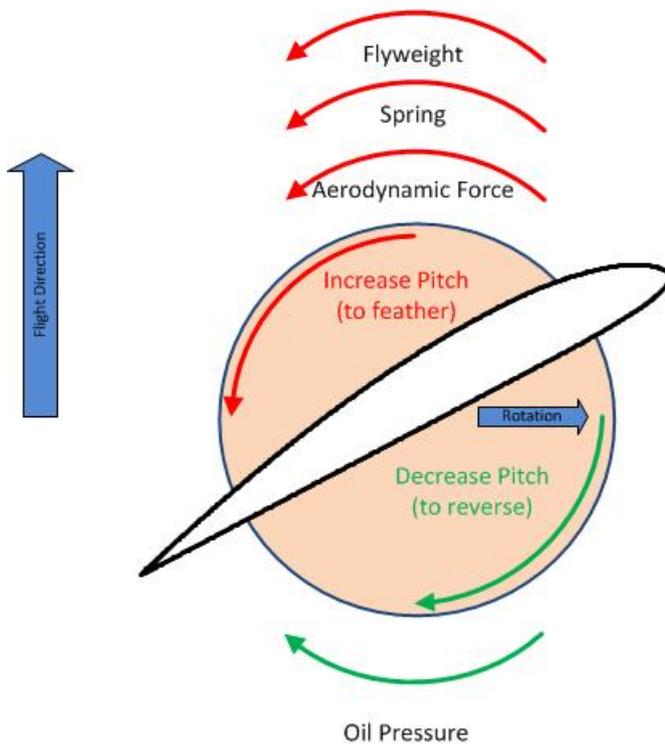
Mass and centre of gravity were within the prescribed limits.

During a 100-hour maintenance check on 28 January 2010, among other things, inspection revealed the left engine bearer to be fractured outboard, and the right engine bearer fractured inboard. Inspection showed that the left engine exhaust system was deformed; the engine was removed and replaced by one taken from another aircraft of the same type. As a result of these defects, there followed Hard or Overweight Landing Checks, Severe Turbulence and/or Manoeuvres Check, Unscheduled Inspection and an additional Borescope-Inspection of the right engine compressor turbine.

1.6.1 Propeller Regulation of PT-6 Engines

The Pratt & Whitney PT-6A-112 engine is a turboprop engine with two separate spools. The compressor is driven by the compressor turbine. The propeller is driven by the power turbine via a reduction gear box.

The propeller RPM is controlled by a governor changing the pitch of the blades. This is provided by modifying the oil pressure routed to the hydraulic cylinder. This pressure counteracts the different moments, reacting to the propeller blades and a force of a spring, installed inside the cylinder. Lack of oil pressure forces the blades into the feather position. If the propeller lever is retarded over the catch to feather position, the cylinder is connected to the oil return line and therefore the spring and the moments on the propeller will turn the blades into feather position.



Schematic diagram of the loads on the propeller Source: BFU BFU

1.6.2 Flight Manual

The flight manual carried in the aircraft (Pilot's Operating Handbook and FAA approved Airplane Flight Manual) which also was part of the operations manual - Operations Manual Part B (OM-B) - stipulated the most important airspeeds. In part Normal Procedures the approach speed was 102 KIAS.

Air Speeds for Safe Operation	
Air Minimum Control Speed v_{MCA}	92 KIAS
Intentional One Engine Inoperative Speed	102 KIAS
One Engine Inoperative Obstacle Clearance Speed	105 KIAS
One Engine Inoperative Best Rate-of-Climb Speed	111 KIAS

The part Emergency Procedures contained a checklist for cases of engine failures above v_{MCA} (Engine Failure in Flight – Speed above v_{MCA}). Among other things, the stipulated memory items were: Checking which engine is affected, pulling the power

lever of the affected engine into idle, putting the propeller of the affected engine into feather, increasing the power of the remaining engine and not falling below a speed of 111 KIAS.

The checklist Engine Securing Procedure stipulated the following actions for an inoperative or shut-off engine:

Autofeather:	OFF
Power Lever:	FLIGHT IDLE
Propeller Control Lever:	FEATHER
Fuel Control Lever:	CUTOFF

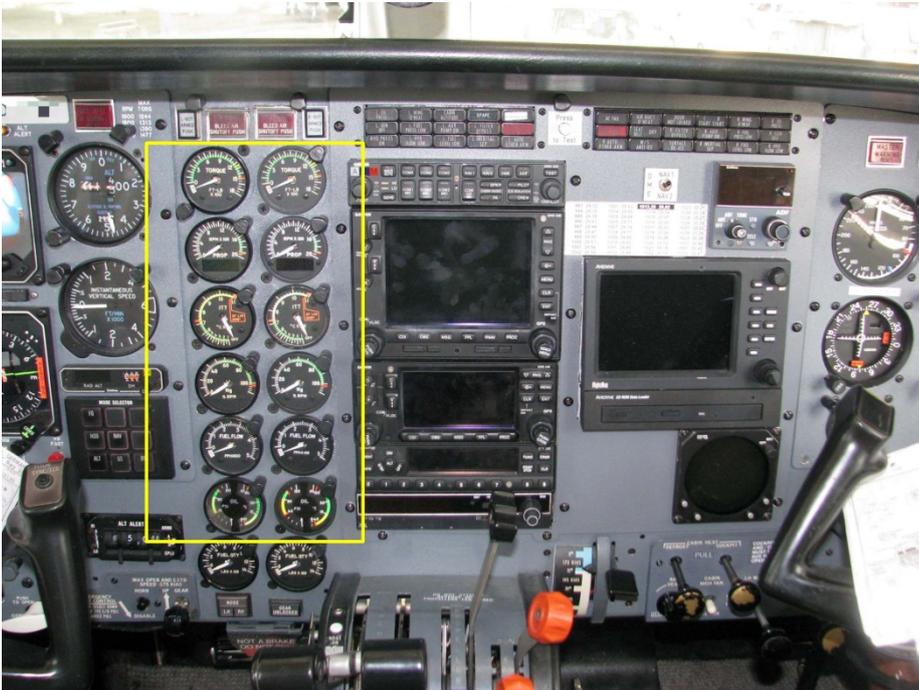
In addition to these four memory items seven optional items were listed. Among others, the generator was to be switched to the OFF position.

The checklist stipulated an approach speed of 111 KIAS in case of an engine inoperative landing. Rudder trim was to be shifted towards neutral when reducing power. Only when the landing is ensured should the landing gear and the flaps be extended and then speed can fall below 111 KIAS. Furthermore, it was referred to the V_{MCA} of 92 KIAS.

The flight manual stipulated for the go-around with one engine inoperative that the power lever should be moved forward toward take-off power while proceeding straight ahead with a bank angle of 5° and a slight shift toward the running engine. The rate of climb should be 111 KIAS.

1.6.3 Additional Aircraft Information

The aircraft was equipped with the following indicators for each engine: Engine torque indicator, propeller RPM indicator, ITT indicator, Ng per cent RPM indicator, fuel flow indicator and oil pressure / temperature indicator.



Engine indications

Photo: BFU

The aircraft was equipped with electronically extendible landing lights on the lower surface of both wings. The switch to operate the landing lights was on a panel on the left cockpit wall. The switch had the positions: LDG LT EXT, OFF and RETRACT.

The aircraft manufacturer stated that v_{MCA} of 92 KIAS, published in the manual, is valid when the propeller of the inoperative engine is in the feathered position. If the propeller is windmilling v_{MCA} would be 5 - 10 kt higher. An extended landing gear would not have a great effect. The aircraft manufacturer could not state which effect a bank angle of more than 5° would have on the v_{MCA} .

1.7 Meteorological Information

At the time of the accident, Instrument Meteorological Conditions (IMC) prevailed at Munich Airport and it was dark night.

Wind: 260°, 3 kt

Clouds: 1-2 oktas at 500 ft, 3-4 oktas at 1,300 ft, 5-7 oktas at 2,300 ft above ground

Visibility: 1,800 m

Precipitation:	Light snowfall, drifting snow
Temperature:	-2 °C
Dewpoint:	-2 °C
Air Pressure:	1,014 hPa

1.8 Aids to Navigation

The Instrument Landing System (ILS) for runway 26L was fully operational. The ILS checks after the accident revealed no technical deficiencies.

