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Swiss Transportation Safety Investigation Board STSB

Final Report No. 2309 by the Swiss Transportation Safety Investigation Board STSB

concerning the accident involving the Airbus Helicopters AS 350 B3 helicopter, registration HB-ZIS,

on 14 July 2015

Guggigletscher, Lauterbrunnen/BE

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Ursachen

Der Unfall ist auf einen Kontrollverlust des Helikopters zurückzuführen, nachdem es durch eine instabile Unterlast zu einem Seilüberwurf der Transportleine kam. Dieser führte zu Beschädigungen im Bereich von Heck- und Hauptrotor.

Als ursächlich wurde folgender Faktor ermittelt:

- eine zu hohe Fluggeschwindigkeit mit einer instabilen Last.

Als beitragend wurden folgende Faktoren ermittelt:

- ein unzureichender Treibstoffvorrat;
- die fehlende Beurteilung des Lastanschlages durch das Flugbetriebsunternehmen;
- ein für dieses Transportvorhaben ungeeigneter Lastanschlag.

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 Art 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 prevention, due consideration shall be given to this circumstance.

The final 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 Summer Time (CEST) applied as local time in Switzerland. The relation between LT, CEST and coordinated universal time (UTC) is: LT = CEST = UTC + 2 h.

Contents

Synopsis

Narrative

Owner	MX Management AG, Hauptstrasse 26, 3800 Interlaken, Switzerland
Operator	Air-Glaciers SA, P.O Box 27, 1951 Sion, Switzerland.
Manufacturer	Airbus Helicopters
Aircraft type	AS 350 B3
Country of registration	Switzerland
Registration	HB-ZIS
Location	Guggigletscher, municipality of Lauterbrunnen/BE
Date and time	14 July 2015, 08:22

Investigation

The accident occurred at 08:22. The notification arrived at approximately 08:40 UTC. The investigation was opened on 14 July 2015 by the Swiss Transportation Safety Investigation Board (STSB) in co-operation with the cantonal police of Berne, immediately after the notification was received. France designated an accredited representative who assisted with the investigation.

This final report is published by the STSB.

The following was basis for the investigation:

- On-site evidence preservation
- Data recording from the collision warning and the map display devices
- Interviews
- Various photo and video recordings
- Various expertises

Summary

On the morning of 14 July 2015, the four-man crew of HB-ZIS met on the base in Lauterbrunnen and were then transported by car to Zweilütschinen to the helicopter's location. It was planned to carry out a day's programme with 17 flight missions. Shortly after 06:50, the AS 350 B3 helicopter, registered as HB-ZIS, took off for its first mission with approximately 300 l of fuel on board. When in the course of the day's programme HB-ZIS arrived in the Jungfraujoch region, the three marshallers disembarked and the pilot carried out the first transport turns from the research station to the tunnel entrance at the Jungfraujoch station.

The next flight mission involved the removal of a roof weighing 600 kg from the Sphinx observatory to the railway station of Eigergletscher. This roof had pre-defined lifting points, so that it could be lifted off by a helicopter and thereafter replaced on the building. The pre-defined lifting points also seemed to be suitable to the persons involved for the removal of the roof. Consequently no- assessed critically the quality and appropriateness in detail and the roof was attached in the same way as in earlier cases. Since HB-ZIS had to be refuelled at the base in Lauterbrunnen, the transport of the roof was combined with this flight.

When the transport flight was undertaken just before 08:20, the fuel gauge on HB-ZIS indicated 74 l, according to a marshaller. After the load was lifted off the ground, the pilot accelerated rapidly to a ground speed (GS) of approximately 50 kt. As a result, the load became increasingly unstable. The 30 m longline then was thrown over, leaving many traces on HB-ZIS. As a result of the damage which occurred, the helicopter became uncontrollable and crashed on the Guggigletscher. The pilot was fatally injured in the crash and the helicopter was destroyed. There was minor damage to the terrain.

Causes

The accident is attributable to a loss of control of the helicopter after an unstable external load allowing the longline being thrown over the airframe. This caused damage to the area of the tail rotor and main rotor

The following causal factor was identified:

- An excessive airspeed with an unstable load.

The following contributory factors were identified:

- An inadequate fuel reserve.
- Failure to evaluate the load attachment by the air transport operator.
- An inappropriate load lifting system for this transport mission.

Safety recommendations

With this final report no safety recommendations and no safety advises were issued.

1 Factual information

1.1 Flight preparations and history of the flight

1.1.1 General

The flight was conducted under visual flight rules (VFR). It was a commercial aerial work flight with an external load.

1.1.2 Pre-History

In connection with renovation work on the high altitude research station Jungfraujoch, among other things a roof had to be replaced on the Sphinx observatory. This roof served to cover an opening through which bulky items could be put into the laboratory. The existing pyramid roof, a timber construction roofed with sheet metal, dated back from the 'seventies.

Figure 1: Sphinx Observatory; the red arrow points to the roof

Lifting of the roof was carried out on each occasion with the help of a helicopter. For this purpose wire rope slings were attached to four fixed positions in the timber construction under the roof, drawn in through drill holes in the wood. It could not be unveiled when these slings were mounted. To prepare for a transport, the roof had to be lifted using a rack and pinion jack in order to bring the slings outside. Extensions were then attached to the four slings to prepare the load for a transport by helicopter.

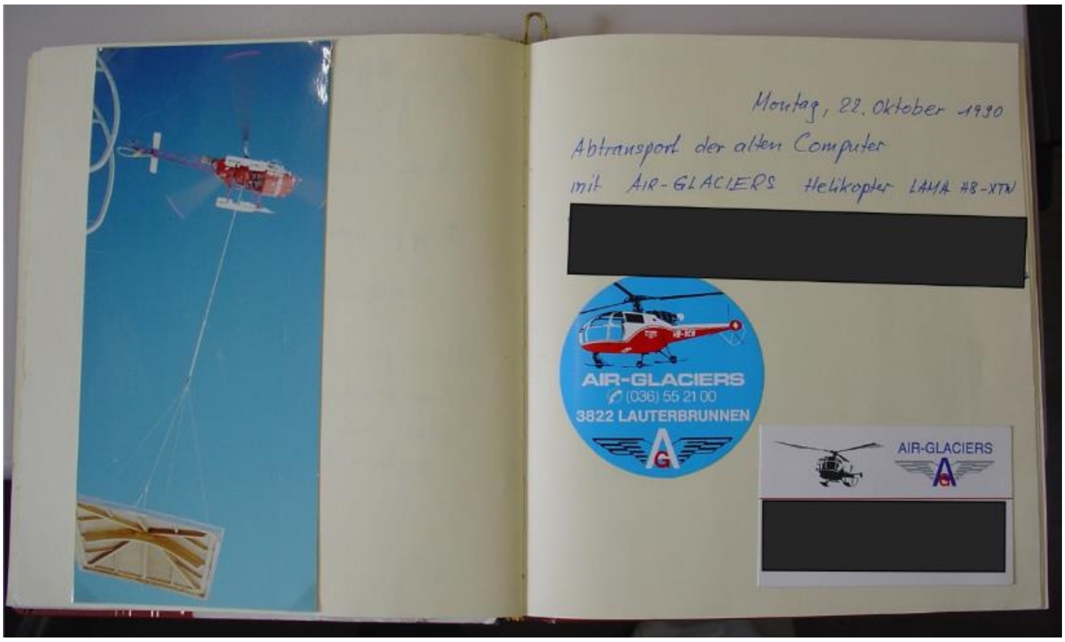


Figure 2: Documentation of a roof transport operation in 1990.

It was originally planned to lift the roof, place it nearby on the glacier and prepare it for a transport by railway. These plans were later modified and it was intended to fly the roof to the railway station of Eigergletscher. From there the roof would then have been transported down into the valley by railway. The transport of the roof by helicopter was part of the flight mission in conjunction with other transport flights as part of the renovation work on the Jungfraujoch. The date of 14 July 2015 was fixed.

