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Swiss Transportation Safety Investigation Board STSB

Aviation Division

Final Report No. 2276
by the Swiss Transportation Safety Investigation Board STSB

concerning the accident involving the
Eurocopter AS 350 B3,
registration HB-ZLN,

on 21 December 2013

Ober Erlen, Glarus Süd municipality, GL

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Ursachen

Der Unfall ist darauf zurückzuführen, dass der Helikopter während eines Landeanfluges mit grosser Vertikal- und erheblicher Vorwärtsgeschwindigkeit auf dem Boden aufschlug.

Die Ursache konnte nicht restlos geklärt werden. Sie liegt mit grosser Wahrscheinlichkeit im betrieblichen Bereich.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Article 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident/incident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All information, unless otherwise indicated, relates to the time of the accident.

All times in this report, unless otherwise indicated, are stated in local time (LT). At the time of the accident, Central European Time (CET) applied as local time in Switzerland. The relation between LT, CET and coordinated universal time (UTC) is:
LT = CET = UTC + 1 hour.

Final Report

Aircraft type	Eurocopter AS 350 B3 "Ecureuil"	HB-ZLN
Operator	Heli-Linth AG, Flugplatz, 8753 Mollis, Switzerland	
Owner	Heli-Linth AG, Flugplatz, 8753 Mollis, Switzerland	

Pilot	Swiss citizen, born 1968
Licence	Commercial pilot licence helicopter (CPL(H)) according to Joint Aviation Requirements (JAR), based on a commercial pilot licence according to Federal Aviation Regulations (FAR) and valid for Swiss-registered aircraft, issued by the Federal Office of Civil Aviation (FOCA)

Flying hours	**total**	10,027 hours	**during the last 90 days**	131 hours
	on the type involved in the accident	6291 hours	**during the last 90 days**	131 hours

Location	Ober Erlen, Glarus Süd municipality, GL		
Coordinates	731 820 / 201 160 (Swiss grid)	**Elevation**	approx. 860 m AMSL
Date and time	21 December 2013, 12:08		

Type of operation	VFR, commercial
Flight phase	Landing approach
Type of accident	Collision with ground

Injuries to persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	0	0	0	0
Serious	3	2	5	0
Minor	0	0	0	0
None	0	1	1	Not applicable
Total	3	3	6	0

Damage to aircraft	Destroyed
Other damage	Minor damage to the terrain due to fuel leakage

1 Factual information

1.1 Pre-flight history and history of the flight

1.1.1 General

For the following description of the pre-flight history and history of the flight, the statements of the crew and passengers, the aviation operator's documentation, the recording device data and the statements of several eye witnesses were used.

The flight was conducted according to visual flight rules (VFR). The flight was an aerial work flight.

1.1.2 Pre-flight history

The aviation operator's daily schedule stipulated three missions for the crew (consisting of one pilot and two flight assistants) for Saturday, 21 December 2013 using the Eurocopter AS 350 B3 "Ecureuil" helicopter, registration HB-ZLN. These comprised various transport flights, some with passengers / internal cargo and some with external cargo. Two passengers (the partner and seven-year old son of one of the flight assistants) accompanied the crew for the duration of the duty day.

Shortly after 07:00, the crew and the two passengers met at the headquarters of the aviation operator on Mollis aerodrome (LSMF). According to the pilot's statement, he clarified the weather situation, calculated the weight and centre of gravity, and checked the DABS[1]. The helicopter was prepared for the planned missions. The necessary transport materials were loaded into the helicopter, which on the right side was equipped with a cargo basket for storing material. The front left seat had been removed. The helicopter was refuelled with 200 litres of kerosene, meaning that there were approximately 260 litres available before departure. According to the pilot's statement, there was then a brief discussion of the duty day over a coffee.

Shortly after 08:00, the crew and two passengers took off towards Kies in the Niderental valley. From there, the crew completed their first mission, a transport flight, while the two passengers waited on the ground.

Then, at approximately 09:00, the crew and the two passengers flew to Ober Erlen, south of Matt in the Sernftal valley (cf. Fig. 1 and Annex). The aviation operator regularly used this landing site for transport flights. Once they arrived, the two passengers again remained on the ground while the crew completed the second mission, another transport flight.

The two passengers then embarked the helicopter once again. The contractor for the third mission, who had arrived at the Ober Erlen landing site by car, also embarked the helicopter. At approximately 09:15, the helicopter took off from Ober Erlen and initially flew to the forest clearing known as the Ziegerzug, above Alp Loch (cf. Fig. 1), where the two flight assistants and the contractor disembarked with the rotor still turning. The pilot and two passengers then flew to Alp Loch, where the helicopter was landed. The effective flying time (FT) from the take-off in Mollis to the landing in Alp Loch was 58 minutes. The time recorded by the vehicle and engine multifunction display (VEMD) was 73 minutes: this corresponds approximately to the rotor turning time (RTT).

The pilot and two passengers then walked to the Ziegerzug, where they felled wood together with the contractor and the two flight assistants for approximately two hours.

[1] DABS: Daily Airspace Bulletin Switzerland - daily publication with graphical representations of hazards, restrictions and changes in Swiss airspace

At approximately 12:00, they all returned to the helicopter at Alp Loch by foot. The equipment necessary for the wood-felling was stored loosely in the cargo basket and the cabin (including in the cabin a chainsaw and a fuel canister). The two passengers took their seats on the right rear bench seat behind the pilot seat. One of the two flight assistants was sitting on the rear left bench seat and the contractor was sitting directly next to the left door. The intention was for the contractor to vacate the helicopter with his equipment after the flight to Ober Erlen with the rotor still turning, so that the helicopter could then fly back to the headquarters in Mollis without delay. None of the occupants on the rear bench seats were wearing a safety belt. The second flight assistant was sitting next to the pilot on the aviation operator’s equipment, which consisted of a coiled cargo line and a cargo net. The pilot, who was wearing a seat belt, commented that while the helicopter is being loaded before departure he concentrates on the flying requirements when he has a flight assistant with him, particularly in this area, which had a large number of cables.

The pilot was not wearing a helmet and was connected to the on-board communication system (intercom) via a headset. The flight assistant in the front left position was also connected to the intercom via his helmet. The second flight assistant was wearing neither a helmet nor a headset. Of the three passengers, two were wearing a headset and were therefore connected to the intercom.

1.1.3 History of the flight

At approximately 12:07, the helicopter took off from Alp Loch (approximately 1360 m AMSL) to fly back to Ober Erlen (approximately 860 m AMSL). The pilot first initiated a slight climb approximately parallel to the goods cableway that leads from Matt to Alp Loch. He then began a slight descent and crossed the goods cableway (cf. Fig. 1). He then significantly increased the speed and rate of descent and the helicopter crossed the Sernftal valley. The pilot passed one of the high-voltage pylons on the valley floor and then turned right while continuing to descend on what was essentially the downwind leg of the approach for the landing at Ober Erlen. This meant that he was flying approximately parallel to the high-voltage power line and the Sernf river.

As the pilot had already realised at the Ziegerzug that there was a light southerly wind, he decided to slightly extend the downwind leg and therefore only turn into the base leg of the approach by one of the high-voltage pylons, a little further back than usual. According to the pilot, before the turn their height was approximately 15 - 20 metres above the pylon, corresponding to approximately 80 - 100 metres above ground. The nose of the helicopter was pointing slightly downwards and the pilot began to slowly reduce the speed. According to the pilot’s statement, everything was normal until this point. The other occupants were also unable to determine anything unusual. At the start of the right turn, the groundspeed was approximately 95 kt at a calculated average rate of descent of approximately 2000 ft/min (cf. Fig. 1).