1.9 Radio Communications

The radio communications were recorded and made available for evaluation purposes.

1.10 Aerodrome Information

Munich Airport has two parallel runways; each is 4,000 m long and 60 m wide and oriented 083°/263°. Airport elevation is 1,487 ft AMSL. At the time of the accident runway 26 was in use.

1.11 Flight Recorders

The aircraft was not equipped with a Cockpit Voice Recorder (CVR) or Flight Data Recorder (FDR). These recording devices were not mandatory.

1.12 Wreckage and Impact Information

The aircraft impacted the snow-covered ground about 60 metres to the left of the extended centreline for runway 26L and about 100 metres prior to the runway threshold.

The aircraft first made ground contact with the left wing, the left main landing gear, and nose gear. The aircraft then veered to the right and came to rest about 30 m south-east of runway 26L, with the fuselage pointing in a north-easterly direction.

About 85 cm of the left wingtip was torn off. The right main landing gear had been torn off. The flaps were extended. No technical faults were found in the aircraft controls. The rudder trim tab was deflected to the left.

About 50 minutes after the accident a police helicopter stationed at the airport was deployed to document the accident site from the air. The police made video recordings and thermal images. When using a thermal imager warmer areas appear brighter than colder areas.



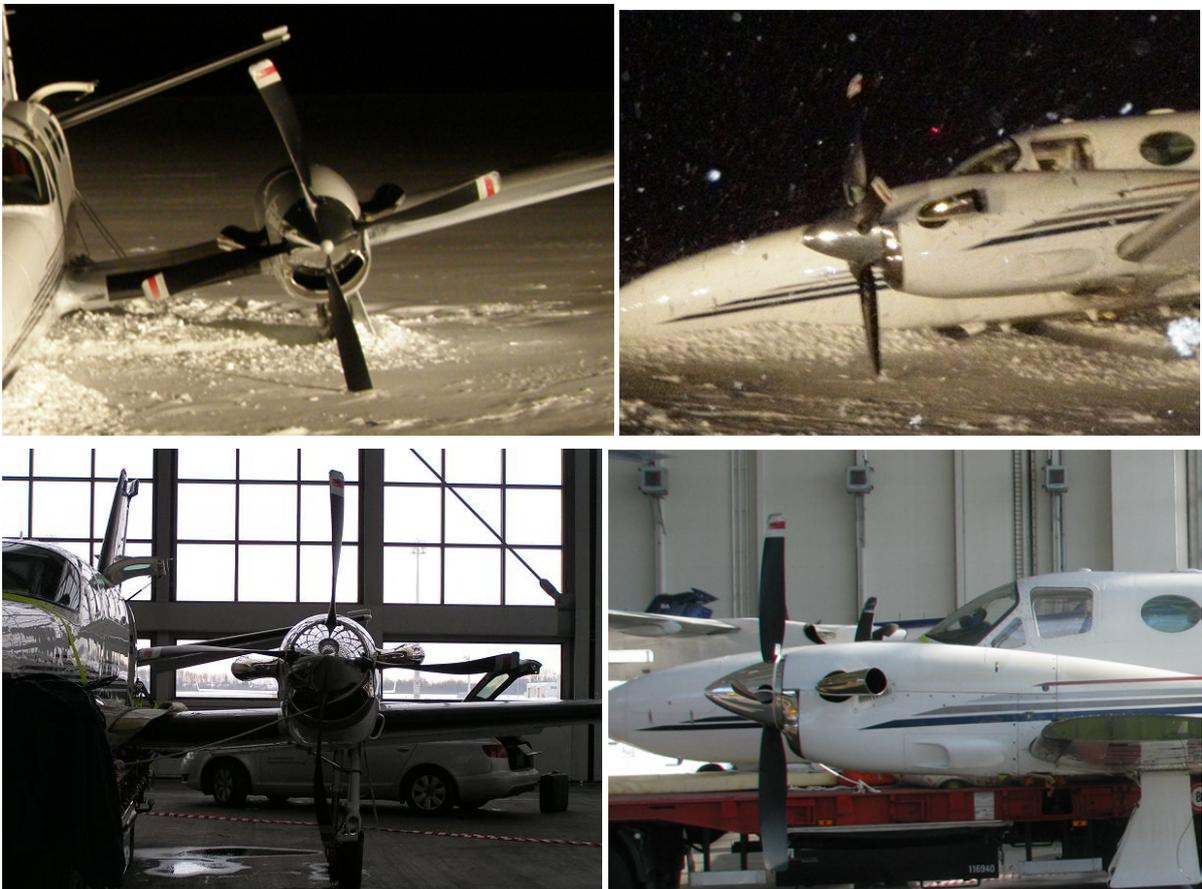
Thermal images of the airplane - different heat emission of the engines

Source: Police

The left engine cowl had external traces of oil. An oil film was also found on the left horizontal tailplane.

When the cockpit was inspected, both power levers were found to be at flight idle. The left propeller pitch control lever was set to feather, while the right propeller pitch control was at the forward stop (max). The fuel selector for the left engine was at the rearmost position (cut off), and the one for the right engine at the forward end-stop

position. The flaps lever and flap setting indicator were at 15°. The rudder trim indicator was directed right. The co-pilot's altimeter setting was 1,013 hPa, while on the left side it was at 29.94 inches Hg (1,014hPa). The switch for the landing lights on the left cockpit wall was set to 'retracted'. The main switch for the cockpit lighting was set to 'night'. The switch for the generator of the left engine was in position 2 ON. The clipboard on the left control horn contained the approach chart for the ILS / LOC approach to runway 26L. The course arrow on the Horizontal Situation Indicator (HSI) was set to the landing course. A placard labelled "zeigt 4 kts zu viel an" (indicates 4 kt too much) was found below the airspeed indicator on the left instrument panel; the placard on the right airspeed indicator showed: „zeigt 2 kts zu wenig an“ (indicates 2 kt too little).



Position and deformation of the propeller blades of the left engine at the accident site and after the salvage operation and the transport to a hangar

Photos: BFU

The two landing lights on the underside of the two wings were retracted.

1.12.1 Engine Examination

Both engines were removed from the aircraft and examined by the BFU at a maintenance organisation.

On the right engine all four propeller blades were uniformly bent by about 90° opposite to the normal direction of rotation. Examination of the right engine showed that it was very difficult to turn the compressor. The power turbine housing was deformed and the turbine could not rotate fully. The oil filter was filled with clear oil, and no metal particles were visible. Individual chips were found in the oil sump. The fuel filter was clean and filled with fuel. All the compressor blade tips had circumferential scrape marks.

The BFU asked the engine manufacturer for scenario descriptions which would correspond with the indications (increase of the engine ITT to more than 900°C and decrease of engine torque to zero) the pilots had described. Only one scenario was described: The RPM of the engine is below idle (sub-idle) and, in addition, torque is demanded by the accessories on the gearbox. Acceleration would not occur, ITT would increase whereas the RPM would remain the same. Engine torque would also remain in lower values.

On the left engine, all four propeller blade tips were deformed and the leading edges were damaged. Examination of the left engine determined that both the compressor and power turbine were free to rotate. The exhaust casing was slightly deformed. The oil filter was filled with clear oil, and no metal particles were visible. The fuel filter was clean and filled with fuel. A small quantity of oil was found in the exhaust duct. The oil level was 2.25 US-Quarts (2.13 litres) below the maximum.

The engine manufacturer performed a full acceptance test including the feather function during the engine examination in Canada. This test showed no irregularities. The same is true for the two examined Fuel Control Units (FCU).

1.12.2 Fuel Examination

Fuel samples were taken from the wing tanks and sent to a laboratory for mineral oil and environmental analysis. The analysis showed that the samples corresponded with the requirements DEF STAN 91-91/ISSUE 6 (DERD 2494) of 8 April 2008 and the ASTM D 1655 for Jet A-1 and the AFQPJOS Joint Fuelling Check List for Jet A-1, ISSUE 24 of October 2008.

In addition, the laboratory analysed a fuel sample taken from the tank truck in Hanover which had refuelled the aircraft. No irregularities were found.

1.13 Medical and Pathological Information

A voluntary alcohol test was conducted with both pilots. Both results were negative.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The pilots stated that after the airplane had come to a standstill they could leave it unaided since they had both been uninjured.