On the previous day, the operator planned the daily schedule for the crew of the helicopter AS 350 B3 registered as HB-ZIS. One pilot and three marshallers were scheduled. In order to bypass the flight restriction which applies before 08:00 on the helicopter base in Lauterbrunnen, the helicopter HB-ZIS was parked after the end of the flight operations on this day in Zweilütschinen with 100 l fuel on board. The pilot arranged for the AS 350 B3 to be refuelled with 200 l, so there was 300 l of fuel on board of HB-ZIS. This refuelling was neither logged in the HB-ZIS techlog nor somewhere in the fuel truck. After completing these tasks, the crew made their way back to the base. On the base, the pilot had a conversation with an experienced marshaller concerning the upcoming transport flight from the Sphinx observatory. The point was raised that a 70 m longline would make sense for the transport to the railway station of Eigergletscher. This would enable the helicopter to land in the vicinity of the railway station. Then the accompanying marshaller would have been able to unhook the load and the longline. The load attachment was not discussed during this conversation.

On the morning of 14 July 2015, the four-man crew of HB-ZIS met on the base in Lauterbrunnen. After completion of the pilot's usual flight preparation, the men were transported to Zweilütschinen by car. They prepared the helicopter for the upcoming day's programme, which involved a total of 17 flight missions with 78 turns. In addition to other rigging material, on this day three longlines 20, 30 and 50 m in length were carried.

1.1.3 History of the flight

Shortly before 06:50, the pilot started the engine of HB-ZIS, in order to transport four passengers towards Männlichen Parwengi. A marshaller was assisting the pilot. After the passengers had disembarked, the pilot flew back to Zweilütschinen and picked up the other marshallers and the remaining material. The crew then continued with the flight programme according to plan.

Shortly before 08:00, the crew took off from the Mönchsjoch hut towards the Jungfraujoch to begin flight missions nos. 7 and 8, both on behalf of the high altitude research station. Mission no. 7 on the programme involved the removal of the roof described in Chapter 1.1.2. Flight mission no. 8 involved the transport of various demolition materials within approximately 40 turns from the research station to the tunnel entrance at the Jungfraujoch station. During the overflight, mission no. 7 was briefly discussed. It did not yet seem to have been clear to the crew whether the roof was to be transported as a whole or in parts. The pilot mentioned that there was still sufficient fuel on board HB-ZIS for approximately half an hour and he therefore decided to start first with mission no. 8. He planned to combine mission no. 7, the removal of the roof from the Sphinx observatory to the railway station of Eigergletscher with the ferry flight to the base in Lauterbrunnen, where the helicopter would have had to be refuelled.

Marshaller 2 was dropped off on the roof of the research station, the lifting site for mission no. 8. The helicopter then landed on the viewing platform west of the Jungfraujoch, where the other two marshallers were offloading the material to set up a depot. In addition to the rigging and transport material, fuel cans were also unloaded. Then marshaller 1 made his way to the offloading point in front of the tunnel entrance near the railway station, in the west of the restaurant. Marshaller 3 waited at the material depot until he was needed for mission no. 7.

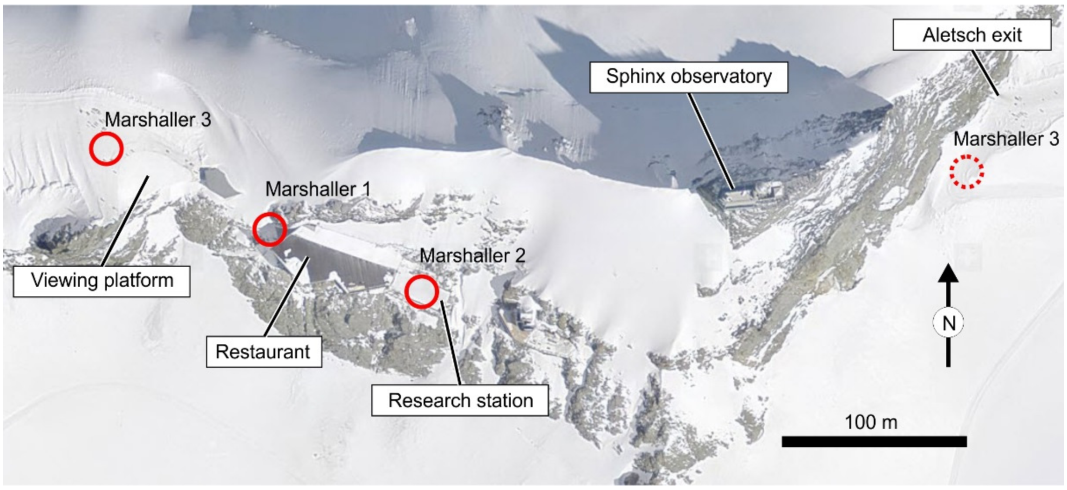


Figure 3: Aerial photograph with the locations (red circles) of the marshallers before the start of flight missions no. 7 and no. 8. The broken red circle indicates the location of marshaller 3 before the flight involved in the accident. This image and all the following basic maps in this report have been reproduced with the consent of Swisstopo, the federal Office of Topography (JA150149).

At the tunnel entrance, marshaller 1 met one of the two fitters from the construction company and handed over to him four 5 m long textile rope slings, which were to be used to attach the load. In the process, marshaller 1 learned that the roof of flight mission no. 7 was to be flown in one piece to the helicopter base Lauterbrunnen. The fitter also explained to marshaller 1 that the four loop slings would be fixed with shackles to pre-mounted wire rope slings on the roof. Marshaller 1 assumed that these slings were pre-mounted at the four corners of the roof. Marshaller 1 also enquired whether there would be a need for assistance from them to attach the load. The fitter answered in the negative and marshaller 1 acknowledged this. He was aware that the fitters were experienced in attaching and detaching loads on a helicopter because of their employer's area of activity.

The information about flying the roof to Lauterbrunnen was communicated to the pilot by radio. The two fitters later explained that in their view the attachment of this roof was given by the existing wire rope slings, and that they were therefore not anticipating any problems. The attachment of the load was neither discussed nor evaluated.

During the first turns for mission no. 8, the pilot asked marshaller 1 on the radio whether the roof at the Sphinx observatory was ready to be removed and which longline was planned for this mission. Marshaller 1 answered that he did not know about the former, since the two fitters from the construction company would be attaching the load. He also suggested that the pilot should take a brief look from the air to see how far advanced the preparations for the removal were. He suggested to the pilot that a 50 m longline should be used. The pilot then advised marshaller 3 by radio to prepare the material accordingly.

After some 10 to 12 turns, the helicopter landed on the viewing platform, where marshaller 3 had prepared the longline. The marshaller extended the existing longline to a total of 50 m and boarded the helicopter. HB-ZIS then flew up to the Sphinx observatory. After the pilot had examined the roof from the air, he said to marshaller 3 that a 30 m longline would be sufficient. He then flew HB-ZIS to the so-called Aletsch exit and landed. Marshaller 3 disembarked and shortened the longline to 30 m.

Since the roof was now to be flown directly to Lauterbrunnen, marshaller 3 was no longer needed. He remained on the Jungfraujoch. When he disembarked HB-ZIS he glanced at the helicopter's fuel gauge, which was displaying a value of 74 l.

When the 30 m longline was attached, the pilot flew back to the Sphinx observatory. The helicopter hovered above the platform. Attachment of the load by the fitter was accomplished without any problems. The helicopter quickly lifted the load and flew off towards Wengen.

Figure 4: HB-ZIS flying off after taking up the load

The pilot steadily accelerated HB-ZIS to a ground speed (GS) of approximately 50 kt and initiated a gentle descent. At first, the load was hanging steady. However, the roof suddenly moved into a vertical position. The helicopter changed its attitude slightly. The roof then fell back into the slings. After this, the helicopter began to roll from side to side and at the same time the load was swinging and turning. The persons at the Sphinx observatory were now able briefly to see the underside of the roof. Suddenly the load became detached and fell towards the Guggigletscher. When the persons looked at the helicopter, they saw that the nose of the helicopter was pointing upwards at an angle of 50° to 60°. One person also thought they had seen a whitish cloud at this time. HB-ZIS then moved backwards and began to turn away sideways. Initially, it then appeared that the helicopter was attaining a normal flight attitude. But then HB-ZIS began to descend rapidly. The helicopter impacted with an almost horizontal attitude and at a low forward speed on the Guggigletscher. The pilot was fatally injured and the helicopter was partially consumed by fire. Several people observed the accident and immediately alerted the police.