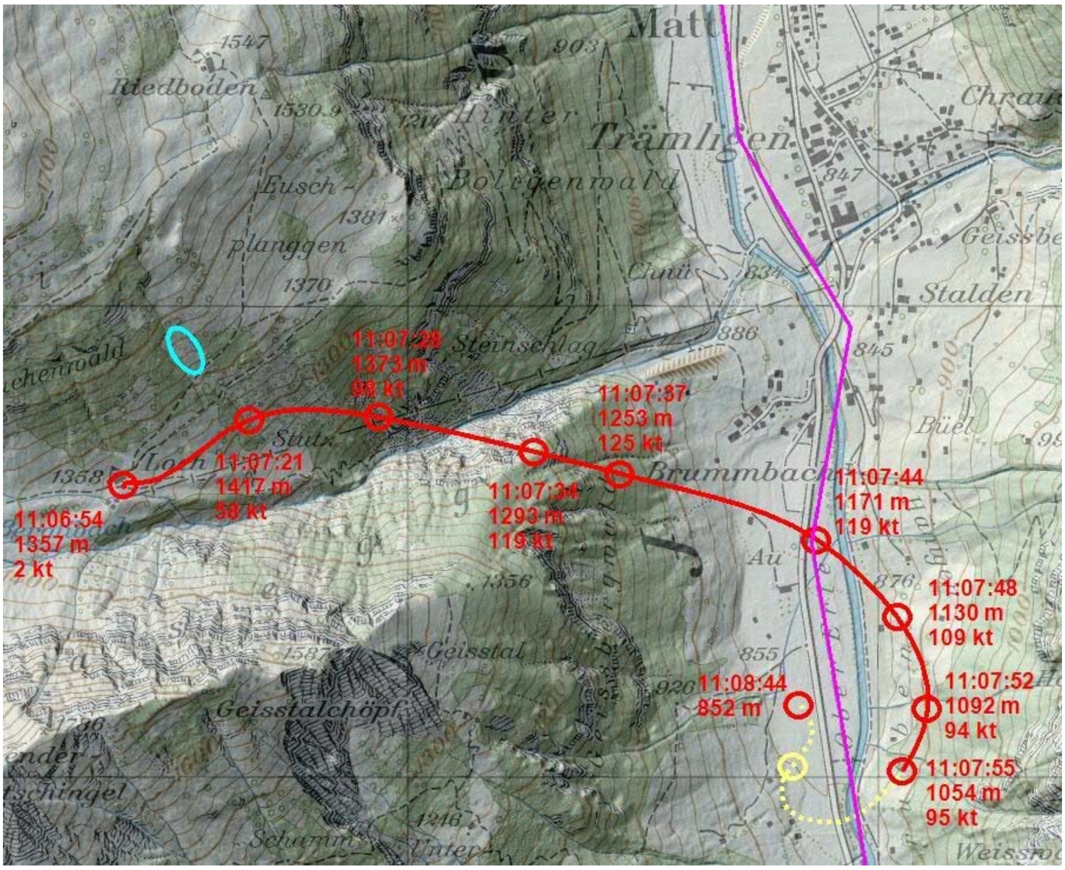

Figure 1: Red: the flight path of the flight involved in the accident according to the PowerFLARM[2] recording with information on altitude [m AMSL] and groundspeed [kt] at selected times [UTC]. Yellow: the last right turn and first impact (yellow circle) according to information provided by the crew, and the traces of impact on the ground. Magenta: the high-voltage power line on the valley floor along the Sernf river. Light blue: the Ziegerzug above Alp Loch; map / aerial photo reproduced by permission of the Federal Office of Topography Swisstopo (JA150149).

According to the pilot's statement, the helicopter suddenly pitched downwards sharply about the transverse axis and the nose pointed very sharply downwards (according to the pilot more than 90°) during the right turn into the base leg of the approach. There is no information on the precise bank angle.

The pilot stated that this pronounced nose-down movement occurred without any control input on his part. He also stated that in this phase he had even pulled back the cyclic in order to reduce speed. The pilot stated that the steering was completely normal until initiating the right turn. According to the pilot's estimate, it had been a smooth approach with no significant build-up of g-force. He stated that the helicopter's hydraulics were far from being overloaded (i.e. servo transparency, cf. Section 1.10.1). He stated that he had not noticed a high or low RPM warning tone.

The pilot was not able to provide more detailed information on the control input he had made in reaction to this unexpected situation. He stated that he had operated the cyclic and finally also pulled on the collective up to the mechanical stop. He stated that although the controls felt normal, the helicopter did not noticeably react to his control inputs. The contractor and the two flight assistants observed the pilot pulling on the collective. The flight assistant on the rear bench seat saw the pilot pumping the collective without this control input having any effect.

[2] PowerFLARM: collision avoidance device – a device that also records the flight path (cf. Section 1.6.3.)

The pilot noticed two lines of yellow text in the lower section of the VEMD, but could not read them.

The flight assistant sitting in the front left space next to the pilot regarded the flight as entirely normal. In his estimation, the right turn took place at a rather high speed. He stated that the helicopter's nose suddenly dropped when three quarters of the right turn had been completed. He stated that the nose had pointed sharply downward and that he had not noticed any warning light or warning tone.

The other flight assistant also regarded the right turn as normal. He stated that the helicopter's nose suddenly dropped only upon exiting the right turn. He stated that the helicopter's nose had pointed down at an angle of approximately 70° and that the helicopter had fallen to the ground like a stone. The helicopter's forward speed and rate of descent were high. He stated that during the nosedive the nose slowly lifted again. He stated that approximately 15 to 20 metres above the ground, the helicopter bit a little again and gradually achieved a horizontal attitude.

The contractor's description largely corresponds to those of the flight assistants.

According to the pilot's statement, he was somehow able to bring the helicopter back to a relatively horizontal attitude shortly before the impact with the ground.

Various eyewitnesses observed both the sharp nosedive at high vertical speed with the nose pointing sharply downward and the transition to an almost horizontal attitude shortly before impact. The eyewitnesses had the impression that the high rate of descent and the relatively low altitude made an accident inevitable. One eyewitness estimated the nose-down attitude of the helicopter during the steep descent at 50°.

The helicopter impacted the ground with a slight nose-down attitude and a slight bank angle to the right. The right skid impacted the ground first and the helicopter was immediately catapulted away from the ground. The tail boom deflected downwards, causing the flex coupling (i.e. the flexible connection between the front and rear parts of the tail rotor drive shaft) to fracture. The cargo basket was torn off the helicopter. While still with a considerable forward speed, the helicopter flew approximately straight ahead, and reached a height of approximately 10 - 15 metres above ground (according to the pilot's estimates). The helicopter then began to rotate about its vertical axis in a counter-clockwise direction. The pilot realised that this probably meant that the tail rotor had failed and immediately reduced the collective. However, the helicopter continued to rotate on its vertical axis. After approximately three rotations of the helicopter on its vertical axis, the main rotor blades impacted the ground and the helicopter came to a standstill, lying on its right-hand side. All four occupants on the rear bank seats were thrown out of the helicopter.

Figure 2: Final position of the helicopter (photo from the day of the accident)

The pilot, who was still seated with his seat belt on, wanted to switch off the engine, but heard it shut off of its own accord. He switched off the electrical supply. The flight assistant sitting at the front in the space to the left of the pilot was able to hold himself steady during the accident by gripping the pilot seat and the front left door. He opened the front left door and was able to vacate the helicopter. He then helped the pilot to vacate the helicopter.

After the accident, three of the four persons who had been sitting on the rear bench seats were lying outside the helicopter, near the landing skid. The fourth person was lying on the opposite side of the helicopter in the immediate vicinity of the main rotor head. One of these persons was of the opinion that during the final phase of the accident, the tail of the helicopter had rotated away above him/her while he/she was lying on the ground.

With the exception of the child, all occupants suffered serious injuries. The child was unharmed. The helicopter was destroyed.

1.2 Alarm and rescue

At 12:09 one of the two flight assistants alerted Swiss Air-Rescue (Rega) by mobile telephone. Rega then initiated rescue measures and two rescue helicopters were dispatched to the site of the accident. Four casualties were then taken to hospital in a total of three flights. The fifth casualty and the child were taken by land to hospital and for a medical check-up, respectively.

At 12:10 an eyewitness alerted the police, who took several measures including deploying the fire brigade. Various eyewitnesses observed smoke rising from the helicopter wreckage directly after the accident, though this ceased soon afterwards. Fire did not break out.

The helicopter was equipped with an automatic emergency locator transmitter (ELT), which transmitted signals after the accident. The transmitter was switched off by the emergency services.

1.3 Wreckage and impact information

1.3.1 Site of the accident

The site of the accident was south of Matt in the Ober Erlen area, to the west of the road from Matt to Elm and the high-voltage power line that runs parallel to it (cf. Fig. 1 and 3). The terrain in the area around the site of the accident is somewhat flat and was covered in snow. The ground was partially frozen.

The landing site at Ober Erlen is regularly used for helicopter landings in connection with aerial work flights. According to the statement of an eyewitness who had regularly observed approaches by helicopters to this landing site, helicopters always approached the site in the same way as he observed directly before the accident.

1.3.2 Impact

The traces indicate that the helicopter impacted the ground with significant vertical and forward speed. The right skid impacted the ground first (cf. Fig. 3). The tail boom then deflected downward and left small traces of the tail skid and the blade tips of the tail rotor.

Figure 3: The first traces of impact from the right skid on the ground (red arrow) and traces of the tail skid and blade tips of the tail rotor (yellow arrow). Final position of the cargo basket and final position of the helicopter (photo from the day of the accident).

The cargo basket, which had been torn off, lay approximately 25 m from the first trace of impact from the right skid. Various other traces were found between the first traces in the snow and the final position of the cargo basket.

The final position of the helicopter was approximately 100 m from the first impact traces. The final position was to the left of the direction defined by the first impact traces from the right skid.

1.3.3 Wreckage

The helicopter was lying on its right-hand side. The landing skid on the right was completely deformed and on the left it was broken. The tail boom had been deflected downward and in a slight lateral direction. The flex coupling between the front and rear tail rotor drive shaft was severed. The vertical stabiliser exhibited traces of significant deformation. The horizontal stabiliser was deformed. The tail rotor was not damaged.

The turbine was in its original position and exhibited traces of deformation in the power turbine area. The main drive shaft between the turbine and the main gearbox was severed. The main gearbox mount was fractured and the main gearbox had been pushed down into the fuel tank. The top part of the plastic tank had therefore ruptured.

All three main rotor blades were connected to the main rotor head's sleeve flanges and star arms and exhibited considerable signs of damage. The main rotor head's sleeve flanges and star arms were significantly twisted and deformed counter to the direction of rotation. The main rotor head was broken.

Some of the main rotor control pitch rods were fractured in the area around the main gearbox base plate. All three pitch rods between the upper, rotating part of the swashplate and the main rotor blades were fractured. The three main rotor control's hydraulic cylinders were in their original positions and were connected to the pitch rods and the lower, non-rotating part of the swashplate. The drive link (or drive scissor) between the upper, rotating part of the swashplate and the main rotor mast was deformed where it was attached to the main rotor mast and had been twisted against the mast. The swashplate guide, on which the swashplate has vertical axial movement along the main rotor mast, had been torn from its mount on the upper part of the main gearbox housing (cf. Fig. 4).