Cabin and cockpit remained undamaged on the inside. The door on the left fuselage side could be opened without problems.

The built-in Emergency Locator Transmitter (ELT) - frequency 406 MHz - was not activated by the impact.

The air traffic control service provider notified the airport fire brigade of an approaching airplane with one inoperable engine about 20 minutes prior to the accident. The fire brigade then took up position in the marshalling area for landing direction 26L and waited for the airplane.

1.16 Tests and Research

Not applicable

1.17 Organisational and Management Information

The operator had an Air Operator Certificate (AOC) issued by the Luftfahrt-Bundesamt (German civil aviation authority, LBA) with permission to carry passengers, freight / post and conduct ambulance flights. According to the AOC the operator operated the following types of aircraft:

- Cessna 560 XL/XLS
- Cessna 560

- PA-42
- Cessna 425

According to the AOC all aircraft of the operator were certified to carry passengers, freight / post and the PA-42 was also certified to conduct ambulance flights.

Since 2005 the operator used the Full Flight Simulator for the aircraft type PA42 of a Flight Training Organisation (FTO) in Bremen for the proficiency checks of their pilots. This FTO mainly trained air transport pilots but also placed the PA-42 simulator at the disposal of other parties. The operator and the check pilot working at the FTO stated that during these check flights it was tried to train CRM issues.

1.17.1 Operations Manual of the Operator

According to the Operations Manual Part A (OM-A) the operator employed 11 pilots and 7 free-lance pilots. For the Cessna 425 five persons were listed as PICs and four as co-pilots.

Four of the five PICs also were supervision captains on the Cessna 425. According to the OM-A, a supervision captain is appointed by the operator and should be approved by the LBA. The tasks include the conduct of line checks.

The operations manual of the operator stipulated the tasks of the co-pilot, among other things:

1.5.1 Duties and responsibilities of the First Officer (FO)

1.5.1.1 General

- *During Flight Duty the FO receives his orders from the commander and performs them under his supervision.*
- *He supports the commander in planning and performance of the flight.*
- *Should the FO take over the commander's duties, he has to perform them according to 1.4.1. [of OM-A] The commander's responsibility remains unchanged.*

1.5.3 In-flight Duties:

- a) he supports the commander.*
- b) he performs radio traffic according to applicable rules and regulations and to the commander's instructions.*

c) he files the documents according to the rules and regulations and the actual flight.

d) in case he is PF, the commander takes over point b) and c).

4.1.1 Minimum Cockpit Crew required

[...]

In case of two type rated pilots one has to be checked out as Commander, the other at least as first officer on the aircraft type concerned. The second in command may be substituted by a right seat checked out captain.

[...]

If more than one pilot holds the required qualification as Commander one will be nominated as airplane commander; the other will be SIC (Second In Command) if he is qualified for the right hand seat according to Chapter 5.

Freelance pilots flying also for other operators have to confirm [...] that they operate only two types or variants.

A line check was to be conducted every 12 months and, among other things, it was to be checked how crew members apply their CRM skills. Concerning the CRM training the following was stipulated:

5.2.6.4 Crew Resource Management (CRM) training

Crew Resource Management is defined as the effective utilization of all available resources, i.e. flight crew, ground crew aeroplane systems and other supporting facilities assisting in the achievement of a safe and efficient airline operation.

CRM is a development of the Crew Co-ordination Concept (CCC).

The CRM training includes:

- combined crew practice in case of an evaluation;*
- combined discussions of abnormal and emergency scenarios;*
- finding clues that inside or outside the aeroplane unusual situations or activities develop that might interfere with safety of passengers or aeroplane;*
- basic training about human factors;*
- techniques to compensate for stress situations which might arise;*

- *the period of validity of a CRM training shall be 12 calendar months. That means the first CRM Training will be an Initial Course and the next will be Recurrent Courses. If issued within the final 3 calendar months of validity of a previous CRM the period of validity shall extend from the date of issue until 12 calendar months from the expiry date of that previous CRM.*
- *CRM training has to be performed by suitably qualified instructors/personnel and the CRM Course must be accepted by the Authority.*

Part 8.7 Non Revenue Flights contained stipulations for non-commercial flights (passengers and freight). It stipulated, among other things:

8.7.2 Non-Passenger Flights

When no passengers are carried, as for example during flight crew training, test flights, delivery and demonstration flights or empty positioning flights, the normal requirements of the OM should be met.

The OM-B contained the POH of the airplane and additional stipulations as to how the crew cooperation was to take place.

Regarding the application of checklists it was stipulated that the crew should complete the normal checklist after they had completed all items on the checklist. The Pilot Flying (PF) should request reading of the checklist by naming their respective titles.

The OM-B stated that abnormal and emergency checklists should be treated as do-checklists, i.e. they should be read from the beginning to the end. Thereby, the Pilot Non Flying (PNF) should read the checklist item by item while the PF completes the items and both pilots should monitor the tasks. The OM-B noted how important it was to know the items of the abnormal and emergency checklist by heart.

The OM-B part 2.4 Call-Out Procedures stipulated for an approach and a go-around, respectively:

Abandoned Approach

When within 500 ft AGL, the aircraft must be within the „approach window“.

- within one dot deflection, both LOC and GS
 - IVSI less than 1.000 ft/min
 - IAS with $V_{AP} \pm 10$ kt - no less than V_{REF}
 - no flight instrument flags with the landing runway or visual references not in sight
 - landing configuration, except for full flaps (non-precision or single engine approaches).
- If the aircraft is not within this „Window“, a go-around must be executed.

Excerpt of the operator's OM-B

1.17.2 Flight Schedule, Conduct of Ambulance Flights

The operator stated that the two pilots were scheduled for the Cessna 425 and the PA-42 as needed. The flight documentation showed that between 2 January 2010 and the day of the accident the PIC had flown 24 flights on the PA-42, 18 of which as PIC and five as co-pilot; on the Cessna 425 he had conducted six flights as PIC and five as co-pilot. During the same time period the co-pilot had flown 21 flights as PIC on the PA-42 and three as co-pilot; on the Cessna 425 he had conducted 11 flights as PIC and four as co-pilot. On 24 January 2010 both pilots flew as a crew and conducted a total of six flights in changing functions.

The duty roster showed that between the beginning of January 2010 and the day of the accident on 46 of 111 flights (PA-42 and Cessna 425) PICs flew as co-pilots.

1.17.3 Operator Supervision

The Luftfahrt-Bundesamt was responsible for the supervision of the operator's flight operations.

The responsible Principal Operations Inspector (POI) stated that the LBA aimed at three audits per year in each approved air operator company. In general, it was possible to conduct two audits per year. Due to a chronic shortage of staff, one POI was responsible for 10 operators (airplane) or up to 18 operators (helicopter). He himself was responsible for two additional operators besides the one in question which he had been auditing since 2006. In addition, he was also the head of an LBA department.

On 17 November 2009 a partial audit and on 11 December 2009 an extension audit was conducted at the operator in question. One key aspect of the audits was the

quality management system. In addition, operational flight plans and pilot's files were examined at random. Checking for verifications of proficiency checks of pilots conducting flights from either pilot's seat was not part of these two audits.

1.18 Additional Information

1.18.1 Aeronautical Regulations

At the time of the accident JAR-FCL 1, German, was valid for the licensing of pilots. It stipulated that ATPL applicants with a flying experience of at least 500 hours in flight operations with two pilots according to JAR-FCL 1.250 (b) (3) and in accordance with EU OPS on single-pilot multi-engine aircraft certified in accordance with JAR/FAR 23 are to be regarded as having completed the MCC training.

At the time of the accident, Commission Regulation (EC) No 859/2008 EU OPS 1 of 20 August 2008 was the valid legal foundation for commercial flight operations with fixed-wing airplanes within the European Union and therefore in Germany. The subsequent requirement for flights in accordance with instrument flight rules or at night was that a crew had to consist of at least two pilots whenever special requirements for single-pilot operation were not met.