1.1.4 Location and time of the accident

Location	Guggigletscher, municipality of Lauterbrunnen/BE 17 km south south-east of Interlaken
Date and time	14 July 2015, 08:22
Lighting conditions	Daylight
Coordinates of the wreckage	641 440 / 156 111 (swiss grid 1903)
Elevation	2790 m AMSL 9154 ft AMSL
Coordinates of the final position of the load	641 653 / 156 133 (swiss grid 1903)
Elevation	2850 m AMSL 9350 ft AMSL

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew members	Passengers	Total number of occupants	Other
Fatal	1	0	1	0
Serious	0	0	0	0
Minor	0	0	0	0
None	0	0	0	Not applicable
Total	1	0	1	0

1.3 Damage to aircraft

The helicopter was destroyed.

1.4 Other damage

There was minor field damage.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Pilot

Person	Swiss citizen, born 1964
Licence	Commercial pilot licence helicopter – CPL(H) according to the European Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA).
Ratings	Type rating AS 350 as pilot in command, valid till 31 March 2016
	Mountain flying (MOU(H))
	External cargo sling (ECS)
Last proficiency check	Operators proficiency check (OPC) on 28 April 2015
Medical certificate	Class 1, VNL (shall have available corrective lenses for near vision).
	Valid from 4 February 2015 till 13 August 2015
Last medical examination	4 February 2015

1.5.1.1.1 Flying experience

Total	9139:21 hours
On the type involved in the accident	1888:22 hours
During the last 90 days	67:46 hours
On the accident type	61:18 hours

The pilot had been employed by the air transport operator for many years and had extensive experience of mountain flying with external loads.

1.5.1.1.2 Duty plan

In the week before the accident, the duty plan included the following flights:

07.07.2015	Off duty			
08.07.2015	HB-ZIS	AS 350 B3	1:12 hours	17 turns
09.07.2015	HB-ZNR	AS 350 B3	4:22 hours	62 turns
10.07.2015	Off duty			
11.07.2015	HB-ZRK	EC 135	1:35 hours	4 turns
12.07.2015	Off duty			
13.07.2015	HB-ZIS	AS 350 B3	2:17 hours	49 turns

1.5.2 Marshaller 1

Swiss citizen, born 1990

Marshaller 1 began his training in May 2014 and subsequently worked with the operator. During the winter months there was a break in his work, as the marshaller was in full-time employment in a skiing area. Before 2014 marshaller 1 had already worked occasionally at weekends for the operator in the hangar. On the day of the accident he was appointed as team leader.

1.5.3 Marshaller 2

Swiss citizen, born 1971

Marshaller 2 began his activities with the operator in 1993 in a part-time role. In the years 1998 to 2001 he worked full-time as a marshaller. Thereafter, marshaller 2 again worked part-time for the operator as marshaller for 15 to 25 working days.

1.5.4 Marshaller 3

Swiss citizen, born 1990

Marshaller 3 had some five years professional experience. For the first three years he was employed as a marshaller with another operator.

1.6 Aircraft information

1.6.1 General information

Registration	HB-ZIS
Aircraft type	Airbus Helicopters AS 350 B3
Characteristics	Single-engine multi-purpose helicopter with six seats and skid landing gear. Fully articulated main rotor with three blades, conventional torque compensation with tail rotor.
Manufacturer	Airbus Helicopters, France
Year of manufacture	2008
Serial number	4493
Owner	MX Management AG, Hauptstrasse 26, 3800 Interlaken, Switzerland
Operator	Air-Glaciers SA, Case postale 27, 1951 Sion, Switzerland
Engine	Turbomeca Arriel 2B1, serial number 46456
Equipment	VFR equipment with MovingTerrain chart display equipment
	PowerFlarm collision avoidance device
	External load system (cargo swing) and external mirror
Operating hours	Airframe: 4941 hours (TSN[1])
	Engine: 1464 hours (TSN)
Maximum permissible masses	Maximum permitted take-off mass: 2250 kg

[1] Time since new – TSN

	Maximum mass with external loads: 2800 kg
Mass and centre of gravity	At the time of the accident, the mass of the helicopter was 2035 kg. Both mass and centre of gravity were within the permissible limits according to the flight manual (FLM).
Maintenance	The most recent scheduled maintenance work, a 100-hour check on the airframe and engine, was certificated on 29 June 2015 at 4902:21 operating hours.
Technical restrictions	No outstanding points were entered in the hold item list (HIL).
Permitted fuel grade	JET A1 kerosene
Registration certificate	Issued by the FOCA on 4 June 2013, valid till deletion from the aircraft register.
Airworthiness certificate	Issued by the FOCA on 14 July 2008, valid till revoked.
Airworthiness review certificate	Date of issue: 25 February 2015 Validity expiry date: 18 March 2016
Approved operations	Commercial
Category	VFR by day

1.6.2 Fuel gauge

HB-ZIS had a fuel tank with a capacity of 540 kg. The fuel gauge was on the left-hand side of the upper screen of the vehicle and engine multifunction display (VEMD). The indication consisted on one hand of a bar chart showing the fuel amount as a percentage and on the other hand of a digital display in litres, below the graphic display.

As soon as the fuel quantity falls below a value of 60 l (48 kg), the amber warning FUEL is illuminated. In the emergency procedures in the FLM, the pilot is instructed to land as soon as possible. Furthermore a note states that 15 minutes flying time at maximum continuous power remains. In addition, a warning is given concerning major flight attitude changes.

1.6.3 External load system

HB-ZIS was equipped with an external load system of the cargo swing type. This system is characterised by a pyramid-shaped steel structure (7) with a centrally attached swivel hook (2), which was secured by four steel cables (5 and 8) to the bottom of the fuselage (1 and 3) of the helicopter.

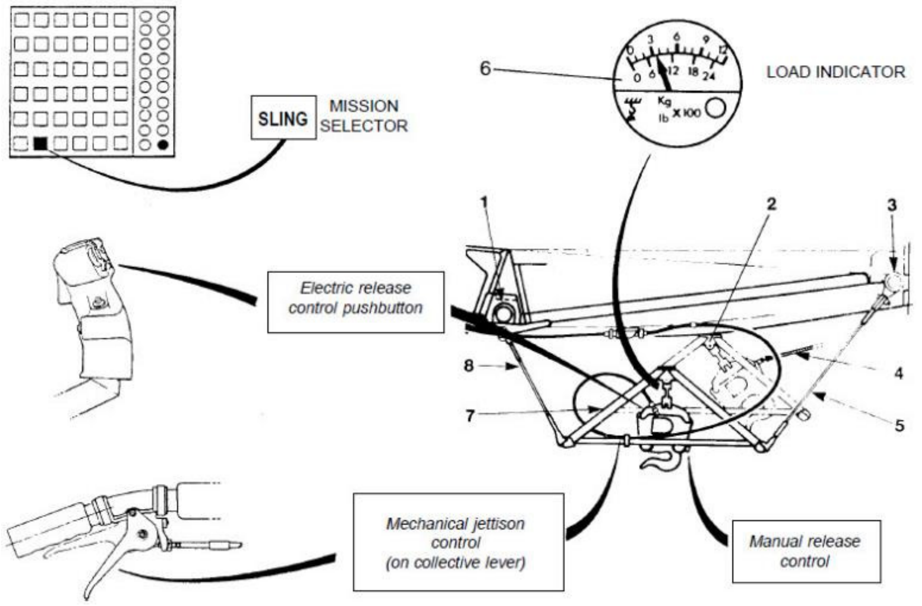


Figure 5: Illustration of the external load system from the Airbus Helicopters flight manual.

The swivel hook can be retained in the unloaded condition by a flexible line (4), in order to increase ground clearance. The swivel hook can be operated from the cockpit electrically or mechanically. A load indicator is also fitted (6).