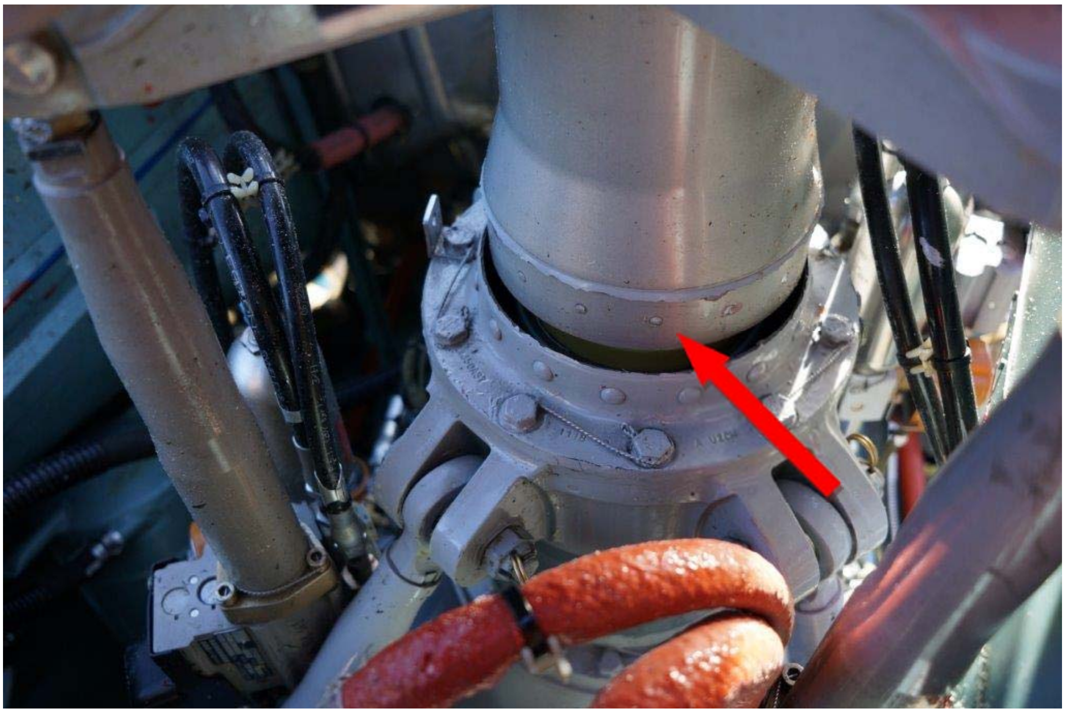

Figure 4: Swashplate guide, torn from its mount on the upper part of the main gearbox housing (red arrow).

Most of the cabin interior remained intact. The rear bench seats were in their original positions and did exhibit signs of deformation. The pilot seat was in its original position and had been significantly deformed downwards and to the right (cf. Fig. 5). Some of the equipment that had been loose in the cabin during the flight involved in the accident was still in its original position; some was outside the cabin.

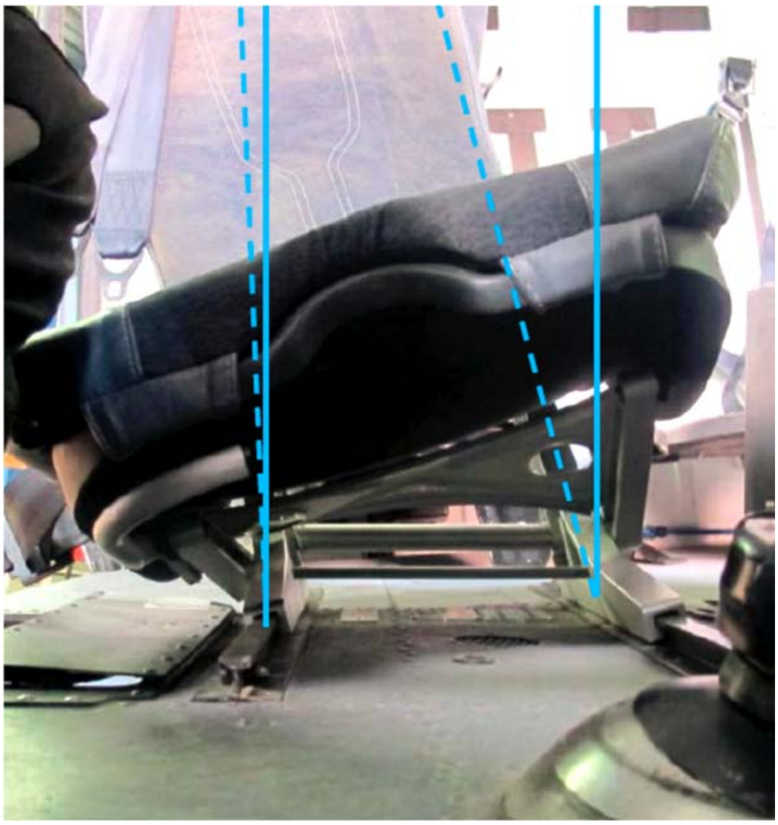

Figure 5: Pilot seat – significant deformation down and to the right

The turbine start switch on the cabin ceiling was in the ON position and secured with the guard. The collective twist grip was in the FLIGHT position. The hydraulics system switch on the collective was in the ON position. The fuel shut-off valve lever had not been used.

The plastic of the high-visibility pilot's door had been torn off and the door lay next to the wreckage of the helicopter (cf. Fig. 2). Although the small door behind the pilot door on the right near the rear bench seat was deformed and had been torn from its latch, it was still in its original position. The doors on the left side were not damaged.

1.4 Meteorological information

1.4.1 General meteorological situation

Switzerland lay on the edge of an extended area of high pressure centred over South-eastern Europe. An extension of the thermal high extended to Italy and was causing a southerly Foehn wind in the Alps.

1.4.2 Weather at the time and location of the accident

There was a brisk south-westerly wind along the Jura mountains and over the Swiss plateau. The Sernftal valley remained largely protected. There was a katabatic wind on the valley floor. Apart from a few cirrus and a cloud bank on the Panixer Pass, which were indicative of the southerly Foehn wind, the sky was cloudless.

Cloud/Weather	1/8 cirrus, sunny
Visibility	10 km or more
Wind	135 degrees, 2 kt
Temperature/dewpoint	3 °C / 0 °C
Atmospheric pressure QNH	1033 hPa
Hazards	None

1.4.3 Astronomical information

Position of the sun	Azimuth: 177°	Elevation: 20°
Lighting conditions	Daylight	

1.4.4 Webcam image

Figure 6: View to the south-west from Weissenberge above Matt (approx. 1300 m AMSL), 21 December 2013, 12:10. The site of the accident on the valley floor near Ober Erlen (red circle).

1.5 Aircraft information

1.5.1 General

The Eurocopter AS 350 B3 “Ecureuil” is a single-engine turbine helicopter with six seats. The helicopter was equipped with landing skids and a conventional tail rotor. The main rotor rotated in a clockwise direction when viewed from above.

The main rotor control was via pitch rods and three hydraulic cylinders, which were connected to the non-rotating lower part of the swashplate. The helicopter is only equipped with one hydraulic system as standard; a dual system can be installed as an option. The helicopter involved in the accident was equipped with only one hydraulic system. A pump provides the necessary pressure in the hydraulic system, which is driven via a belt from the main drive shaft between the turbine and the main gearbox.

The helicopter with the serial number 7347, registration HB-ZLN, was at the time of the accident the most modern model (AS 350 B3e) and was equipped with a twin-shaft Turbomeca Arriel 2D engine with a take-off power of 950 shp[3].

The helicopter was built in 2012 and indicated 1145 operating hours at the time of the accident.

1.5.2 Equipment

HB-ZLN was equipped for transport flights with external cargo and featured a cargo hook, a high-visibility door, a vertical reference floor window, and a mirror for observing the external cargo.

Skis had also been fixed to the skids in order to prevent the helicopter from sinking into snow.

A cargo basket (heli-utility basket) was mounted to the right side of the helicopter; this was torn off during the accident. Equipment with a total mass of approximately 64 kg was placed in the cargo basket. The maximum permitted load for the basket was 91 kg.

The cockpit of HB-ZLN was equipped with a GPS-based MovingTerrain electronic flight information system and a PowerFLARM collision avoidance device.

1.5.3 Fuel reserves

Before the departure from Mollis in the morning there were approximately 260 litres of fuel in the helicopter’s tank. The total flying time until the accident was approximately one hour. The fuel consumption of this helicopter type is just under 180 litres per hour.

The VEMD recordings indicate fuel reserves of 85 kg (approximately 108 litres) at the time of the accident.

On this helicopter type the low fuel warning light illuminates at 60 litres.

1.5.4 Mass and centre of gravity

The mass and centre of gravity of the helicopter were within the manufacturer's specified limits throughout the flight involved in the accident. The mass was approximately 2040 kg. The maximum permitted mass for this helicopter type is 2250 kg.

Estimates indicate that even if the equipment which was loose in the cargo basket and the cabin had shifted to their respective extreme fore or aft positions, the centre of gravity would still have been within the limits stipulated by the manufacturer.

1.5.5 Maintenance

The last periodic check, a 25/30-hour check of the turbine and airframe, was certified on 5 December 2013 at 1121 operating hours.