The regulation contained extensive specifications concerning crew resource management. OPS 1.943 defined the initial operator's crew resource management (CRM) training:

a) When a flight crew member has not previously completed initial operator's crew resource management (CRM) training (either new employees or existing staff), then the operator shall ensure that the flight crew member completes an initial CRM training course. [...]

b) If the flight crew member has not previously been trained in the area of human factors then a theoretical course, based on the human performance and limitations programme for the ATPL (see the requirements applicable to the issue of Flight Crew Licences) shall be completed before the initial operator's CRM training or combined with the initial operator's CRM training.

c) A CRM initial training has to be conducted by at least one trainer which meets the requirements of the aeronautical authority and can be supported in some areas by experts.

d) The CRM training is conducted in accordance with the extensive curriculum described in the operations manual.

OPS 1.965 defined recurrent training and checking. Subsequently, CRM was also part of the training:

[...]

iv) crew resource management (CRM):

A) integration of CRM elements into all the phases of the recurrent training — by all the personnel conducting recurrent training. The operator shall ensure that all personnel conducting recurrent training are suitably qualified to integrate elements of CRM into this training;

B) modular CRM training — by at least one CRM trainer acceptable to the Authority who may be assisted by experts in order to address specific areas.

[...]

b) Operator proficiency check

1. An operator shall ensure that:

i) each flight crew member undergoes operator proficiency checks to demonstrate his/her competence in carrying out normal, abnormal and emergency procedures; and

ii) the check is conducted without external visual reference when the flight crew member will be required to operate under IFR;

iii) each flight crew member undergoes operator proficiency checks as part of a normal flight crew complement.

2. The period of validity of an operator proficiency check shall be six calendar months in addition to the remainder of the month of issue. If issued within the final three calendar months of validity of a previous operator proficiency check, the period of validity shall extend from the date of issue until six calendar months from the expiry date of that previous operator proficiency check.

[...]

e) CRM. An operator shall ensure that:

1. elements of CRM are integrated into all appropriate phases of the recurrent training, and;

2. each flight crew member undergoes specific modular CRM training. All major topics of CRM training shall be covered over a period not exceeding three years;

[...]

OPS 1.965, Appendix 1 stated the requirements for the recurrent training and checking of pilots:

a) Recurrent training. Recurrent training shall comprise:

1. Ground and refresher training

i) the ground and refresher training programme shall include:

A) aeroplane systems;

B) operational procedures and requirements including ground de-/anti-icing and pilot incapacitation; and

C) accident/incident and occurrence review.

[...]

4. Crew resource management training

i) Elements of CRM shall be integrated into all appropriate phases of recurrent training; and

ii) A specific modular CRM training programme shall be established such that all major topics of CRM training are covered over a period not exceeding three years, as follows:

A) human error and reliability, error chain, error prevention and detection;

B) company safety culture, SOPs, organisational factors;

C) stress, stress management, fatigue and vigilance

D) information acquisition and processing, situation awareness, workload management;

E) decision making;

F) communication and coordination inside and outside the cockpit;

G) leadership and team behaviour, synergy;

H) automation and philosophy of the use of automation (if relevant to the type);

I) specific type-related differences;

J) case based studies;

K) additional areas which warrant extra attention, as identified by the accident prevention and flight safety programme (see OPS 1.037).

iii) Operators shall establish procedures to update their CRM recurrent training programme. Revision of the Programme shall be conducted over a period not exceeding three years. The revision of the programme shall take into account the de-identified results of the CRM assessments of crews, and information identified by the accident prevention and flight safety programme.

Recurrent checking. Recurrent checking shall comprise:

1. Operator proficiency checks;

i) Where applicable, operator proficiency checks shall include the following manoeuvres:

A) rejected take-off when a flight simulator is available, otherwise touch drills only;

B) take-off with engine failure between V1 and V2 or as soon as safety considerations permit;

C) precision instrument approach to minima with, in the case of multi-engined aeroplanes, one engine inoperative;

D) non-precision approach to minima;

E) missed approach on instruments from minima with, in the case of multi-engined aeroplanes, one engine inoperative; and

F) landing with one engine inoperative. For single-engined aeroplanes a practice forced landing is required.

ii) When engine out manoeuvres are carried out in an aeroplane, the engine failure must be simulated.

iii) In addition to the checks prescribed in subparagraphs (i)(A) to (F) above, the requirements governing the issue of flight crew licences must be completed every 12 months and may be combined with the operator proficiency check.

iv) For a pilot operating VFR only, the checks prescribed in subparagraphs (i)(C) to (E) above may be omitted except for an approach and go-around in a multi-engine aeroplane with one engine inoperative.

v) Operator proficiency checks must be conducted by a type rating examiner.

2. Emergency and safety equipment checks. The items to be checked shall be those for which training has been carried out in accordance with subparagraph (a)3 above.

3. Line checks

i) Line checks must establish the ability to perform satisfactorily a complete line operation including pre-flight and post-flight procedures and use of the equipment provided, as specified in the Operations Manual.

ii) The flight crew must be assessed on their crew resource management CRM skills in accordance with a methodology acceptable to the Authority and published in the Operations Manual. The purpose of such assessment is to:

A) provide feedback to the crew collectively and individually and serve to identify retraining; and

B) be used to improve the CRM training system.

iii) CRM assessment alone shall not be used as a reason for a failure of the line check.

iv) When pilots are assigned duties as pilot flying and pilot non-flying they must be checked in both functions.

v) Line checks must be completed in an aeroplane.

vi) Line checks must be conducted by commanders nominated by the operator and acceptable to the Authority. The person conducting the line check, who is described in OPS 1.965(a)4(ii), shall be trained in CRM concepts and the assessment of CRM skills and shall occupy an observer's seat where installed.

In the case of long haul operations where additional operating flight crew are carried, the person may fulfil the function of a cruise relief pilot and shall not occupy either pilot's seat during take-off, departure, initial cruise, descent, approach and landing. His/her CRM assessments shall solely be based on

observations made during the initial briefing, cabin briefing, cockpit briefing and those phases where he/she occupies the observer's seat.

OPS 1.968 required the operator to specially train and check pilots who conduct flights from either pilot's seat. Among other things, OPS 1.968 Appendix 1 stipulated:

a) Commanders whose duties also require them to operate in the right-hand seat and carry out the duties of co-pilot, or commanders required to conduct training or examining duties from the right-hand seat, shall complete additional training

and checking as specified in the Operations Manual, concurrent with the operator proficiency checks prescribed in OPS 1.965(b). This additional training must include at least the following:

- 1. Engine failure during take-off*
- 2. a one engine inoperative approach and go-around; and*
- 3. a one engine inoperative landing. [...]*

1.18.2 Similar Accidents and Serious Incidents

On 18 July 2009 a serious incident occurred at Frankfurt/Main Airport with the same airplane of the operator in question. During an ambulance flight at night, take-off occurred on the taxiway located between the two parallel runways 25L and 25R. A Boeing B737 standing at the western end of the taxiway was overflown with a marginal vertical distance. The BFU initiated an investigation into the serious incident.

On 25 August 2009 the BFU issued the Safety recommendation 25/2009 to the European Aviation Safety Agency (EASA) in connection with the investigation of an air accident involving a Beech 300 which had occurred on 12 January 2006 in Freiburg (Sate File No BFU1X001/06). The Safety recommendation included the following:

Recommendation No 25/2009

The European Aviation Safety Agency (EASA) should regulate to require that Single-Pilot Aircraft engaged in EU-OPS 1.940 flights made in accordance with Instrument Flight Rules and at night, must have a minimum crew of two pilots, and that their training is in accordance with JAR FCL including Multi-Crew-Concept (MCC) training.

EASA confirmed receipt of the safety recommendation in writing on 5 January 2010 and informed the BFU that these would be part of an in-house discussion.

On 21 June 2011 EASA informed the BFU in writing as to the status of the implementation:

Task OPS.062, addressing second pilot requirement for air ambulance flights with aeroplanes has been introduced in the Agency 2010-2013 Rulemaking Programme. The Agency considers this addresses the issue.

In the letter dated 21 June 2011 EASA described the status of the implementation of the safety recommendation as "Open".

The BFU received a letter from EASA dated 5 December 2011:

"For the part of the Safety Recommendation on minimum flight crew, rulemaking task RMT.0334 (former OPS.062) 'Second pilot requirement for air ambulance flights with aeroplanes' is on the Agency's Rulemaking Programme inventory.

For the part of the Safety Recommendation on the Multi-Crew Cooperation (MCC), Commission Regulation (EU) No 1178/2011 of 03 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council, includes, in Annex I Part-FCL, requirements for single pilot aeroplanes operated by a multi-pilot crew.