1.6.4 Calculation of flight performance values

Taking into account the pressure altitude and temperature at the time of the accident when the load was lifted, a recalculation using the table in the FLM indicated that a hover out of ground effect (HOGE) would have been possible up to a mass of approximately 2150 kg. In this respect, the manufacturer assumes the following conditions:

- no wind.
- no P2 air bleed [no air bleed from compressor stage 2].
- maximum take-off power.

1.6.5 Helicopter journey / techlog

The helicopter journey/techlog of HB-ZIS was not on board during the accident. It was secured at the base in Lauterbrunnen as part of the investigation. The last daily check was certificated on 13 July 2015 at 08:00. The pilot involved in the accident was flying HB-ZIS on that day and certificated 230 l of fuel on board. He then flew for 2:17 h in total between 08:00 and 17:20.

In this regard, there are no entries for 14 July 2015 in the journey/techlog.

According to information provided by the base manager, it was the usual practice when parking the helicopter in the terrain overnight to leave the journey/techlog back at the base. In this case, the daily check is usually carried out during the first refuelling taking place at the base in Lauterbrunnen.

1.6.6 External load

The transported external load consisted of a pyramid-shaped roof with a pitch of approximately 15°. The dimensions of 3.70 m x 4.05 m give a projected roof area of 15 m^2. The total weight of the roof was just over 600 kg.

The load-bearing structure of the roof consisted of a main beam of glulam[2] timber, two roof rafters mounted transversely in relation to this main beam and four diagonal wooden beams which formed the pyramid edge of the roof. The structure was bounded on all sides by fascia boards.

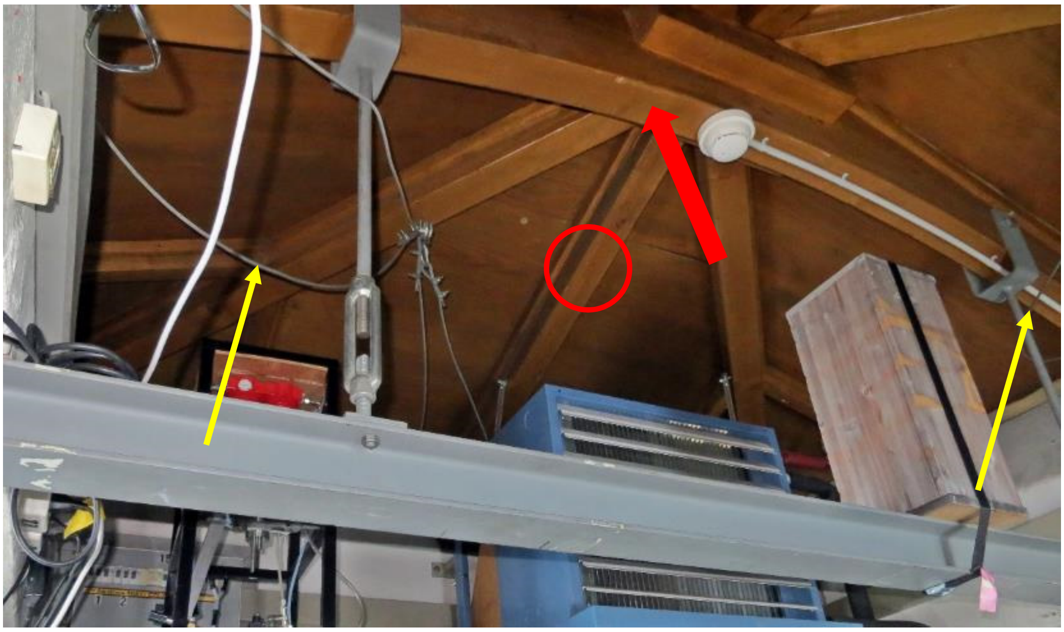


Figure 6: Interior view of the roof. The thick red arrow indicates the main beam. The red circle marks one of the two roof rafters. The yellow arrows indicates the two pre-mounted wire rope slings in the main beam.

Wooden planks were nailed to this load-bearing structure. They served as support elements for the sheet metal roof cladding.

For lifting and transport of the roof, both the main beam and the roof rafters were drilled through close to the edge of the roof. Wire ropes were passed through these holes; they were connected to a sling.

The wire ropes which were pulled into the holes act under load on the rafters and main beam as a split wedge. In this situation a danger of a fibre fracture of these structural elements exists. From the statics of the roof structure it is evident that when the roof is lifted respectively transported, the two fixing points on the glulam beam ultimately sustain the total load of the roof. The load on the two slings, which are attached to the roof rafters, is low; they stabilise the roof when it is lifted respectively transported.

1.7 Meteorological information

1.7.1 General weather situation

A wedge of the Azores high extended into Central Europe. Concurrently a flat mid-tropospheric ridge was present. It maintained subsidence and anticyclonic conditions.

1.7.2 Weather at the moment and at the location of the accident

Morning was dry and warm. On the mountain gap of Jungfraujoch wind blew from north-west. The 10-minute average wind speed was 14 kt. Gusts reached roughly

[2] Glulam stands for glued laminated timber and is a structural engineered wood product comprising a number of layers of dimensioned lumber bonded together with durable, moisture-resistant structural adhesives.

20 kt. On the Schwarzmönch, a spur of the Jungfrau summit towards north-west, wind was deflected by topography. Hence, at 2700 m AMSL, wind direction was south-west. A wind speed average of 5 kt and gusts up to 9 kt were recorded.

In the free atmosphere over Payerne the midnight radiosonde detected the freezing level at 4700 m AMSL. The troposphere was significantly warmer than the International Standard Atmosphere (ISA). In relation to the ISA the temperature deviation on Jungfraujoch, at 3580 m AMSL, was plus 9, on the Schwarzmönch, at 2700 m AMSL, plus 12 centigrade.

Weather	Sunny
Cloud	1/8 cirrus
Visibility	25 km
Wind at the lifting site	320 degrees, 14 kt, gusting to 20 kt
Temperature/dewpoint at 3600 m AMSL	2 °C / -13 °C
Atmospheric pressure QNH	1021 hPa, atmospheric pressure adjusted to sea level, calculated with the values of the ISA standard atmosphere.
Hazards	none

1.7.3 Astronomical information:

Position of the sun	Azimuth: 83°	Elevation: 23°
Lighting conditions	Daylight, the accident site was in the shadow of the topography	

1.8 Aids to navigation

Not applicable

1.9 Communications

There are no indications of any difficulties with radio communication between the pilot and the marshallers. No radio contact existed between the fitters who were responsible for attaching the external load and the pilot.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

No conventional flight recorders were installed on HB-ZIS. Nor are these prescribed for such type of aircraft.

The helicopter was equipped with a collision avoidance and chart display system in which GPS data are recorded. It was possible to secure and analyse both devices.

In the following the flight path of HB-ZIS relating to flight mission no. 7 was reconstructed in simplified form. The video recording could also be implied for this purpose. The recordings show the load being taken up and the first part of the departure with the load. The load was suspended steady below the helicopter up to the end of this recording.