No complaints were entered in the technical documents in the period between the last periodic check on 5 December 2013 and the accident.

According to the pilot’s statement, there had been no technical problems with the helicopter up until initiating the last right turn before the planned landing in Ober Erlen. He stated that in general no specific technical problems had occurred with this helicopter.

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[3] shp: shaft horsepower (1 shp = 0.746 kW)

1.5.6 Flight manual

In Section 3 “Emergency procedures” under 3.3 “Tail rotor failures”, subsection 3.3.1 “Complete loss of tail rotor thrust” the flight manual (FM) for the Eurocopter AS 350 B3e describes the procedure to be applied in the event of loss of tail rotor thrust according to the situation:

“3.3.1.1 HOVER-IGE[4] (or OGE[5] in HV diagram[6])

LAND IMMEDIATELY

1. *Twist Grip ………….….... IDLE position.*
2. *Collective ……………….. INCREASE to cushion touch-down.*

3.3.1.2 HOVER-OGE (Clear area, out of HV diagram)

Simultaneously,

1. *Collective ……………….. REDUCE depending on available height.*
2. *Cyclic …………………… FORWARD to gain speed.*
3. *Airspeed ………………... MAINTAIN Vy or higher.*
4. *Collective ………………. ADJUST to obtain minimum sideslip angle.*

LAND AS SOON AS POSSIBLE

If a go-around was performed, carry out an autorotative landing on an area suitable for the autorotation procedure.

3.3.1.3 IN CRUISE FLIGHT

1. *Airspeed ………………… MAINTAIN Vy or higher.*
2. *Collective ……………….. ADJUST to obtain minimum sideslip angle.*

LAND AS SOON AS POSSIBLE

APPROACH AND LANDING

On a suitable area for autorotative landing:

1. *Twist grip ……………….. IDLE position.*
2. *Carry out an autorotative landing* […]”

1.6 Recording devices

1.6.1 General

HB-ZLN was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR). These were not prescribed.

The helicopter was not equipped with the System Vision 1000, which at the time of the accident was standard for new Eurocopter AS 350 B3e helicopters and which had previously been available as an option. This system is mounted in the centre of the cabin ceiling behind the two front seats and records various parameters, images of the cockpit and the instruments, and environmental noises.

[4] IGE: in ground effect

[5] OGE: out of ground effect

[6] HV diagram: height-velocity diagram (diagram showing whether a safe autorotation is possible for a given combination of height and speed).

1.6.2 Electronic flight information system

The electronic flight information system records the GPS position at regular intervals. It was not possible to secure the recordings for the flight involved in the accident.

1.6.3 PowerFLARM

The collision avoidance device records the GPS position at regular intervals. The datasets are then saved to the permanent memory in blocks. This means that if the power supply is interrupted, a certain number of datasets can be lost.

The recorded data show the flight involved in the accident from take-off from Alp Loch until 11:07:55 UTC, when the helicopter was about to initiate the final right turn (cf. Fig. 1 and Annexes). The recordings were made at intervals of 1 second. At the time of the last recording, the helicopter was descending with a groundspeed of approximately 95 kt and at an altitude of approximately 1050 m AMSL, i.e. at a height of approximately 200 m above the planned landing site.

Data recording only restarted after 11:08:44 UTC, when the helicopter was already in its final position (cf. Fig. 1 and Annex 1).

This approximately 50 second interruption to the recording can, according to the statement of the manufacturer, FLARM, be explained by the fact that the power supply to the device was temporarily interrupted when the helicopter first impacted the ground. This meant that the datasets that had not yet been written to the permanent memory were lost. This is likely to have been approximately 20 seconds of recording. When the power supply was re-established, the device had to restart and the GPS satellite signals be received. This process appears to have taken approximately 30 seconds.

The recording of the last flight before the flight involved in the accident (from Mollis to Alp Loch) is complete. It indicates that in the morning, when flying from Kies, the pilot had approached the landing site at Ober Erlen in a manner similar to that adopted later during the flight involved in the accident, when he approached from Alp Loch (cf. Annex 2).

1.6.4 Vehicle and engine multifunction display

The vehicle and engine multifunction display (VEMD), which primarily serves to inform the pilot of the helicopter's various technical systems, also records certain parameters. However, there is no systematic recording; instead recording of various parameters only takes place in the event of a failure. Which parameters are recorded is dependent upon the type of failure. The time of the failure is also registered. Furthermore, any overlimits are recorded, though not the time at which they occurred. Only the parameters and the extent of the overlimit are registered.

Three minutes of flying time was recorded for the flight involved in the accident. This recording comprises the time during which the compressor rpm (NG) was more than 10% of the operating rpm. This time is measured in seconds and rounded up to the nearest minute.

A total of 31 failures were registered during the flight involved in the accident. The first failure was recorded at 2:12 and the last at 2:22. The first failure was INVAL COL PITCH, which indicates an invalid collective pitch potentiometer anticipator value. According to the statement of the manufacturer, this failure is usually one of the first failures to be recorded in the case of accidents, due to contact with the ground and the resulting structural deformation or contact with the main rotor. Also registered at 2:12 was the failure EDR FAIL; this was probably triggered as a result of the temporary loss of power to the engine data recorder (cf. Section 1.6.5). The manufacturer's analysis of the various failures stipulates the following: *"The failures recorded on the VEMD for the flight #1293* [flight involved in the accident] *are most probably a consequence of the crash."*

One overlimit was recorded during the flight involved in the accident. This concerned the maximum permissible torque value being exceeded by a large margin. The manufacturer's investigation report states the following: *"This over limit was most probably a consequence to the main rotor blade impact with the ground."*

1.6.5 Engine data recorder

The engine data recorder (EDR), which is connected to the turbine and the digital engine control unit (DECU), records various parameters (primarily of the turbine) for the purpose of maintenance. It is not an FDR in the traditional sense.

On the one hand, certain parameters are continuously recorded at intervals of 1 second. On the other hand, if there are discrepancies or overlimits, a separate, more detailed recording for a certain period of time is made (context reading and limit reading).

There is a continuous recording available for the flight involved in the accident. It lasts for 2:15 minutes and begins when the electrical supply is switched on. The data reveals that the compressor rpm (NG) increases by 10% at approximately 0:22 minutes and the VEMD measurements therefore begin at this point (cf. Section 1.6.4). The data is consistent with the flight path recordings of the PowerFLARM and the pilot's description of the flight. In particular, the data reveal a descent with heavily reduced collective and low torque and NG values. Towards the end of the recording the values reveal a brief increase in the rotor rpm (NR). The recording ends abruptly after 2:15 minutes, which corresponds to a VEMD time of approximately 1:53 minutes. The recording ends at approximately the same time as the end of the PowerFLARM flight path recording. It is therefore plausible that the abrupt end of the recording was due to a temporary loss of power to the EDR, which was probably a result of the initial impact with the ground. As the EDR, like the PowerFLARM, saves the data permanently in blocks, any interruption to the power supply can also mean the loss of data for a certain period of time before the actual interruption occurred. At 2:12 min VEMD time, the failure EDR FAIL was registered by the VEMD (cf. Section 1.6.4), i.e. approximately 19 seconds of the continuous recording were lost.

In order to restart after a power supply interruption, the EDR requires approximately 10 seconds during which the individual functions then gradually reactivate. The continuous recording is only saved again to the permanent storage after approximately one minute, which explains why there is no further continuous recording of the flight involved in the accident.

As the context and limit readings, which are initiated by the occurrence of an event that triggers such recordings, are recorded at shorter intervals than the continuous recording, they are influenced differently by an interruption to the power supply than the continuous recording. This is consistent with the fact that for the flight involved in the accident, context and limit readings are available, some of which cover periods not covered by the continuous recording. In particular these recordings reveal two other EDR POWER ON events for the flight involved in the accident, which confirms that the EDR power supply was temporarily interrupted.

The context and limit reading for the section of the flight involved in the accident before the interruption to the power supply reveal that approximately 4 seconds after the continuous recording ended, the main rotor rpm (NR) reached a maximum value of approximately 426 rpm, which is 110.4 % of the nominal rpm (386 rpm). The maximum permissible main rotor rpm is 430 rpm. The main rotor rpm was over

410 rpm for a registered time of 1.5 seconds. This value is the threshold for triggering the aural warning for a high rotor rpm. Around 4 seconds after the end of the continuous recording the context and limit readings also ended.

Subsequent context and limit readings were only recorded after the EDR restarted after the temporary interruption to the power supply, which was probably caused by the initial impact with the ground. These indicate numerous cases of the limits being exceeded, which were consistent with the sequence of the accident.

1.7 Technical investigations

1.7.1 Engine

The compressor exhibited evidence of damage to the rotor blades. This is due to the compressor blades making contact with the air inlet during the accident.

The power turbine rotor blades were broken at the expected location, the overspeed notch, and were contained by the shield ring. This led to visible deformation of the engine near the power turbine.

The design is so that the turbine blades break away from their mountings and fracture if the rotation speed of the power turbine is 140-150% of the nominal rotation speed. The debris produced by this is then contained by the shield ring that surrounds this area.

Exceeding the nominal rotation speed was a logical consequence of the severing of the flex coupling between the power turbine and the main gearbox, which in turn was due to the main rotor blades hitting the ground during the accident.

Overall, the investigation revealed that the turbine was operating and delivering power at the time of the accident.