FCL.010 contains a definition for multi-pilot operation. For aeroplanes, this paragraph defines a multi-pilot operation as an operation requiring at least 2 pilots using multi-crew cooperation in either multi-pilot or single-pilot aeroplanes.

FCL.720.A contains in paragraph (b)(3) the requirement that pilots flying a single-pilot high performance aeroplane seeking the privilege to operate the aeroplane in multi-pilot operations shall meet the requirements of (d)(4), which requires the pilot (as for the multi-pilot aeroplanes) to hold a certificate of satisfactory completion of an MCC course."

1.19 Useful or Effective Investigation Techniques

The early and careful photo and video documentation of the accident site from the ground and the air made it possible to capture perishable evidence like propeller tracks in the snow, heat emission of the airplane and the position of the propeller blades on the left engine even before the BFU investigation team arrived.

Based on the recorded radar data (position, altitude and time) the ground speed of the airplane was calculated. By taking the weather data into consideration TAS and IAS were calculated.

Thereby, it was determined that within the last minute prior to the impact the ground speed decreased from about 88 kt to about 80 kt. Based on these calculations the indicated airspeed (IAS) for this time period decreased from about 112 kt to about 95 kt. About 30 seconds prior to the impact the airplane left the ILS glidepath downward.

2. Analysis

2.1 Technical Aspects

The examination of the left engine did not show any technical deficiencies which would have resulted in an engine failure. The BFU is of the opinion that the engine indications described by the pilots are contradictory. It could not be clarified with sufficient certainty why the pilots shut off the engine. The pilots stated that they had shut off of the engine because ITT had increased and torque had decreased to zero. If the increase of the ITT was not caused by the malfunction of the instruments, it could only be caused by an increase of injected fuel quantity. This would have resulted in an increase of power. This is contradicted by the statement that torque had decreased to zero. Only the scenario described by the engine manufacturer where the engine would have been accelerated from a sub-idle mode, would have supported the described indications. Since the pilots did not make any observations, e.g. about a decrease in engine noise and did not report any other engine parameters, it is not explainable as to how and why the engine would have reached such an area. Since the investigation did not reveal any mechanical engine damage it is highly likely that the engine was generally capable of producing power.

The photos taken shortly after the accident clearly document that at that time the propeller of the left engine was not feathered. It can be excluded that during the flight

the propeller would have moved on its own accord from the feather position without the pilots noticing it. Had one of the pilots moved the propeller lever by accident from the feather position after the shut-off of the engine the position of the blades would not have been changed because oil pressure cannot be built in a shut-off engine. It can also be excluded that the propeller lever was moved towards low pitch by accidentally turning a propeller blade at the accident site because it is necessary to apply some power to turn a propeller blade. The only explanation for the findings is, that the crew did not move the propeller lever into feather when they shut off the engine in flight. The BFU is of the opinion that the propeller lever was moved to the feather position after the accident. The propeller blades were fixed in their positions by the ground contact. Due to their design the propeller blades moved into the feather position during the salvage operation and the transport of the wreckage because there was no oil pressure to counteract the spring pressure. Once the propeller blade stuck in snow and dirt was removed the system worked faultlessly which indicates that it is highly unlikely that the system had failed. This was confirmed by the examination of the propeller governor on the test stand.

The police helicopter took infrared images of the airplane which showed very clearly the differing heat emission of the two engines indicating that the left engine was not running.

The fact that all four propeller blades showed the same damages on their tips indicates that the propeller windmilled at the time of ground impact, i.e. the propeller was not in the feathered position. The traces found on the ground which were caused by several rotations of the propeller also point in the same direction. The photographs taken shortly after the accident document unambiguously that the propeller was not in feather at that time. If the propeller of the shut-off engine was not in feather during the flight it had to be driven by the air stream (windmilling). The traces the propeller left in the snow were about 0.80 to 1.00 m apart from each other. On the one hand the traces can clearly be attributed to the left engine and on the other hand they clearly show that the propeller turned. Based on a ground speed of the airplane of 60 kt after the initial impact and given the distance of the propeller traces of 0.80 - 1.00 m a propeller rpm of 579 and 463 min^{-1} was calculated. At a speed of 70 kt the rpm would have been between 675 - 540 min^{-1} and at 30 kt between 289 - 232 min^{-1} . Had the propeller been in feather such revolutions per minute would not have been reached.

During the flight the oil pressure affected the hydraulic cylinder which prevented the propeller from moving into feather. There was partial oil pressure. The oil pump of the governor was also driven due to the still existing rotation of the propeller; i.e. there was sufficient pressure to maintain a slight climb of the blades. It is highly likely that the oil loss on the left engine occurred because the compressor was turned by the dynamic pressure which caused the oil pump to press oil into the different areas of the engine, mainly into the bearings. Since there was no sealing air for the bearings and oil suction did not meet the conditions of normal operation, oil could move into the gas tract of the engine.

The four propeller blades of the right engine were bent by about 90° which is a typical deformation of a metal propeller impacting the ground with a high revolution per minute (power). The traces on the right engine (stress marks and tempering colour) show that the engine was running at the time of the impact. The investigation determined no indications of a power limitation of the right engine.

2.2 Operational Aspects

The pilots stated they had completed the memory items and "begun" the checklist engine failure after they had seen the ITT indication showing a temperature of 900°C and the torque indication showing zero. The BFU is of the opinion that it would have been necessary to receive as comprehensive an impression of the situation as possible and clearer information about the engine problems and their consequences by, for example, reducing the power and monitoring the indications for possible changes. In general, the pilots' decision to shut-off the engine by way of precaution is not to be called into question. To put the propeller into feather was one of the most important items (memory items) during engine failure and the securing of the engine. The investigation showed that the pilots did not do that.

Had the pilots fully completed the engine failure checklist they would have noticed their error and moved the left engine into feather. This item was also part of the engine securing checklist which would have had to be completed afterwards. In addition, the generator of the engine involved was to be switched off. According to the OM-B the crew would have had to complete these items from memory and then check them by completing the checklist. Even though the co-pilot asked the controller for a little time "... until we have everything secured ..." when he was asked if a frequency change were possible and he about five minutes later informed the controller that now the engine was "secured" and a frequency change possible, the

position of the propellers at the accident site and the switch position ON of the left generator indicate, however, that the crew could not have completed the checklists.

The aircraft manufacturer stated that an engine failure in cruise flight does not necessarily have to result in serious problems for trained and professional pilots. After the power on the remaining running engine was increased and the airplane trimmed, the pilot should, if possible, try to find the cause for the engine failure before putting the propeller into feather. The manufacturer recommends checking the switch position for the ignition and the indications for the fuel rate and the fuel quantity of the engine in question.

The BFU does not understand why the crew did not try to re-start the engine in the approximately 30 minutes until the landing. That way the crew gave away the option to make use of this engine for the remainder of the flight. It is also incomprehensible why the pilots did not notice the pitch of the left propeller with the help of the RPM indicator after they had shut off the engine.

The pilots' statements show that about 3 NM prior to the threshold as the approach lights became visible the landing gear was extended and the flaps were set to 15°. The calculations indicate that from this point on speed continuously decreased. It is therefore highly likely that the determined speed reduction is connected to the extension of the landing gear and the flaps. The BFU calculations show that in the last minute prior to the impact the aircraft fell below the blue line speed of 111 KIAS and approached v_{MCA} .

The BFU is of the opinion that the statement "no power was available" is a subjective observation of the pilots or a description under the direct impression of the accident, respectively. The deformation of the propeller and the trajectory veering to the left of the extended runway centre line indicate that the right engine ran high-powered. However, it is highly likely that the crew was not cognisant of the fact that the left engine was not in feather when they increased the power. It is therefore understandable that the PF was surprised by the resulting strong yaw movement to the left.

There were several interviews and the pilots made differing statements as to why the power was to be increased. Whereas the PIC talked about an increase of power the co-pilot initially stated several times a go-around was intended. Later on he revised his statement and simply talked about an intended increase in power. The co-pilot's initial statement and the fact that the landing lights were shut off and retracted

indicates that a go-around was to be initiated. In addition, the operator's OM-B stipulated that below 500 ft GND a go-around manoeuvre has to be executed if the speed exceeded or fell below the approach speed by more than 10 kt or if it fell below the reference speed (V_{REF}). Once the speed fell below 100 KIAS this was the case and the crew would have had to initiate a missed approach. The PIC's statement and the revised statement of the co-pilot which only refer to an increase in power during the final approach are in contradiction to the above.