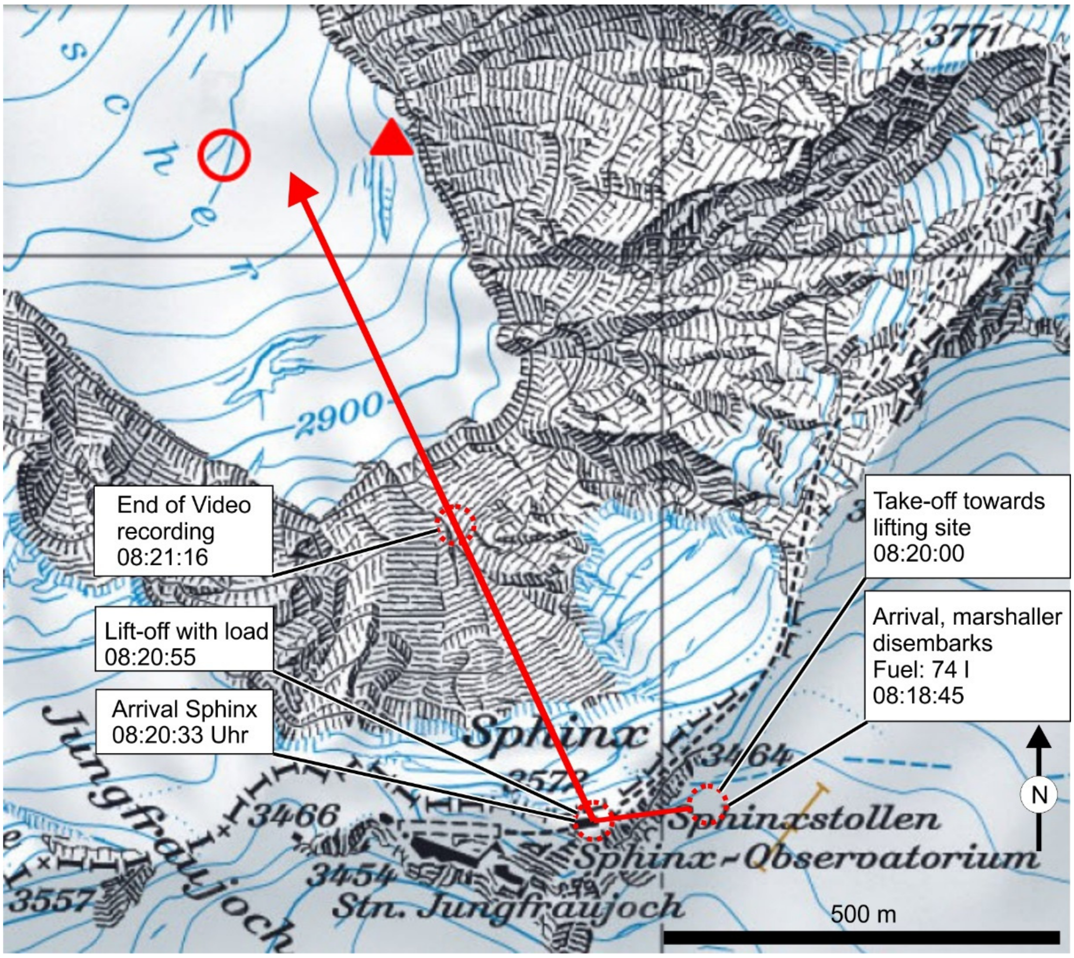


Figure 7: Flight path of HB-ZIS. The red circle marks the final position of the wreckage; the red triangle shows the final position of the external load.

The engine control unit (ECU) in particular was damaged by the effects of the fire, such that the data could not be analysed. The ECU communicates with the VEMD. Serious faults relating to fuel regulation are transmitted by the ECU to the VEMD and are stored there.

For one second the VEMD recorded excess torque (107%). Moreover, the gas generator speed was exceeded for one second (102%). Apart from that, no system faults were recorded.

1.12 Wreckage and impact Information

1.12.1 Site of the accident

The accident site was located on the glacier named Guggigletscher in the Bernese Oberland. This glacier lies to the north-west, below the Sphinx observatory and is accessible only with special equipment. The terrain around the site of the accident falls away gently and was approximately 400 m from the face of the glacier to the north-west. The surface of the ice had thawed slightly owing to the temperature.

The external load was found approximately 200 m from the accident site, close to a glacier crevasse. The surface of the roof or rather the pyramidal peak was pointing upwards and the timber structure was facing towards the ice.

Figure 8: Overview of the site of the accident. The red arrow marks the final position of the wreckage

1.12.2 Impact

The helicopter crashed in its normal attitude on the glacier with a high vertical speed and a very low forward speed.

Figure 9: Final position of the wreckage

1.12.3 Wreckage

1.12.3.1 Helicopter

The abdominal and shoulder belts were being worn and withstood the stresses.

The following detailed findings were established in relation to the wreckage:

- The main cabin area was destroyed and partially consumed by fire.
- Both landing skids were broken into several pieces.
- The engine and parts of the cowling were on the rear of the cabin floor to the right.
- The main gearbox with the rotor head laid pointing forward on the left side of the cabin floor.

- Two rotor blades were damaged and were still attached to the rotor head.
- The third rotor blade was torn out of the rotor head and was located approximately 100 m in the direction of flight in front of the wreckage on the glacier.
- The tail boom was separated at the cabin and in front of the horizontal stabilizer.
- The tail boom was twisted counter clockwise in relation to the direction of flight in the area of the tail rotor transmission.
- The tail rotor drive shaft was separated just in front of its transmission.
- In the area of the vertical stabilizer a distinct incision, approximately 30 cm long, was found with synthetic fibre residues.
- The tail rotor blades were still attached to the gearbox and exhibited substantial damage.

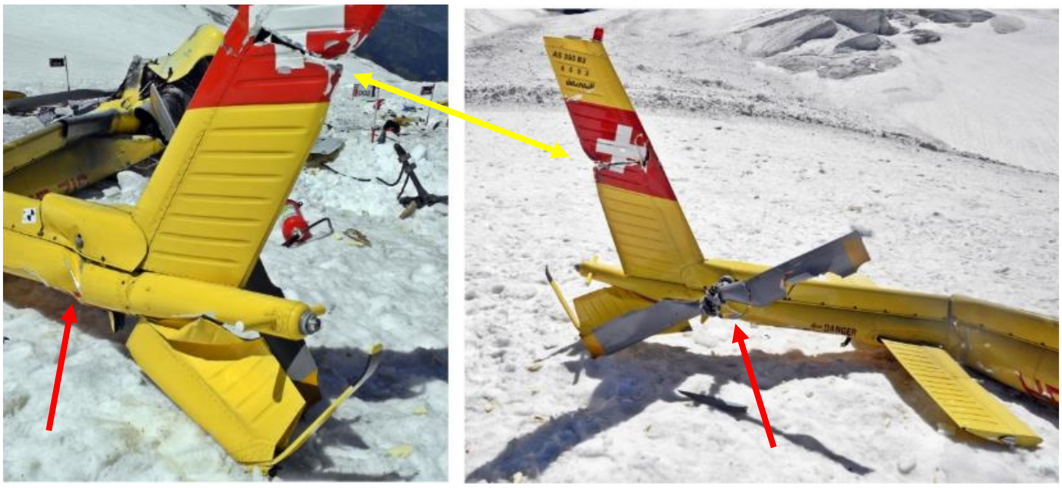


Figure 10: Detail photo of tail boom. The red arrows point to the twisted area. The yellow arrow points to the incision in the vertical stabiliser.

- On the tail boom, as well as on the rotor blades, distinct marks of the longline could be identified.
- In total, three segments of the 30 m longline were found. Approximately 5 m of the longline are missing.

1.12.3.2 External load

The sheet metal roof cladding exhibited plastic deformation and the roof was badly damaged on one side. All four textile loop slings and the wire rope slings fastened to them by round shackles were found in the vicinity of the roof. The 14.6 m long separated end segment of the longline also lay near to the four textile loop slings, which were still hanging in the cargo hook. After the roof was lifted off the ice surface, the following findings, among other things, were made:

- The roof structure was damaged in various places.
- One roof rafter was loose under the roof, with the nails pulled out.
- One roof rafter was still connected to the roof structure by its nails.
- The glulam beam was torn off lengthwise, to a large extent along the glued joints.

Figure 11: Final position of the external load

1.13 Medical and pathological information

The pilot's body underwent a post-mortem examination. The multiple injuries caused by the impact were the primary cause of death. In the blood analyses, a carboxy-haemoglobin (CO-Hb) content of 19 % was measured. In the case of smokers, depending on the amount of tobacco consumed, a CO-Hb value of approximately 10-15 % may be attained.

Although one can assume a rapid cessation of the respiratory and circulatory function after such injuries, it cannot be excluded that for a very short while a few breaths or heartbeats occurred, such that the smoke and gases caused by the fire could have been inhaled.

Furthermore, there were no injuries on the body which could be attributed to the longline.