1.7.2 Tail boom

It was possible to unambiguously attribute the deformation of the tail boom downwards to the initial impact of the helicopter with the ground which caused the entire tail boom to deflect downward due to its inertia. This has been observed in similar accidents. This deformation led to the fracture of the flex coupling between the front and rear parts of the tail rotor drive shaft and the failure of the tail rotor.

The lateral deformation of the tail boom and the deformation in the lower section of the vertical stabiliser was due to contact with the ground during rotation and very probably occurred in the final phase of the accident.

1.7.3 Main rotor

The damage to the main rotor blades and the substantial twisting of the main rotor head’s sleeve flanges and star arms counter to the main rotor’s direction of rotation are consistent with contact of the main rotor blades with the ground whilst significant turbine power was present.

1.7.4 Main rotor control

The partial fracture of the main rotor control pitch rods in the area around the main gearbox base plate were undoubtedly a result of the accident. It was also determined that the fracture of the pitch rods between the upper, rotating part of the swashplate and the main rotor blades was due to contact between the main rotor blades and the ground whilst significant turbine power was present. This contact was also the cause of the damage to the drive link (or drive scissor) between the upper, rotating part of the swashplate and the main rotor mast.

The investigation revealed that the rivet connections between the swashplate guide, on which the swashplate has vertical axial movement along the main rotor mast, and the upper part of the main gearbox housing (cf. Fig. 4) had sheared off. According to information provided by the helicopter manufacturer, this type of damage is often observed in accidents involving contact with the main rotor. There is no known case of this type of damage having occurred under normal flying conditions.

The drive link (or drive scissor) between the upper, rotating part of the swashplate and the main rotor mast suffered minimal deformation in the main rotor's direction of rotation as a result of the damage process. This drive link (or drive scissor) is mounted using a form-locked connection to prevent it from rotating.

Examination of the hydraulic system revealed that the pump was functioning normally and that aside from the deformation of the hydraulic oil container, which was caused by the accident, the system did not show any signs of damage.

After the hydraulic cylinder and the drive link (or drive scissor) had been removed from the swashplate, it was possible to freely rotate the upper, rotating part of the swashplate against the lower, non-rotating part. Free axial movement of the swashplate on the swashplate guide was also possible.

1.7.5 Conclusion

The various phases of the accident were responsible for all damage observed. No evidence of pre-existing damage was found.

1.8 Personnel information

1.8.1 Pilot

The pilot was the Managing Director of the aviation operator and also fulfilled the functions of Chief Pilot and Flight Operations Manager.

He also had a great deal of experience in general and on the type involved in the accident (the Eurocopter AS 350 B3 "Ecureuil") in particular. The pilot had particular experience in relation to aerial work flights. His training on the type involved in the accident was good.

The pilot had flown for the aviation operator as a full-time occupation for many years. He had good knowledge of the local conditions. The pilot stated that he had approached the landing site at Ober Erlen countless times.

All available evidence suggests that the pilot started the flight well-rested and in good health. There are no indications that fatigue played a role at the time of the accident.

1.8.2 Flight assistants

One of the two flight assistants was the Chief Flight Assistant at the aviation operator. He had been working for the company full-time since 2008.

The second flight assistant had been working part-time for the aviation operator for four years; in the winter months he worked full-time.

Both flight assistants were experienced.

1.8.3 Passengers

One of the passengers was the contractor for the flight, who had been on several flights on the route of the flight involved in the accident. The other two passengers were the partner and seven-year-old son of one of the flight assistants.

1.9 Information on the aviation operator

1.9.1 General

The aviation operator Heli-Linth AG, based at Mollis aerodrome, was founded in 1972. It offers sightseeing, taxi and transport flights of all kinds. It also performs missions on behalf of Rega and training flights.

At the time of the accident, the company operated three Eurocopter AS 350 B3 helicopters.

1.9.2 Flight operation manual

The aviation operator stipulates operation of its helicopters in the flight operation manual (FOM). At the time of the accident, Revision 0 of 14 August 2013 was valid.

Section 2.6 "*Rights and responsibilities of the commander*", 2.6.5 "*Use of seat belts*" stipulates the following:

"The commander must ensure that all persons on board are wearing seat belts upon departure, in the event of turbulence, in emergencies and during landing. […]"

Section 5.1 "*Flight preparations*", item 5.1.1 stipulates the following:

"The commander may not begin any flight until the flight preparation documents have been prepared and he is convinced that

a) […]

d) the load is distributed and secured in such a way as to guarantee flight safety;

e) […]"

Section 8.1 "*Max. permitted number of persons and compulsory use of seat belts*", item 8.1.4 states that:

"The crew and passengers must wear seat belts upon instruction by the commander or the responsible member of the cabin crew. The commander or the responsible member of the cabin crew is responsible for ensuring all persons on board use a seat belt during landing. FOCA inspectors, examiners and Heli-Linth AG crew members are excepted from this regulation."

Section 9 "*Special types of helicopter operation*", item 9.1.2 stipulates the following:

"The helicopter may only be loaded under the supervision of the commander or an experienced assistant on his behalf. The commander is responsible for appropriate loading of the helicopter and for complying with weight limits. […]"

1.9.3 Statements by the aviation operator concerning the accident

In the days following the accident, various employees of the aviation operator expressed the opinion that the drive link (or drive scissor) between the upper, rotating part of the swashplate and the main rotor mast had shifted by 30 to 40 degrees during the flight, significantly altering the rotor blade pitch control mechanism. The shift of the drive scissor was explained as a result of the shearing of the rivets holding the swashplate guide on the main gearbox housing (cf. Section 1.3.3), which was assumed to have occurred some time before the accident.

1.9.4 Accident in March 2012

On 21 March 2012 another pilot from the aviation operator was involved in an accident on the Claridenfirn glacier in a Eurocopter AS 350 B3 helicopter, registration HB-ZKK (cf. Final Report No. 2191).

During a heli-skiing mission, the pilot lost visual reference points due to diffuse lighting conditions and collided with the snow pack after an aborted landing approach. Four of the six persons on board suffered minor injuries and the helicopter was destroyed.

Amongst other things, the investigation determined that not all of the passengers were wearing seat belts; this constitutes a serious hazard.

1.10 Additional information

1.10.1 Servo transparency

In the case of helicopters that are equipped with only one hydraulic system, servo transparency describes a situation in which the rotor system's retroactive force on the controls is so great that it can no longer be compensated by the hydraulics. The part of the retroactive force that exceeds the maximum available force of the hydraulics is then transferred via the pitch rods to the controls: the cyclic and the collective.

Pilots who are not familiar with this phenomenon can be surprised by sudden forces on the controls and the sluggishness of the controls.

Factors which favour the occurrence of servo transparency include high mass, high speed, high density altitude and high g-forces. A necessary precondition for the occurrence of this phenomenon is a large angle of attack of the main rotor blades, so in the case of servo transparency, normal conditions can be re-established by reducing the collective (insofar as the height above ground allows this).

In the case of the AS 350 helicopter type, the phenomenon causes a tendency for the helicopter to roll to the right and the nose to pitch up whilst the collective tends to reduce. The phenomenon is therefore considered particularly dangerous in the case of right turns flown at a low height above ground.

There is a corresponding paragraph in Section 2.3.6 "*Maneuvering limitations*" of the flight manual (FM) for the AS 350 B3e. In 2003, the helicopter manufacturer Eurocopter published a general communication on the phenomenon (service letter no. 1648-29-03).

Investigations of various accidents around the world came to the conclusion that servo transparency was a contributory factor. However, this cannot be proved retrospectively.

In the context of the investigation of an accident involving an AS 350 B3 that occurred in Norway in July 2011, a detailed investigation into servo transparency was performed (cf. Final Report SL 2012/13 by the Norwegian investigating authorities). This determined that during a presentation in 2011, the manufacturer, Eurocopter, had mentioned that servo transparency does not occur on the AS 350 B3 type if the speed is below 90 kt or the torque is below 45%.

Not least because of the accident investigation in Norway FOCA published in January 2014 SAND-2014-001 (safety awareness notification data) on the subject of servo transparency on the AS 350 type as part of the SAND recommendations.

Based on the pilot's description, Eurocopter considers it unlikely that servo transparency could have occurred in the present case: "[…] *the pitch down movement observed at the end of the right turn cannot be assigned to a possible servo transparency.* […]"

1.10.2 Vortex ring state

The term vortex ring state describes an aerodynamic effect on helicopters that can occur when a helicopter descends in the downwash produced by the main rotor. A vortex system can then form in the area around the main rotor blade tips, which changes the airflow conditions over the main rotor blades. A consequence of these changed flow conditions is that the lift produced by the rotor is massively reduced and the helicopter’s rate of descent increases. The effect is increased by raising the collective. The cyclic feels spongy and its effectiveness is reduced. The phenomenon is usually accompanied by vibrations.

According to common consensus, the occurrence of this situation is dependent on three factors:

1. Low horizontal speed relative to the surrounding air (below 30 kt)
2. High rate of descent (over 500 ft/min)
3. Some engine power (i.e. no autorotation)

The situation can be corrected by transitioning to autorotation or by increasing horizontal speed.