According to the manufacturer V_{MCA} increased by 5 - 10 kt to 97 - 102 KIAS due to the drag produced by the non-feathered propeller.

The rescue personnel waiting for the approaching aircraft observed strong winds and changing bank angles of the airplane during the final approach. This shows that the approach was not flown with a constant bank angle of 5° in the direction of the running engine. The approach with increased bank angle and the extended landing gear resulted in a further increase of the V_{MCA} compared to the value given in the flight manual. Although it cannot be proven, since there was no flight data recorder, it is to be assumed that the PIC counteracted the veering to the left by an instinctive full application of the rudder. Due to the low speed the effectiveness of the rudder was not sufficient, however.

2.3. Specific Conditions

Within the operator, both pilots were deployed as PICs on PA-42 and Cessna 425. Whereas the PIC was employed by the operator, the co-pilot worked as free-lance pilot and additionally had the position of supervision captain.

The BFU is of the opinion that given the age seniority of the co-pilot, the significantly higher total flying experience and the fact that he held an instructor rating (FI PPL(A) and CRI SEP) there was an authority gap between the two pilots in favour of the co-pilot. Furthermore, he had, compared to the PIC, a much more dominant personality. The observation of these personal characteristics was in agreement with the statements his supervisor and his check pilot made.

The BFU is of the opinion that important reasons for the accident are an insufficient communication and co-operation, respectively, of the two pilots. This is proven by the fact that several checklists were not completed and the partially contradictory statements regarding the initiation of a missed approach procedure. The BFU is of the opinion that the events indicate that not a well-functioning crew conducted the

flight together but that two single pilots sat next to each other in the cockpit. This conclusion concurs with experiences and observations the check pilot had made during check flights.

The motivation - general discontentment and the stagnant career - of the two pilots described by witnesses may have affected their concentration during the conduct of the flight. That the pilots forgot to put the propeller into feather when they shut off the engine and neither pilot noticed and corrected it in the further course of events may have been aided by this.

The BFU estimates that both pilots had faith in the skills of the other and generally held the opinion that they could trust each other. From the PIC's point of view the pilot sitting in the right seat was a very competent crew member who would say something should difficulties arise. The BFU is of the opinion that due to the personal characteristics attributed to him, it is highly likely that the pilot in the right seat was very actively engaged in the solving of the problem. This may have given the PIC an additional sense of safety. The co-pilot probably assumed that the PIC as experienced pilot had the situation under control. This could have resulted in a certain general carelessness which probably would not have occurred in the same way in combination with an inexperienced co-pilot.

The crew noticed the problems with the left engine at 0130 hrs; the approach with the accident occurred at 0200 hrs. At this time of night humans often experience a drop in performance if they are in a circadian rhythm. Fatigue can show itself by fading concentration and that certain mistakes are not noticed or only belatedly and that actions become sluggish. It was not possible to reconstruct the exact daily routine of the two pilots prior to the accident. The documentation provided to the BFU showed, however, that the co-pilot had been on flight duty the third night in a row. It cannot be excluded that fatigue reduced his concentration and mental performance, respectively.

Due to the weather conditions the crew conducted an ILS approach. According to the weather data in about 1,300 ft the airplane was below the 3/8 - 4/8 cloud cover. At this time the aircraft was about 3 NM from the runway threshold. This concurs with the statement that the approach lighting was in sight. In 500 ft GND the cloud cover was only 1/8 - 2/8 which allowed visual contact. Therefore, the cloud base was significantly above the decision height of 200 ft GND for an ILS CAT I approach.

2.4 Defences

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

With single-engine aircraft the failure or shut-off of an engine in flight results in an emergency landing which has to occur within a radius the aircraft can reach by gliding. Such a scenario does not necessarily lead to an emergency situation with a twin-engine airplane.

The Cessna 425 was certified for single-pilot operation and could, therefore, be safely operated by one pilot. For commercial flight operations it was stipulated that in general this aircraft type was to be operated by two pilots; there were certain exceptions. Since the cockpit crew was increased compared to general aviation this was to result in redundancy and an increase of the safety level (better division of work, relief of the PIC and avoidance of mistakes).

The operator stipulated in the operations manual that all flights had to be conducted with two pilots. The operations manual also stated the pilots' tasks and functions aboard and instructions for the use of the different checklists. Concerning the engine failure checklist and the engine securing checklist it was stipulated that the memory items are to be completed immediately followed by checking and supplementing further items using the checklist.

In this case it became clear that the two pilots did not cooperate in a sufficiently structured manner when the engine problem occurred and needed to be solved; they neglected to put the propeller in feather. Checklists and their completion are the defences for pilots against forgetting important actions especially in stressful situations. This is true for single-pilot and multi-crew cockpits. The PIC would have had to request the completion of the respective checklists (engine failure and engine securing). On the other hand, the co-pilot would have had to insist on the use of the checklists.

In order to minimise the effects human error has on flight safety and to make optimal use of the potential a second pilot adds in commercial flight operations - and in this case a very experienced pilot - a consequent adherence to MCC and CRM principles and procedures is paramount. This accident shows that the pilots had deficiencies in this area. The statement of the very experienced co-pilot that the content of the CRM training was more geared towards commercial air transport and could not really be

applied to general aviation indicates an insufficient acceptance by the pilot. Insufficient acceptance resulting in an inconsequential implementation during flight operations could also indicate deficiencies concerning content and presentation of CRM training.

2.5 Organisational Environment

2.5.1 Operator

The duty roster of the last weeks prior to the accident provided to the BFU shows that within the operator PICs were deployed as PICs and as co-pilots. Hence, they relatively often sat in the right seat. In November 2008 in the scope of a proficiency check in accordance with OPS 1.965 in the PA42 simulator, the PIC had once conducted a "right-hand seat introduction". The BFU is of the opinion that the operator's view is not correct according to which the co-pilot was qualified to conduct flights from the right-hand seat since he held the CRI and FI ratings. The CRI rating was limited to single-engine piston aircraft and the FI rating to the training of private pilots (PPL A). The documentation of the operator did not contain any proof that the two pilots had received trainings and checks required by OPS 1.968. Even though the EU OPS requirements concerning training and checking of PICs, which are to occupy the right seat as well, are mostly geared to air transport with their MPL aircraft, the items which are to be checked primarily would have been helpful for a successful solution of the engine problem, the approach and the go-around with one inoperable engine.

Within the operator, the PICs were deployed on the left or the right seat dependent on the need. The BFU is of the opinion that the decision as to who is flying in which position was more influenced by the equal treatment of the pilots than any other criteria. On flights where there is a standard crew, i.e. one experienced PIC and a rather inexperienced co-pilot, a certain "natural" gap in authority is the case. When two PICs fly as a team, it is not so self-evident. Very different authority gradients can occur depending on the combination of personal characteristics and experiences of the pilots. For example, for a PIC a particular pressure could arise to recognise everything correctly and make immediate decisions if another, more experienced, captain is present. Just as well, the pilot in the right seat could be in a situation where he does not or not right away voice his observations in order to not question the authority of the pilot in the left seat. Under certain circumstances there could be an insufficient involvement or challenge of the other pilot. The BFU is of the opinion that

through respective arrangements between two pilots optimal crew cooperation can be reached.

The documentation provided for the investigation showed that the CRM initial and recurrent trainings within the operator did not fully comply with the OPS requirements. The operator's documentation also showed that the PIC did not participate in any CRM recurrent training in 2006 and 2009 and the co-pilot not in 2007 and 2008.

Even though the operator tried to have the FTO train the pilots in MCC and CRM content during the PA42 simulator sessions the case at hand shows that in day-to-day operations deficits occurred. The statements of the check pilot concerning check flights he had conducted with different pilots of the operator let the BFU come to the conclusion that the pilots incorporated CRM content only to a limited extent in their daily practice. Thus, many things were up to the individual attitude of pilots in general and to PICs in particular.