The post-mortem examination unveiled no indications of the pilot suffering any health impairment during the flight involved in the accident.

From a forensic-toxicological point of view, at the time of death there were no indications of consumption of alcohol or narcotics or other flight-relevant extraneous substances.

1.14 Fire

The helicopter caught fire and was partially consumed by fire.

1.15 Survival aspects

1.15.1 General

The accident was not survivable.

1.15.2 Search and recovery

The helicopter was equipped with an emergency locator transmitter (ELT). The unit was destroyed. No ELT signals were registered or received.

The alarm was raised by various observers of the accident. A helicopter belonging to the operator and one from the Swiss Air-Ambulance Rega with rescuers arrived at the accident site.

1.16 Tests and research results

1.16.1 Investigation of the airframe and engine

The airframe and engine were examined in the presence of the manufacturer's representatives. Because of the extent of destruction due to fire, only a limited examination was possible.

No technical faults were found which might explain the circumstances of the accident. The results of the examination of the engine indicate that it was able to deliver power. The gas generator was rotating under power when the helicopter crashed. The damage which was ascertained is subsequent damage which occurred during the crash.

The dynamic components, the main and tail rotor blades exhibit damage which indicates low rotational energy at the time of impact. It is possible that one main rotor blade may have become detached before the impact. According to experience, this may occur after loss of the corresponding control of the main rotor. Such a condition causes an uncontrolled flapping motion of the blade and leads to overstressing.

This loss of a blade causes overstressing of the main transmission gearbox attachment to the airframe, due to the resulting imbalance in the rotor system, and to the failure of the main drive shaft. This explains the little damage due to rotational energy on the two remaining main rotor blades after the impact, with the engine still running.

1.16.2 Longline information

The synthetic fibre longline used during the flight involved in the accident was most probably supplied to the air transport operator in 2010. This type of longline was not fitted with a protective cover and featured the following specifications:

- Selatec K12 red, with a diameter of 12 mm;
- High performance Dyneema fibre, twelve-ply twisted with a polyurethane (PU) coating;
- Minimum breaking force (MBF) 140 kN;
- Dead weight 8.3 kg/100 m.

According to information from the operator, at least on one end of the longline labelling can be found for identification. No labels with crucial data, as required for such longlines, could be found.

Figure 12: Example of an end of a longline with thimble and label. This longline also does not have a protective cover.

The three segments of the longline found at the site of the accident all had a diameter of approximately 16 mm and respective lengths of 14.6 m (no. 1), 7.95 m (no. 2) and 2.4 m (no. 3).

Segment no. 1 was still attached to the external load (see Section 1.12.3.2), whereas segments no. 2 and no. 3 were found on the glacier between the wreckage and the external load. Owing to the serious damage and deformations of the segments of the longline, no definite matching of the different separation points could be achieved. In the macro- and microscopic examinations of the rope segments, relatively straight separation planes were ascertained in each case, indicating damage due to cutting. These separations may well be due to a combination of initial incisions, followed by tearing of the longline.

The forensic examination of the pieces of fibre found on the vertical stabilizer were no different from the fibre samples from the longline which was used.

1.16.3 Visual assessment of the remainder of the longline

The remainder of the longline used were assessed by the manufacturer. In the process, the incorrect maintenance of the splice and the join was evident. From this point of view, this rope should no longer have been used in flight service. In view of the range of uses, this longline had reached a point where it should have been discarded. This is substantiated by the loosening and chamfering in the area of the splice and at some points on the free length.

A new longline has a diameter of 12 mm. Through its use the diameter had increased up to 16 mm (see Fig. 13).

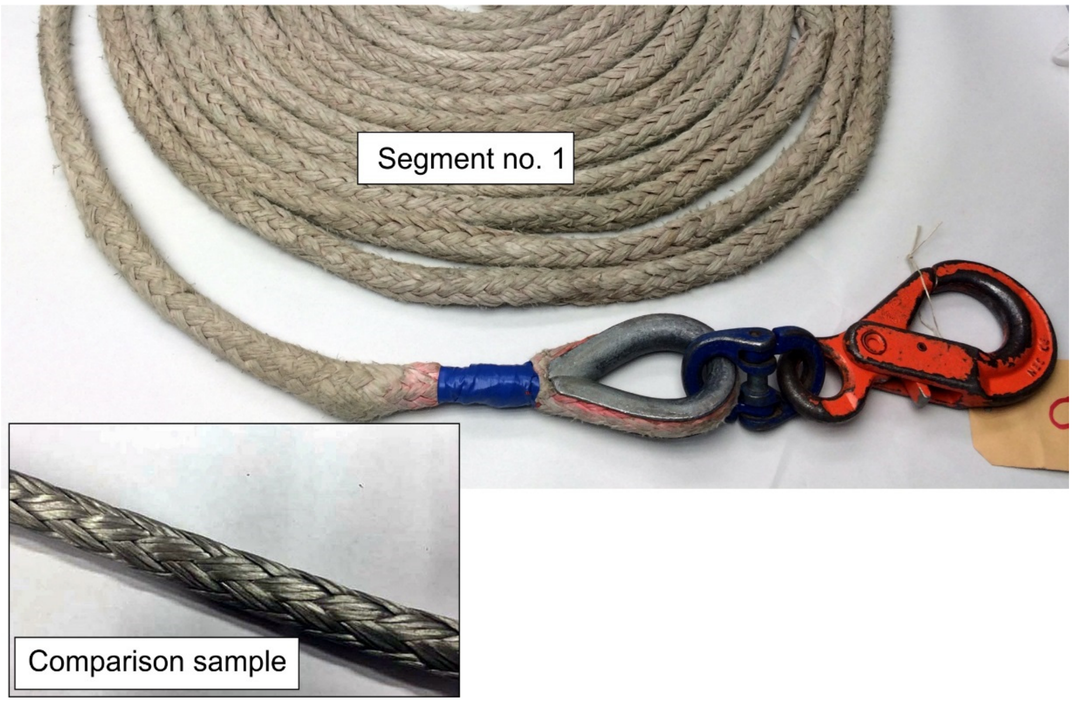


Figure 13: Segment no. 1 of the 30 m longline with the incorrectly spliced end. The sample for comparison shows the condition of a Dyneema longline fresh from the factory.

1.16.4 Investigation of the external load

Plastic deformation was found on the two roof rafters and on the glulam beam, in the area of the four fixing point holes. At the torn-off end of the glulam beam the hole for the inserted wire rope slings ran in the plane of the glue line of two layers of laminate. This suggests that the inserted wire rope initiated the break in the glued joint under load. The wire rope slings laid loose beside it. At the other three fastening points of the wire rope slings, the wood had not failed at the drilled hole.

In the case of this glued joint, a ratio of broken fibres of approximately 10 % was determined in the laboratory. With a high-quality glued joint, failure of the wood can generally be expected. The proportion of broken fibres of only 10 % indicates a low-grade glued joint. The proportion of broken fibres, together with the strength of the joint, enables an accurate estimate of the quality of the glued joint and of its strength. Additional investigations found that glued joints on test specimens taken from the main beam in the area of the fixing points were delaminated or generally exhibited a proportion of broken fibres of less than 20 % and insufficient shear strength.

1.16.5 Aerodynamic behaviour of the external load during the flight

The vertical distance between the helicopter skid and the edge of the roof was approximately 35 m. It must be assumed in the case of transport of this type that the load may shift from the horizontal position.

In aerodynamic terms, the transported roof is comparable with a kite or a simple wing profile. It reacts sensitively and in an uncontrolled manner if the airstream or the attitude of the roof changes.

For this roof, with its surface area of 15 m^2, for an airflow velocity of 20 m/s (72 km/h or 39 kt) with an angle of incidence of 15°, the estimated lifting force was approximately 7000 N.

The mass of this roof was approximately 600 kg, corresponding to a downward force of 5900 N. Assuming the previously mentioned conditions applied, the resultant net lift was over 1000 N. A slack rope and uncontrolled movements of the load could therefore be expected.