Based on the pilot’s description and a comparative analysis of the two approaches in Ober Erlen on the day of the accident (cf. Annex 2), the helicopter manufacturer Eurocopter is of the opinion that it is essentially possible that the helicopter could have entered a vortex ring state on the flight involved in the accident. However, one of the manufacturer’s test pilots stated the following: *“I performed a lot of flights in vortex conditions on AS 350 but I never saw such a behavior, especially an uncommanded pitching down of 60° with forward speed!* […] *Furthermore, during vortex ring state we willingly pitch down the helicopter in order to increase the forward speed and go out of the vortex condition, and the exit is in general immediate.* […]”

1.10.3 Horizontal stabiliser stall

The horizontal stabiliser on the tail boom of the helicopter is exposed to air streams from different directions depending on the flight conditions and attitude. Depending on the flight conditions and attitude, a stall is therefore possible in conditions where the angle of attack on the horizontal stabiliser is positive or negative with the result that the helicopter pitches up or down.

In the present case, the helicopter manufacturer Eurocopter came to the conclusion, based on an analysis of the flight path data, that any horizontal stabiliser stall during the last right turn would have led to a pitch-up movement. Based on the pilot’s description, Eurocopter therefore believes this hypothesis to be unlikely.

2 Analysis

2.1 Technical aspects

2.1.1 Investigation of the wreckage

The detailed investigation of the wreckage, particularly in the area of the main rotor control, did not provide any indication of existing technical defects which might have caused or influenced the accident. It was possible to consistently ascribe all damage to the various phases of the accident.

2.1.2 Swashplate guide

Due to the type of damage to the rivets between the swashplate guide and the main gearbox housing, as well as the unhindered movement of the swashplate along the swashplate guide, it can be concluded that the rivets sheared off at the point at which the main rotor hit the ground. This damage is consistent with the sequence of the accident and, according to the statement provided by the manufacturer, had also been detected in other accidents involving contact with the main rotor. According to the statement provided by the manufacturer, there is no knowledge of rivets ever having sheared off while in flight.

The minimal deformation of the drive link (or drive scissor) between the upper, rotating part of the swashplate guide and the main rotor mast can be attributed to the damage process.

There are therefore no indications that support the opinion – suggested by representatives of the aviation operator shortly after the accident – that a technical defect in this area might have caused this accident.

The fact that according to the pilot's description the helicopter's controls functioned perfectly after the initial impact, and that it was possible for him to perform a relatively controlled touchdown after the initial impact, also supports the case against this argument.

2.1.3 Recording devices

All failures and overlimits (and the timing thereof) registered by the vehicle and engine multifunction display (VEMD) or the engine data recorder (EDR) are consistent with the sequence of the accident (cf. Annex 1). It therefore appears plausible that the initial failure, which was registered at 2:12 min VEMD time, represents the initial impact with the ground, as a result of which the EDR and PowerFLARM suffered temporary interruptions to their power supply. This meant that part of the EDR and PowerFLARM recordings were lost with retroactive effect, which meant that their recordings abruptly ended approximately 19 seconds prior to the accident, while the helicopter was still in flight. As the EDR context and limit readings were influenced differently by the interruption to the power supply, these are available for an additional approximately 4 seconds.

There are therefore no EDR or PowerFLARM recordings for the period immediately before the initial impact, which makes the investigation substantially more difficult. However, based on the recordings of the VEMD it is possible to rule out the existence of failures or overlimits during this phase. The two lines of yellow text observed by the pilot on the VEMD shortly before the initial impact remain unexplained.

The EDR context and limit readings indicate an increase in the rotor rpm to 426 rpm and an exceedance of the 410 rpm threshold approximately 4 seconds after the end of the continuous recording for a duration of 1.5 seconds. According to this recording the warning tone for high rotor rpm must have sounded during this last right turn. However, this was not confirmed by the pilot or the other occupants. The reduction of speed (backwards cyclic) and initiation of the right turn which according to the pilot's statement occurred in that phase would be consistent with the increased rotor rpm in purely aerodynamic terms.

2.1.4 Vision 1000

If a Vision 1000 type recording device had been installed on the helicopter, the investigation would have been made considerably easier (cf. Section 1.6.1). The recording of various technical parameters, images of the cockpit and instruments plus environmental sounds would with high probability have made it possible to make considerably more in-depth findings in relation to both technical and operational aspects.

2.2 Human and operational aspects

2.2.1 Possible scenarios

2.2.1.1 General

As no evidence of a technical problem has been found, the cause of the accident must be due to operational aspects. All the possibilities are listed and the probability that they actually caused the accident analysed below.

2.2.1.2 Servo transparency

The pilot stated that during the last right turn he had been far from a situation in which servo transparency could have occurred. The pilot was experienced, particularly on aerial work flights and flights on the AS 350 B3 type. He must therefore have been familiar with the phenomenon of servo transparency. The last values recorded by the PowerFLARM and the EDR shortly before initiating the last right turn support the pilot's statement. At a groundspeed of 95 kt, a low torque value and a low collective setting, these values were outside the range critical for the occurrence of the phenomenon.

The pilot also mentioned that he had full hydraulic support throughout the accident and that in his opinion the controls felt normal even though the helicopter did not react to the control inputs. This description is not consistent with the phenomenon of servo transparency and neither is the flight assistant's observation of the pilot pumping the collective, which in the event of servo transparency would have been almost impossible due to the stiffness of the controls.

It is therefore unlikely that servo transparency played a role. This assessment was shared by the helicopter manufacturer.

2.2.1.3 Vortex ring state

The behaviour of the controls described by the pilot, whereby they felt normal, but the helicopter did not (or at least not immediately) react to control inputs, is consistent with the phenomenon of the vortex ring state. The fact that several occupants observed the pilot pulling on the collective without any effect also supports this.

Of the three prerequisites for the occurrence of a vortex ring state, a high rate of descent and a certain amount of turbine power were certainly met. However, the last recorded data, the descriptions of the occupants and the traces of the initial impact on the ground suggest considerable forward speed, which means that the third factor, low horizontal speed in comparison to the surrounding air, was missing. The light southerly wind in the area of the site of the accident meant that the helicopter turned into the tailwind on the last right turn, which principally increased the danger of a vortex ring state during the final approach. However, the winds were light.

In view of these facts, it appears somewhat unlikely that the helicopter entered a vortex ring state during the landing approach. The unexpected nose-down movement of the helicopter during the right turn, which the manufacturer’s test pilot had never observed before, must also remain unexplained.

The analysis of the first approach on the landing site at Ober Erlen on the day of the accident (cf. Annex 2), however, reveals that based on the recorded horizontal speed and the calculated vertical speed the helicopter could have entered a vortex ring state towards the end of the approach. However, the missing recordings mean that a direct comparison with the approach during the flight involved in the accident is not possible.

2.2.1.4 Horizontal stabiliser stall

A horizontal stabiliser stall during the last right turn is conceivable in principle. The cause of this might have been a turn flown in an uncoordinated manner. However, according to the statement of the manufacturer, such a stall would have led the helicopter to pitch up, which is not consistent with the pilot’s description. It would also have been easy for the pilot to correct such a phenomenon. This hypothesis therefore appears unlikely.

2.2.1.5 Incorrect assessment by the pilot

The first approach on the landing site at Ober Erlen on the day of the accident and the second approach up to the end of the recordings show that the pilot flew the helicopter dynamically, i.e. at high speed and sometimes with an extreme rate of descent and relatively rapid variations of these. During the first approach in the morning the helicopter entered a state in which a vortex ring state was possible. During the second approach, while reducing speed and initiating the final right turn, there was a short increase in rotor rpm, leading to a value only slightly below the maximum permissible value. This also demonstrates that the helicopter was flown dynamically and at its operational limitations.

It is therefore conceivable that the pilot made an incorrect assessment on the approach and began to reduce the rate of descent too late, resulting in a heavy impact with the ground. The snow-covered terrain could have contributed in such a scenario, as the even structure could have made it more difficult to judge distances and heights.

2.2.1.6 Conclusion

None of the conceivable scenarios match the descriptions and observations of the pilot entirely. The lack of recordings and images, e.g. those that a system such as the Vision 1000 would have provided, means that no definitive conclusion can be drawn.

2.2.2 Survival aspects

The accident was survivable, as the initial, heavy impact occurred when the helicopter had an almost horizontal attitude. This meant that a large part of the energy was absorbed by the landing skids. The deformation of the pilot seat is evidence that there was very high vertical impact energy. The pilot, despite his injuries, then managed to make a relatively controlled touchdown.

The severing of the flex coupling between the front and rear parts of the tail rotor drive shaft meant that the tail rotor failed after the initial impact. The pilot realised this. He reduced the collective a little, with the result that the torque that was generated by the turbine and main rotor and no longer compensated by the failed tail rotor decreased. However, the helicopter then continued to rotate about its vertical axis, as the turbine continued to deliver power to the main rotor. The engine could have been switched to idle by turning the twist grip to the IDLE position. This would have drastically reduced the torque around the vertical axis. This measure is stipulated in the flight manual in the event of tail rotor failure while hovering in ground-effect, which does not exactly match the situation described here. It cannot be determined how a landing with no engine power and heavily deformed or damaged landing skids would have resulted.

During the flight involved in the accident, no-one apart from the pilot used a seat belt, even though it would not have been a problem for the occupants on the rear bench seats. Wearing seat belts would have prevented the four persons on the rear bench seats from being ejected through the right side of the helicopter during the accident due to centrifugal force. In view of the practically intact cabin interior, the danger for these persons would have been much lower. One person's claim that during the final phase of the accident, the tail of the helicopter had rotated away above him/her while he/she was lying on the ground and the fact that one of the occupants was in the immediate vicinity of the main rotor head clearly indicate that being ejected from the helicopter placed the occupants in great danger.