The fact that both pilots only wanted to contribute to a limited extent to the investigation of the accident during their interviews by the BFU, shows that they did not have much trust in the aim of the investigation and the handling of information. The BFU is of the opinion that with the actions of the operator to let the PIC go and no longer use the co-pilot who was working as freelancer, it is very debatable whether the operator can achieve an atmosphere, among the remaining pilots, of openly dealing with errors for the purpose of a safety culture.

2.5.2 Operator Supervision

The Luftfahrt-Bundesamt was responsible for the supervision of the operator. Among other things, audits were the routine means by which the LBA conducted the supervision.

The LBA stated that checking the pilots' files was often part of these audits. The missing proof for trainings and checks according to OPS 1.968 and the irregularly conducted CRM trainings were never objected, however.

The shortage in staffing level and the limited time available for the audits and the simultaneously new and extra audit focal points like quality and safety management systems, allowed the continuous completion of certain audit focal points only to a limited extent.

2.6 Aeronautical Regulations

The BFU is of the opinion that contradictions arise from the JAR/FAR/CS23 valid at the time of aircraft certification, the JAR-FCL for the licensing of pilots and the EU OPS for commercial flight operations.

At the time of certification an aircraft such as the Cessna 425 was certified as single-pilot aircraft according to JAR/FAR/CS23. For this type certification proof had to be provided that it can be safely operated by one pilot.

When deployed in commercial air traffic this aircraft type usually had to be operated by two pilots as stipulated in EU OPS. Based on this regulation an operator had to compile an OM and submit it to the LBA. In the OM the operator had to determine the tasks of the crew members and develop procedures for twin-pilot operation.

As far as licensing was concerned, a pilot had to acquire the type rating for single-pilot, multi-engine piston land for this aircraft type. The training was conducted according to JAR-FCL. On principal, the LBA only issues a type rating for the Cessna 425 and similar types as pilot-in-command. To receive the type rating as co-pilot was not included and the check pilot entered the qualifier "Multi Crew Only".

During further advancement from commercial pilot's licence to Airline Transport Pilot's License (ATPL) there are facilitations regarding professional crew cooperation (MCC). The facilitations were based on the proof of flight time in flight operations with two pilots in accordance with EU OPS on single-pilot multi-engine aircraft certified according to JAR/FAR23. The BFU is of the opinion that the substitution of the MCC training with only the proof of "presence in the cockpit" to acquire the ATPL is problematic. At least this accident has shown that the crew cooperation did not occur on a level comparable to a crew trained in MCC. The BFU identifies flight safety risks for pilots trained like that working aboard a multi-pilot aircraft.

With the coming into effect of EU Regulation (EC) No 1178/2011 on 3 November 2011 MCC training is required. Therefore, the BFU has abstained from issuing another safety recommendation concerning this matter.

3. Conclusions

3.1 Findings

- Both pilots held the required licences and ratings to conduct the flight. Both were rated to pilot the aircraft as PIC.
- Both pilots are to be considered experienced concerning their total flying experience, their experience on the type and with the type of engine.
- The co-pilot was also a supervision captain for the operator.
- The operator deployed both pilots on the Cessna 425 and the PA-42 as PIC and as co-pilot.
- Neither of the two pilots had completed the proficiency check for the conduct of flight from either pilot's seat.
- The pilots did not attend all the stipulated CRM recurrent trainings.
- There was no evidence of physiological factors affecting the performance of the crew members. It cannot be excluded that the co-pilot's performance was affected by fatigue.
- Mass and centre of gravity of the airplane were within the prescribed limits.
- The pilots stated, they had observed the ITT of the engine having been more than 900°C and torque had decreased to zero. Therefore, they decided to shut off the engine.
- The technical examination did not reveal any malfunction which would have justified the failure of the left engine or its precautionary shut-off or would have explained the described engine parameters.
- The pilots did not put the left propeller in feather when they shut off the engine.
- The crew did not consider re-starting the engine.
- The investigation did not reveal any technical deficiencies of the aircraft relevant to the accident.
- During the last 60 seconds prior to the accident the speed of the airplane fell below the prescribed approach speed and was close to V_{MCA} .

- There was no evidence of technical deficiencies on the right engine. At the time of impact the right engine delivered power.
- The airplane veered to the left once power was increased on the right engine - probably to initiate a go-around - due to the resulting RPM and the high resistance of the left engine which was not feathered. Until the impact, this movement could not be counteracted because the rudder effectiveness was insufficient due to the low speed.
- The pilots remained uninjured and the aircraft suffered only minor damage because of the low speed, the flat trajectory and the marginal yaw and bank angle during impact and the condition of the ground.

3.2 Causes

The accident was due to:

- When the left engine was shut off the propeller was not feathered
- During the final approach the speed for an approach with one shut-off engine was lower than stipulated
- The airplane veered to the left during power increase and became uncontrollable due to the lack of rudder effectiveness.

Contributory factors were the non-adherence to checklists during the shut-off of the engine and the poor crew coordination

4. Safety Recommendation

The BFU has issued the following safety recommendations:

Recommendation No 06/2013

The Luftfahrt-Bundesamt (LBA) should ensure that the operators who operate single-pilot airplanes in accordance with EU OPS and on which pilots-in-command occupy the right-hand seat see to it that the intervals and contents of proficiency checks are adhered to. The requirements of EU OPS 1.968 should be implemented correctly.

Recommendation No 07/2013

The Luftfahrt-Bundesamt should ensure that the operators who operate single-pilot airplanes in accordance with EU OPS and on which pilots in command occupy the right seat make stipulations as to how crew cooperation is to be conducted.

Recommendation No 08/2013

The operator should ensure that pilots who are working as pilots-in-command for the operator and are also to occupy the right seat have completed the proficiency check in accordance with OPS 1,968.

Recommendation No 09/2013

The operator should ensure that in flight operations CRM principles are applied consequently.

In order to ensure this a commensurate program should be prepared. The management and the function owners within the operator organisation should set an example and communicate it to and demand it of others.

Investigator in charge:	Jens Friedemann
Assistance:	Thomas Karge, Klaus Himmler
Field investigation:	Friedrich W. Kühne, Jens Friedemann