1.17 Organisational and management information

1.17.1 Air transport operator

1.17.1.1 General

The Air Glaciers AG company was founded in 1965 in Sion. From 1967 onward, it operated two type SA316 Alouette III helicopters and two fixed-wing type Pilatus Porter aircraft. In the subsequent years the operator expanded into the areas of air rescue, work flights and taxi flights by helicopter, both in the mountains and in the flat country. Later a Beechcraft King Air 200 was added; it was deployed for charter flights from Sion (LSGS).

The company's head office is in Sion. Other sites in canton Valais are at Collombey and Gampel. There are also bases in Leysin, Lausanne, Geneva, La Chaux-de-Fonds, Saanen and Lauterbrunnen, which are all administered by decentralised management.

1.17.1.2 Lauterbrunnen base

On the base of Lauterbrunnen, some 20 permanent employees operate type AS 350 B3 and EC 135 helicopters. On this base, various part-time employees are available; they cover personnel requirements at operational peak times. The base is managed by the base manager.

Flight operations from the base in Lauterbrunnen cannot started before 08:00. Therefore, if necessary, helicopters are parked off-base on the terrain (cf. Section 1.6.5).

Rigging material inventory management is carried out by an experienced marshaller. The quality assurance of the rescue material and steel rigging material is provided by a company commissioned outside. Monitoring of the synthetic fibre rigging material is conducted on a continuous basis within the company, by the responsible persons.

The longline used on the flight involved in the accident belonged to a series of synthetic fibre longlines which were used in flight operations from 2010 onwards, after an assessment. In the event of problems the operator always co-operated closely with the supplier. According to information from the person responsible, no repairs on the longlines were carried out in-house.

1.17.1.3 Operations manual

The operator determined the specified procedures for crews in the operations manual. The operations manual approved by the FOCA is for the most part in French and in part in English. The investigation had at its disposal a German translation with the proviso that in the case of doubt the officially approved document is the definitive version.

The following deals only with those passages which are of significance for the accident in question and are translated from German into English:

5.12.1 Passenger flights

The following are taken into account for the calculation of the amounts of fuel and lubricant:

a) Weather forecasts

b) Foreseeable delays attributable to precautions of the air traffic control centre

c) Foreseeable delays in relation to air traffic

d) Any other eventuality which might delay landing or increase fuel or lubricant consumption

[…]

5.12.2 Aerial work

For the calculation of the fuel and lubricant reserve for aerial work flights, items a, b, c and d under Section 5.12.1 must be taken into account.

The quantity of the fuel can be reduced to one turn plus at least 5 minutes flight time.

[…]

9.14.7 Competences of the team leader

9.14.7.1 General

The team leader is competent to carry out assessment of a construction site on the spot and to inform the customer concerning the safety precautions and for the preparation of transports and of loads

9.14.7.2 Before the flight

The team leader is competent for co-ordinating the preparation of loads and gives instructions to the marshallers. He is competent to select a landing site and a refuelling site. He is competent to inform the workers/fitters about the precautionary measures and safety precautions to be taken.

[…]

The team leader is obliged to inform the pilot about the progress of the preparations and the loads to be transported. In the event of disputes, he shall contact the pilot.

9.14.7.5 During the flight

The team leader is competent for maintaining safety on site. He deals with any co-ordination problems. The team leader provides the pilot and marshallers with an information summary. If the circumstances require, he is in charge to suspend the flight.

9.14.8 Organisation, task allocation, co-ordination between the team leader, the pilot and the marshallers

9.14.8.1 Organisation

Air Glaciers, which uses helicopters of the lightweight category, deploys standard crews consisting of 3 persons: a pilot, a team leader and a marshaller.

9.14.8.2 Organisation

Before take-off from the base, preparation takes place with the collaboration of the flight operations manager, the pilot and the team leader. The team leader forwards the preparation instructions to the marshallers concerned.

9.14.8.3 Organisation

On the take-off or landing site for loads, the pilot, the team leader and the customer decide on the transport sequence depending on the materials to be transported.

9.14.8.4 Organisation

The preparation of loads takes place in accordance with the competences of the team leader.

[…]

9.14.8.6 Organisation

The operations centre respectively the pilot shall be informed as soon as possible by radio about major changes to the programme.

1.17.1.4 Load lifting devices according to the marshaller syllabus

The marshaller syllabus is a means of learning, training and providing information for the training of marshallers in commercial helicopter operating companies. Among other things, load lifting devices are described in detail in this document. In the present case the following is of significance:

"LOAD LIFTING DEVICES

1st principle: Assessment

The calculations presented and described below are based on the finding that the forces during underload flight operations with helicopters may be greater than when using a hall crane, and therefore cannot be definitively compared.

[…]

RULES OF TECHNOLOGY

[…]

Marking

According to machinery directive 2006/42/EC Annex I, art. 4.3.2 "Lifting accessories", load lifting devices (LLD) must be marked with the following identifications (manufacturer's brand)!

- Manufacturer - Maximum working load (WLL)

- Material - CE-marking

Further identification, such as the manufacturer's address, serial number (S/N), part number (P/N), indication of length and diameter, name of user or exact type description, use restrictions (e.g. to be used only to lift by helicopter, no HEC), customised features, etc. can be required by EN-standards and, if necessary or on the operator's request, indicated by the manufacturer.

LLD without proper marking are not safe!

[…]

Symmetry - Asymmetry

[…]

The Statics model referring to the 4-leg sling (also to the 2- and 3-leg sling) applies in both cases.

Use on helicopters: Lifting devices with one and two legs must always be calculated in such a manner that

1 leg is enough to bear the entire load and all acting forces (single- and two-leg slings = 1 or 2 legs with sufficient carrying capacity = max. 1 load-bearing leg). Analogously, in case of three- and four-leg slings, only 2 load-bearing legs can be taken into account.

Reason: During helicopter operations, cargo is never static, exactly symmetrically loaded or stable. Due to different leg lengths, uneven slinging points, oscillations/rotations of the load and spiralling at high speeds, a continuous shifting of force transmission within the single legs of the slinging devices must be taken into account. At times and alternatingly, only 1 leg (TWLS) or 2 legs (THLS, FLS) bear the whole load!

[…]

Ageing

Slinging devices, load lifting devices and instruments are subject to ageing caused by use (strain, dirt, sharp edges, overstressing, base solutions, oils, UV light, etc.). The extent of ageing depends on the specific characteristics of the material.

Under dimensioned slinging devices age more rapidly, since the load forces acting upon them are often close to the "yield point" (shortly before the "breakage/tearing point" is reached).

Due to the forces produced during flight operations (banking, dynamic loads, number of working cycles, load alternations and moments of force), the requirements for helicopter transports are considerably different from those concerning industrial applications.

Material, slinging techniques and life spans must be ascertained according to the requirements.

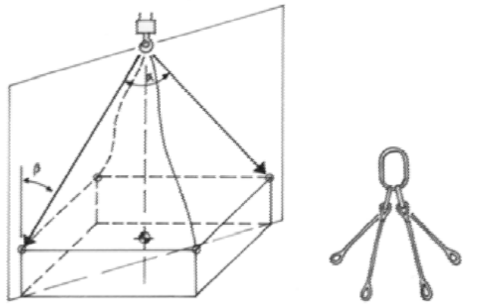
[…]

LOADS ON LOAD LIFTING DEVICES

Multiple-leg slinging equipment

[…]"

AI 45° with 4-leg slings



Slinging factor (SF)	
Load on the LLD:	
Load (mass)	100%
Slinging factor AI	1.41 [-]
Additional load	41%
Total load: 100 x 1.41	**141%**
Load distribution:	
No. of legs in use	4
No. of load-bearing legs	2
Load per leg 141% : 2	**70%**

Mass 100% - Load 141%

1) Slinging factor AI ignored (as it is assumed that the total load is carried by 1 leg).

Figure 14: Illustration and calculation basis for the 4-leg sling from the marshaller syllabus.

1.17.2 Construction company

The construction company which was responsible for the renovation of the roof of the Sphinx observatory also undertakes special jobs in the mountains, among other things.

Refresher courses for the employees are held every two years. During these refreshers the issues on the dangers of working with a helicopter were broached.