The regulations in the aviation operator's flight operation manual are unambiguous. The pilot stated that he had given the task of loading the cabin to the flight assistants in order to concentrate on the flying aspects. The two experienced flight assistants did not wear seat belts and did not instruct the other passengers to do so, which suggests that this was common at the aviation operator. In view of the relatively recent accident involving HB-ZKK, where the investigation criticised the fact that seat belts had not always been worn, the safety culture seems to be questionable.

The many loose and dangerous objects in the cabin posed another potential hazard.

There can be situations in flight operations where consistent wearing of seat belts is difficult and carrying loose equipment in the cabin is unavoidable. The number and duration of flights in this category must therefore be reduced as part of risk minimisation. The present flight did not belong to this category of flight.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The helicopter was licensed for VFR transport.
- There are no indications of any pre-existing technical defects which might have caused or influenced the accident.
- The initial failures were registered by the VEMD at the same time as the initial impact with the ground.
- During the final right turn the EDR temporarily registered a rotor rpm which was slightly below the maximum permissible value of 430 rpm.
- The mass and centre of gravity of the helicopter were within the manufacturer's specified limits throughout the flight involved in the accident.

3.1.2 Pilot

- The pilot was in possession of the necessary licences for the flight.
- The pilot was the Managing Director of the aviation operator and also fulfilled the functions of Chief Pilot and Flight Operations Manager.
- The pilot was experienced, particularly on aerial work flights and flights on the AS 350 B3 type.
- There are no indications of the pilot suffering any health problems during the flight involved in the accident.

3.1.3 Flight assistants

- One of the two flight assistants was the Chief Flight Assistant at the aviation operator.
- The second flight assistant was primarily a part-time employee of the aviation operator.
- Both flight assistants were experienced.

3.1.4 History of the flight

- At approximately 12:07 the helicopter took-off from Alp Loch in order to fly to Ober Erlen and then return to Mollis.
- In a continuous descent with heavily reduced collective and low torque and NG values, the helicopter crossed the Sernftal valley, flew over one of the high-voltage pylons on the valley floor and then turned right onto what was essentially the downwind leg of the approach for the landing at Ober Erlen.
- According to the pilot, before the turn their height was approximately 15 - 20 metres above another high-voltage pylon, corresponding to approximately 80 - 100 metres above ground.
- The nose of the helicopter was pointing slightly downwards and the pilot began to slowly reduce the speed.
- At the end of the right turn, before the landing, the helicopter’s nose pointed sharply downward.
- According to the pilot’s statement, although the controls felt normal, the helicopter did not noticeably react to his control inputs.

- Several occupants observed the pilot pulling the collective without any reaction from the helicopter.
- The flight assistant on the rear bench seat observed the pilot pumping the collective.
- Shortly before the impact, the helicopter gradually re-attained a relatively horizontal attitude.
- The helicopter impacted the ground with significant vertical and forward speed with a slight nose-down attitude and a slight bank angle to the right and was immediately catapulted away from the ground.
- The inertia of the tail boom meant that it deflected downward after the impact, which led to the severing of the flex coupling between the front and rear parts of the tail rotor drive shaft.
- The cargo basket was torn off the helicopter.
- While still at a considerably high forward speed, the helicopter flew approximately straight ahead, again reaching a height of approximately 10 - 15 metres above ground (according to the pilot's estimates).
- The helicopter then began to rotate about its vertical axis in a counter-clockwise direction.
- All four occupants on the rear bank seats were thrown out of the helicopter.
- After approximately three rotations of the helicopter about its vertical axis, the main rotor blades impacted the ground and the helicopter came to a standstill, lying on its right-hand side.
- Five of the six occupants suffered serious injuries.
- The helicopter was destroyed.

3.1.5 General conditions

- None of the four occupants on the rear bench seats were wearing seat belts.
- The flight assistant, who was at the front and to the left of the pilot, was sitting on a coiled cargo line and a cargo net.
- There was loose equipment in the cargo basket on the right of the helicopter and in the cabin.
- The cloud and visibility conditions had no influence on the accident.
- There was a light southerly wind in the area of the site of the accident.

3.2 Causes

The accident is attributable to the fact that the helicopter impacted the ground with great vertical and considerable forward speed during a landing approach.

It was not possible to explain the cause conclusively. There is a high probability that it was due to operational aspects.

4 Safety recommendations, safety advices and measures taken since the accident

Safety recommendations

According to the provisions of Annex 13 of the International Civil Aviation Organization (ICAO) and Article 17 of 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 repealing Directive 94/56/EC, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which must decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Safety Investigation of Transport Incidents (OSITI):

„Art. 48 Safety recommendations

[1] The STSB shall submit the safety recommendations to the competent federal office and notify the competent department of the recommendations. In the case of urgent safety issues, it shall notify the competent department immediately. It may send comments to the competent department on the implementation reports issued by the federal office.

[2] The federal offices shall report to the STSB and the competent department periodically on the implementation of the recommendations or on the reasons why they have decided not to take measures.

[3] The competent department may apply to the competent federal office to implement recommendations."

The STSB shall publish the answers of the relevant Federal Office or foreign supervisory authorities at www.stsb.admin.ch in order to provide an overview of the current implementation status of the relevant safety recommendation.

Safety advices

The STSB may publish safety advices in response to any safety deficit identified during the investigation. Safety advices shall be formulated if a safety recommendation in accordance with Regulation (EU) No. 996/2010 does not appear to be appropriate, is not formally possible, or if the less prescriptive form of a safety advices is likely to have a greater effect. The legal basis for STSB safety advices can be found in Article 56 of the OSITI:

"Art. 56 Information on accident prevention

The STSB may prepare and publish general information on accident prevention."

4.1 Safety recommendations

4.1.1 Recording devices

4.1.1.1 Safety deficit

If a Vision 1000 type recording device had been installed on the helicopter the investigation would have been made considerably easier. The recording of various technical parameters, images of the cockpit and instruments plus environmental sounds would have made it possible to make considerably more in-depth findings both in terms of technical and operational aspects.

Without such recordings it is impossible to draw any definitive conclusions about the cause of the accident in the present case.

4.1.1.2 Safety recommendations

Safety recommendations have been issued for many previous accidents advising the use of suitable recording devices even in light aircraft in order to simplify accident investigation. This is particularly appropriate for commercial flights.

An overview of previously issued safety recommendations in this context can be found, for example, in Final Report No. 1928. The STSB will therefore not make any safety recommendations in the present case.

4.2 Safety advices

None

4.3 Measures taken since the accident

4.3.1 Aviation operator

4.3.1.1 Technical control of the helicopters

As a consequence of the view held by the aviation operator in the days following the accident, according to which the accident could have been a failure in relation to the main rotor control (cf. Section 1.9.3), a second AS 350 B3e helicopter was taken out of service.

On 28 December 2013 the decision was made to rescind this decision and put the helicopter back into service using detailed checks, particularly in relation to main rotor control, every 10 operating hours. These checks were extended to the aviation operator’s other AS 350 B3 type helicopters.

According to a communication by the aviation operator on 1 April 2014, these checks had not determined anything unusual.

4.3.1.2 Seat belts

On 14 January 2014, as a consequence of the accident, a safety bulletin was issued to all pilots, flight assistants and operations management. This included the following points:

“Please be aware that the following regulations are still valid:

- *The FM/FOM guidelines must be complied with and implemented*
- *Employees are requested to consult the FM/FOM in the event of uncertainty*
- *All helicopter passengers must wear a seat belt*
- *Flight assistants who have been instructed by the pilot to check that the tail rotor is free are excepted from this regulation*

- *No other exceptions*
- *A seat and seat belt must be available for every crew member*
- […]

The pilot is responsible for implementing this regulation."