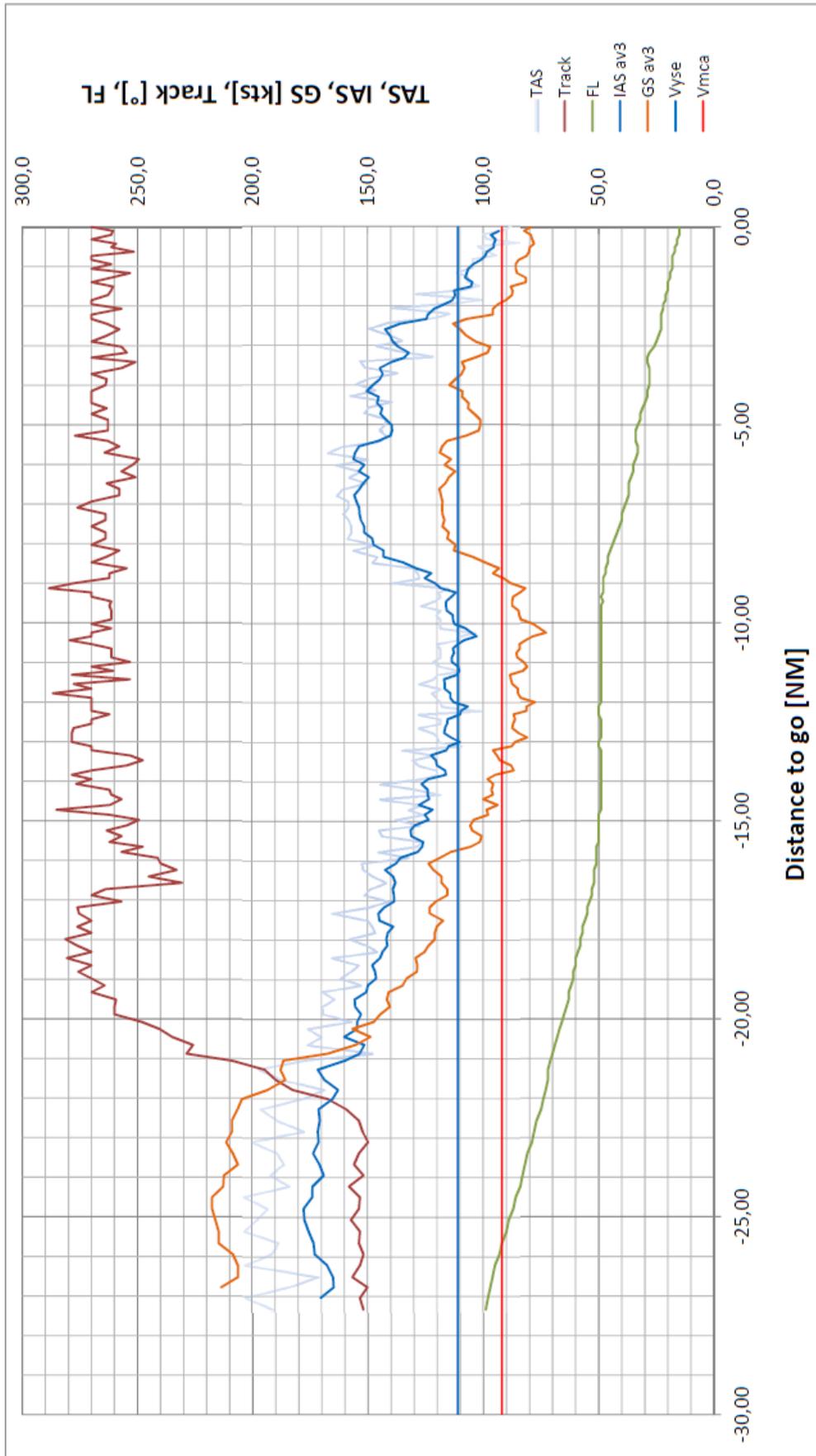
Braunschweig, 22 August 2013

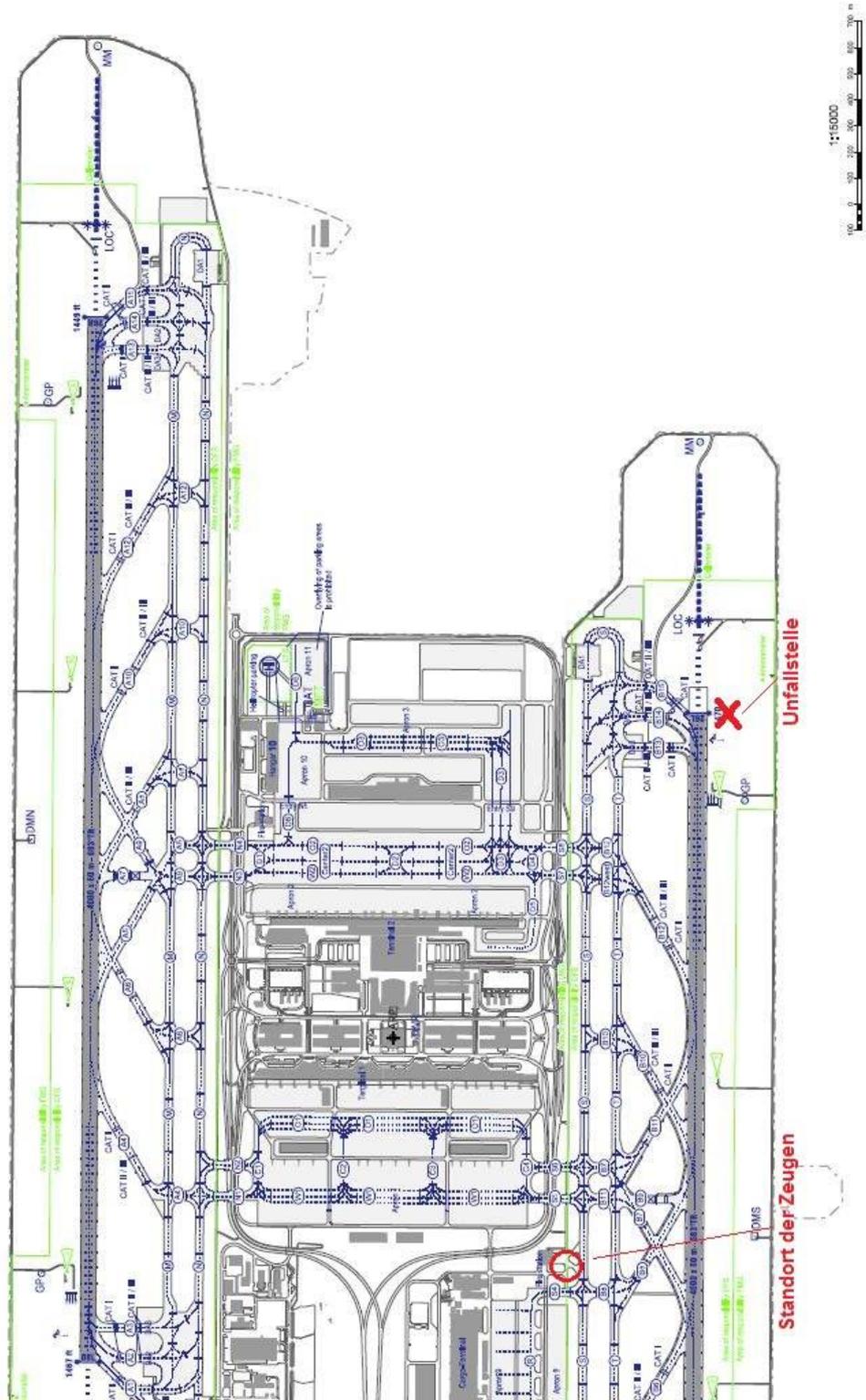
5. Appendices

Appendix 1 Analysis of the flight path and the airspeed

Appendix 2 Excerpt from the aerodrome chart

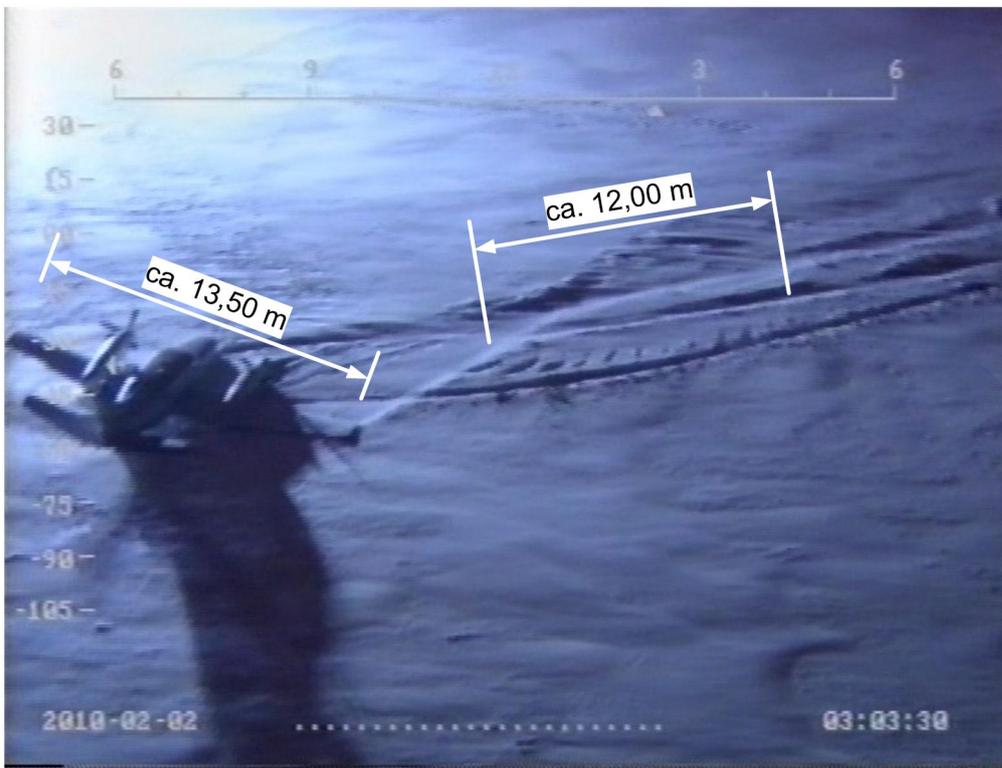
Appendix 3 Aerial photos of the accident site







Accident tracks and final aircraft position (Photo: Police)



Propeller tracks at the accident site on a length of more than 12 meters

Photo: Police, adapted by BFU