1.18 Additional information

1.18.1 Flight planning

Flight mission no. 7 was amended during the course of 14 July 2015 in that the external cargo transport was combined with the essential refuelling of HB-ZIS. The direct distance between the Sphinx observatory and the base in Lauterbrunnen is just under 8 km.

Assuming, in the case of transport of this unstable load, a maximum speed of 10 kt, this distance would take approximately 25 minutes. With an average fuel flow of 140 to 180 l/h, a consumption of just under 70 l is required for this route using an AS 350 B3 helicopter.

1.18.2 Verification of available fuel reserve

The observed fuel level of 74 l was verified on the basis of the following information:

On the basis of the fuel quantity of 300 l at the start of operations, a total flying time of approximately 1:20 hours up to the beginning of flight mission no. 7 and an average fuel consumption of 140 to 180 l/h, this results in a calculated fuel level of 85 l.

Consequently the observed fuel level appears plausible.

2 Analysis

2.1 Technical aspects

There are no indications of any pre-existing technical defects on HB-ZIS which might have caused or influenced the accident.

2.2 Human and operational aspects

2.2.1 Mission processing

Various scenarios concerning the objective of the transport were discussed for this mission. Initially, the intention was to continue using the roof. To this end, it was only to be flown close to a station on the Jungfrau railway. This plan was discarded in the week before the accident, so in the daily schedule of 14 July 2015 for flight mission no. 7 it was planned to transport the roof from the Sphinx observatory to the railway station of Eigergletscher using a 70 m longline.

Since the 'seventies, this roof had occasionally been transported over short distances using the pre-installed wire rope slings and a helicopter. This pre-defined load lifting system appeared to the persons involved to be suitable, so no-one made a critical appraisal of its quality and appropriateness. The operator therefore allowed itself to be misled to transport the roof in the same way and incorporated flight mission no. 7 into the day’s programme. As the results of the material tests on the external load demonstrate, the use of this pre-defined load lifting system for a lengthy flight was inappropriate and risky.

On this day, the pilot of HB-ZIS had no opportunity to examine the load in detail, since this was performed by the specialists on the ground, as was the usual practice. The decision to combine the transport of this roof with the helicopter refuelling in Lauterbrunnen seems to have been taken spontaneously. It is a fact that for the transport of this unstable load a flight time of at least 25 minutes should have been taken into account, since it was possible to fly only at a low speed. It is therefore incomprehensible why the experienced pilot tackled the flight mission with only 74 l of fuel. This circumstance probably escaped the pilot's attention.

2.2.2 Calculation of the necessary fuel amount

In the manufacturer's emergency procedures, the pilot is instructed to land as soon as possible if the amber FUEL warning is illuminated. The remaining flying time reserve of 15 minutes with maximum continuous power is understood as a contingency reserve. By contrast, the operator allows the amount of fuel to be reduced to one rotation plus 5 minutes flying time. It is not clearly evident to which minimum level this applies.

Using the maximum potential of the operator's stipulations, the minimum fuel amount would have been approximately 85 l. In this case, the helicopter manufacturer’s contingency reserve of 15 minutes with maximum continuous power is inevitably consumed by two-thirds.

If one interprets the stipulations in the sense that the manufacturer's contingency reserve must not be compromised in flight operations, a minimum fuel amount of 130 l would have been required.

2.2.3 Accident flight

Although the helicopter was being operated near to its performance limit, the video recordings show that the initial phase of the flight was progressing normally up to the end of these recordings. The pilot quickly accelerated HB-ZIS to 50 kt, which suggests that the pilot had become aware of the low fuel amount. It remains open whether the amber FUEL warning, which illuminates at a fuel level of 60 l, played a role here. It is certain that this speed, in combination with the inappropriate suspension of the load, led to the external load becoming unstable. The longline subsequently then was thrown over, leaving many traces on HB-ZIS. In the tail boom area, this led to damage to the vertical stabilizer and then to the deformation of the tail boom. As a result, the tail rotor drive shaft was separated just in front of its gearbox. It can be assumed up to the severing of the longline that the entire load was now suspended from the tail of the helicopter, which explains the observed uncontrolled flight attitude.

Traces of the longline were also found on the top of the main rotor blades. It is highly likely that the longline also damaged parts of the main rotor control system. The subsequent imbalance led to the failure of the main rotor drive and the fracturing of a rotor blade. In this situation HB-ZIS was no longer steerable and crashed uncontrollably onto the glacier

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- Helicopter HB-ZIS was licensed for VFR traffic.
- The investigation found no indications of pre-existing technical defects on HB-ZIS which might have caused or influenced the accident.
- Both mass and centre of gravity were within the permissible limits according to the flight manual (FLM).
- The helicopter was close to its performance limit for hovering out of ground effect (HOGE).

3.1.2 Crews

- There are no indications of any health problems during the flight involved in the accident in respect of the pilot and the persons involved on the ground.

3.1.3 General conditions

- The weather had no effect on course of events on the accident.
- Flight mission no. 7 envisaged flying a roof from the Sphinx observatory to the railway station of Eigergletscher using a 70 m longline.
- This pyramid-shaped roof had dimensions of 3.70 m x 4.05 m with a mass of approximately 600 kg and had a pre-defined load lifting system.
- The existing load lifting system was used to lift the roof off by helicopter and to replace it on the building in order to be able to put bulky items into the laboratory below.
- In the timber construction of the roof, wire rope slings were attached at four positions. These were pulled in through holes in the wood.
- The load lifting system of the roof in connection with flight mission no. 7 was not evaluated by the air transport operator.
- This load lifting system was inappropriate.
- Flight mission no. 7 was then spontaneously amended: the roof would be flown directly to Lauterbrunnen and this would be combined with refuelling of the helicopter.
- A flying time of approximately 25 minutes must be anticipated for the flight from the Jungfraujoch to the Lauterbrunnen base with a load of this type. The helicopter would consume just under 70 l of fuel on this flight.

3.1.4 History of the flight

- Before starting flight mission no. 7 the pilot reconnoitred the load from HB-ZIS and decided to use a 30 m longline.
- HB-ZIS then landed in front of the Aletsch exit so that marshaller 3 could shorten the longline from 50 to 30 m.
- When disembarking from HB-ZIS marshaller 3 noted that the fuel gauge was showing 74 l.
- At 08:20 HB-ZIS flew to the Sphinx observatory to commence flight mission no. 7.

- The load was attached to the longline by a fitter from the construction company.
- When the load had been lifted off the ground, HB-ZIS flew towards Lauterbrunnen at 08:21. The pilot then accelerated rapidly to a ground speed (GS) of approximately 50 kt.
- Shortly afterwards, the load became unstable and made the longline being thrown over the airframe, striking the area of the tail rotor and main rotor, with corresponding damage.
- The helicopter became uncontrollable and crashed on the Guggigletscher at 08:22.
- The helicopter caught fire and was partially consumed by fire. The pilot was fatally injured in the crash.

3.1.5 Wreckage

- Viewed in the direction of flight, the tail boom was deformed counter clockwise in the area of the tail rotor transmission.
- The tail rotor drive shaft was separated just in front of its gearbox.
- In the area of the vertical stabilizer a distinct incision, approximately 30 cm long, was found with synthetic fibre residues
- On the tail boom, as well as on the rotor blades, distinct marks of the longline could be identified.
- Two rotor blades were damaged and were still attached to the rotor head.
- The third rotor blade was torn out of the rotor head and was located approximately 100 m away in the direction of flight in front of the wreckage on the glacier.

3.2 Causes

The accident is attributable to a loss of control of the helicopter after an unstable external load allowing the longline being thrown over the airframe. This caused damage to the area of the tail rotor and main rotor

The following causal factor was identified:

- An excessive airspeed with an unstable load.

The following contributory factors were identified:

- An inadequate fuel reserve.
- Failure to evaluate the load attachment by the air transport operator.
- An inappropriate load lifting system for this transport mission.

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

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the accident

None

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).

Berne, 7 November 2017 Swiss Transportation Safety Investigation Board