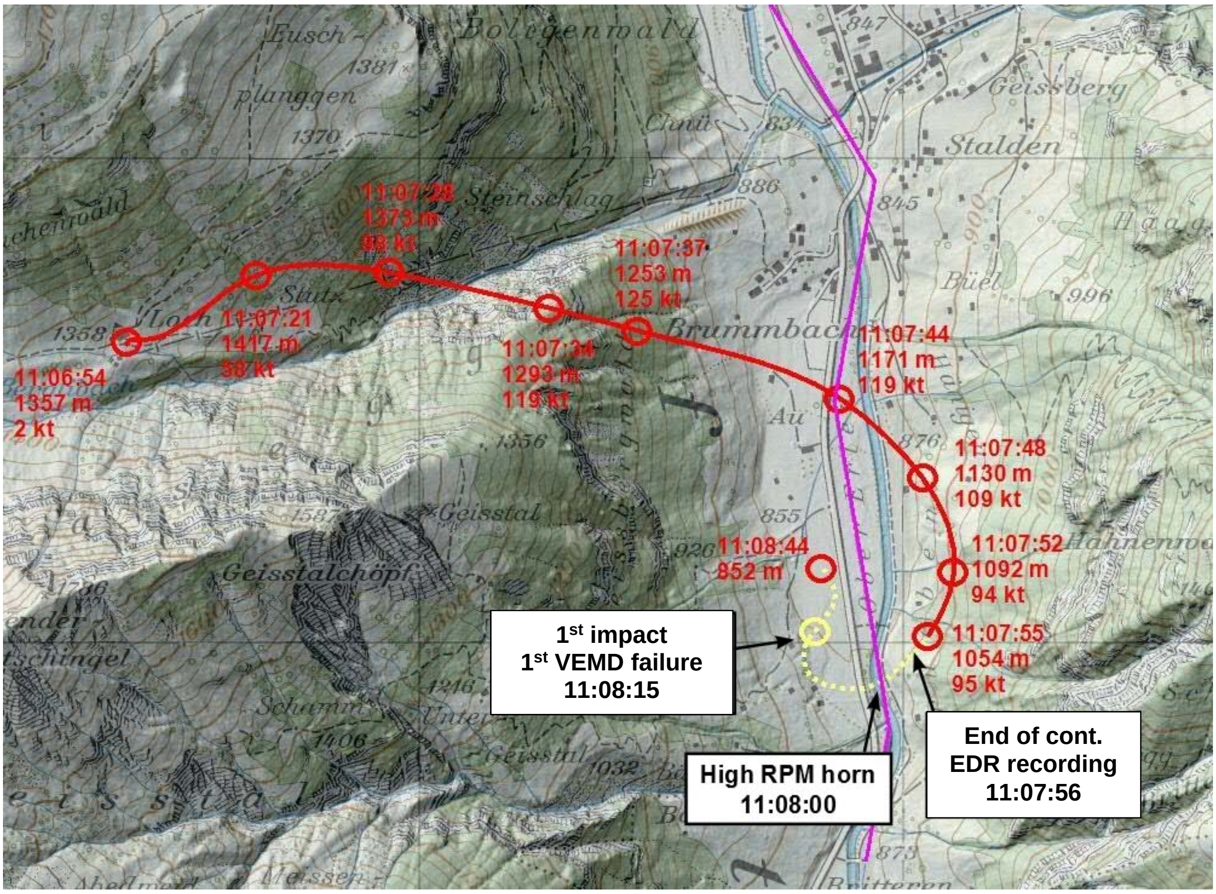
On 8 October 2015 a reminder of the compulsory use of seat belts was sent as an internal instruction.

Payerne, 23 December 2016 Investigation Bureau STSB

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Bern, 13 December 2016

Annex 1: Temporal relations according to analysis of the PowerFLARM, VEMD and EDR data



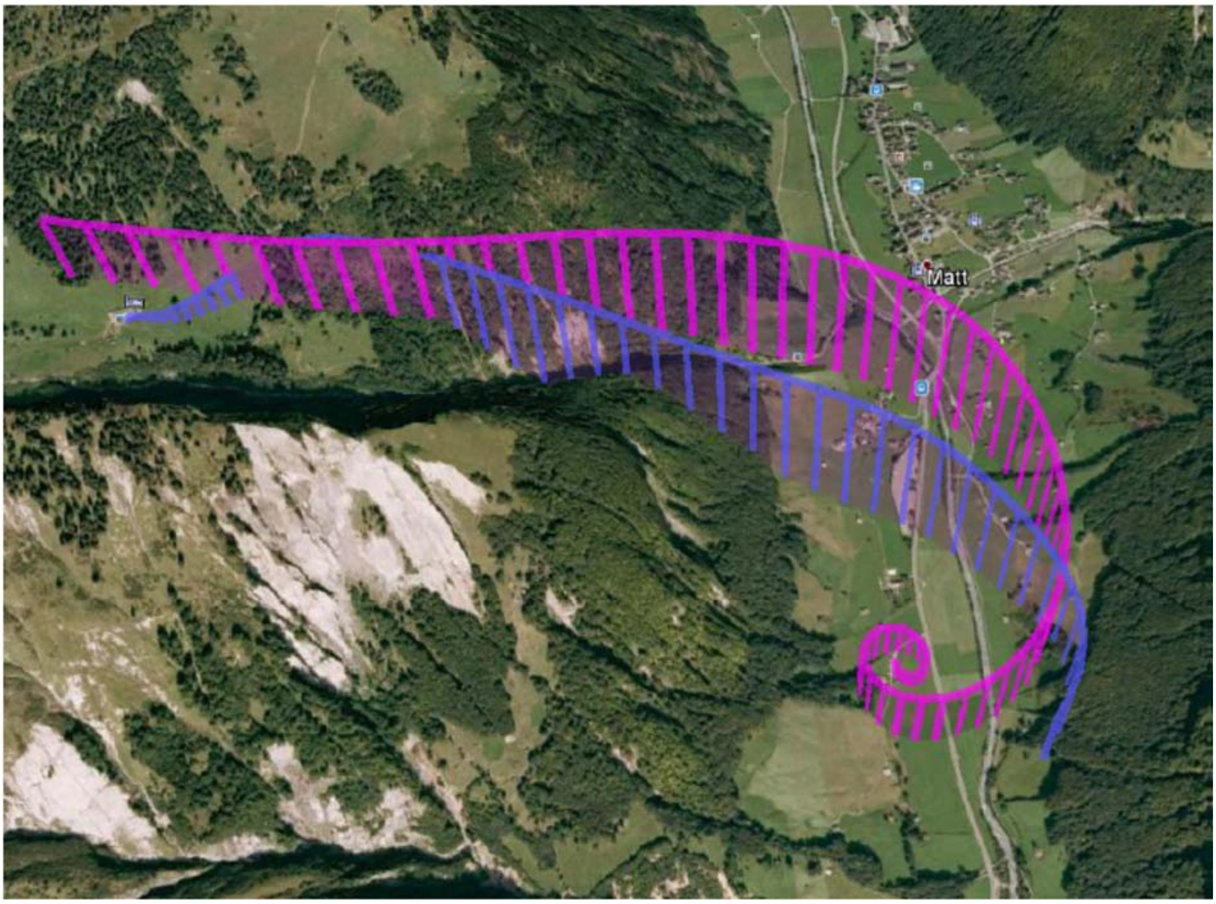
Remarks: Times are PowerFLARM time in UTC.

Synchronisation of the differing time measurements of the PowerFLARM and EDR was achieved by comparing the GPS altitudes recorded by the PowerFLARM and the pressure altitudes recorded by the EDR (estimated accuracy ±2 s).

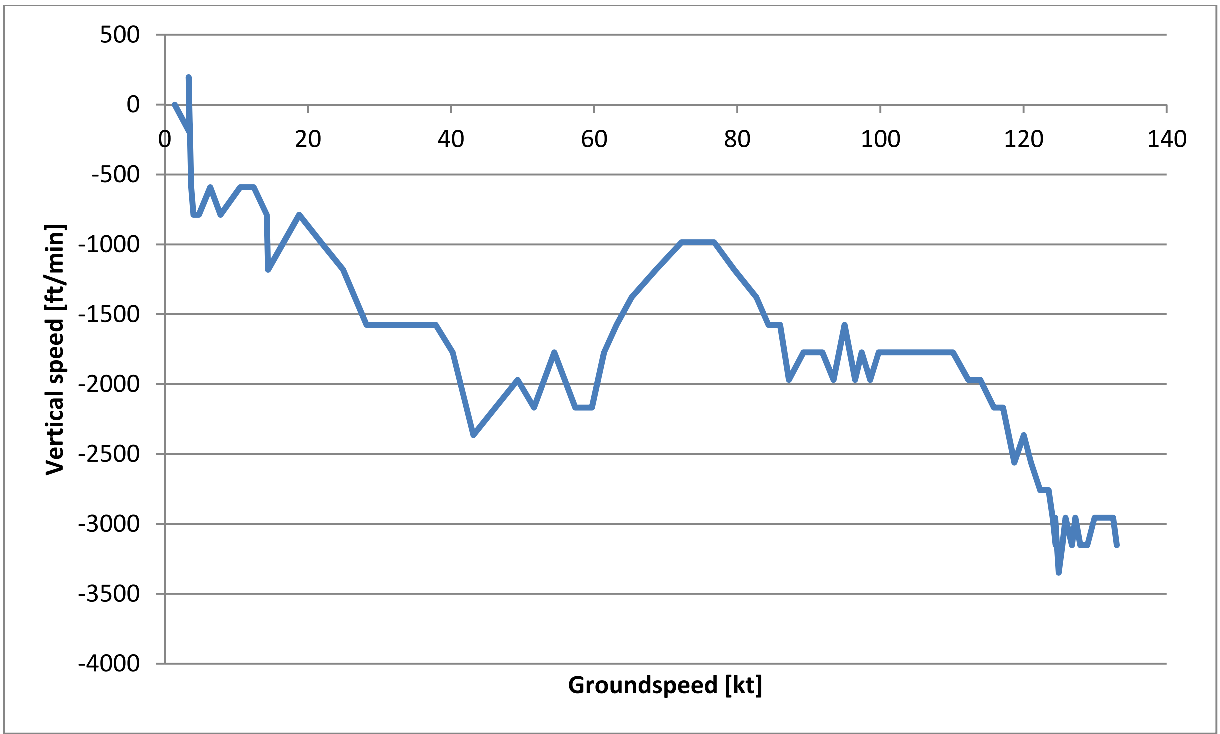
Synchronisation of the differing time measurements of the EDR and VEMD was achieved using the time at which the compressor rpm (NG) exceeded 10% after the engine was started (accuracy ±1 s).

Map reproduced with permission of the Federal Office of Topography Swisstopo (JA150149)-

Annex 2: Comparison of the two approaches on the landing site at Ober Erlen



First approach according to the recordings of the PowerFLARM in magenta. Second approach (flight involved in the accident) according to the recordings of the PowerFLARM in blue. All altitudes are corrected GPS altitude. Representation in Google Earth.



First approach: Recorded groundspeed [kt] vs. vertical speed (calculated from the recordings) [ft/min].