Norwegian Safety Investigation Authority

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Air accident in the Skoddevarre mountains, Alta municipality, Troms og Finnmark county, Norway on 31 August 2019 with Airbus Helicopters AS350 B3, LN-OFU, operated by Helitrans AS

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The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving flight safety.

The purpose of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to make possible safety recommendations. It is not NSIA's task to apportion blame or liability.

Use of this report for any other purpose than for flight safety should be avoided.

Photo: Helitrans AS

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

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Report on air accident

Table 1: Data

Type of aircraft:	Airbus Helicopters AS 350 B3[1]
Nationality and registration:	Norwegian, LN-OFU
Owner:	Skjolden Cruisekai AS, Norway
Operator:	Helitrans AS, Norway
Crew/aircraft commander:	1, dead
Passengers:	5, all dead
Crash site:	Skoddevarre mountains in Alta Municipality in Troms og Finnmark County, Norway (69.91837 N, 23.14478 E)[2]
Time of accident:	Between 17:05 and 17:06 on Saturday 31 August 2019.

All times given in this report are local times (UTC + 2 hours), unless otherwise stated.

Notification of the accident

On Saturday 31 August 2019, the Norwegian Safety Investigation Authority (NSIA) was notified by the Joint Rescue Coordination Centre Northern Norway (JRCC N-N) that a helicopter with six persons on board had crashed in the Skoddevarre mountains south-west of Alta, see Figure 1. A fire had broken out in the helicopter after impact. The NSIA immediately started to prepare for a field investigation. The first team of inspectors from the NSIA caught the early flight from Gardermoen to Alta the next day and arrived at the crash site in the afternoon.

In accordance with Annex 13 to the ICAO Convention on International Civil Aviation, the NSIA notified the investigation authority in the country of manufacture, Bureau d´Enquètes et d´Analyses pour la Sècuritè de l´Aviation Civile (BEA) in France. BEA appointed an accredited representative to lead a team of accident investigators and technical advisors from the manufacturer Airbus Helicopters (AH) and the engine manufacturer Safran Helicopter Engines (SHE). Because the pilot was a Swedish national, the NSIA notified the Swedish Accident Investigation Authority who also appointed an accredited representative. In accordance with Regulation (EU) No 996/2010, the NSIA notified the European Union Aviation Safety Agency (EASA) of the accident. The Civil Aviation Authority of Norway (CAA-N) was notified in accordance with procedures.

[1] Registered Airbus Helicopters AS 350 B3E in the Norwegian Civil Aircraft Register and AS 350 B3 in the type certificate from EASA. The helicopter type is currently marketed as H125 (previously AS 350 B3e).
[2] According to the EU89 coordinate system – geographical degrees (lat/lon).

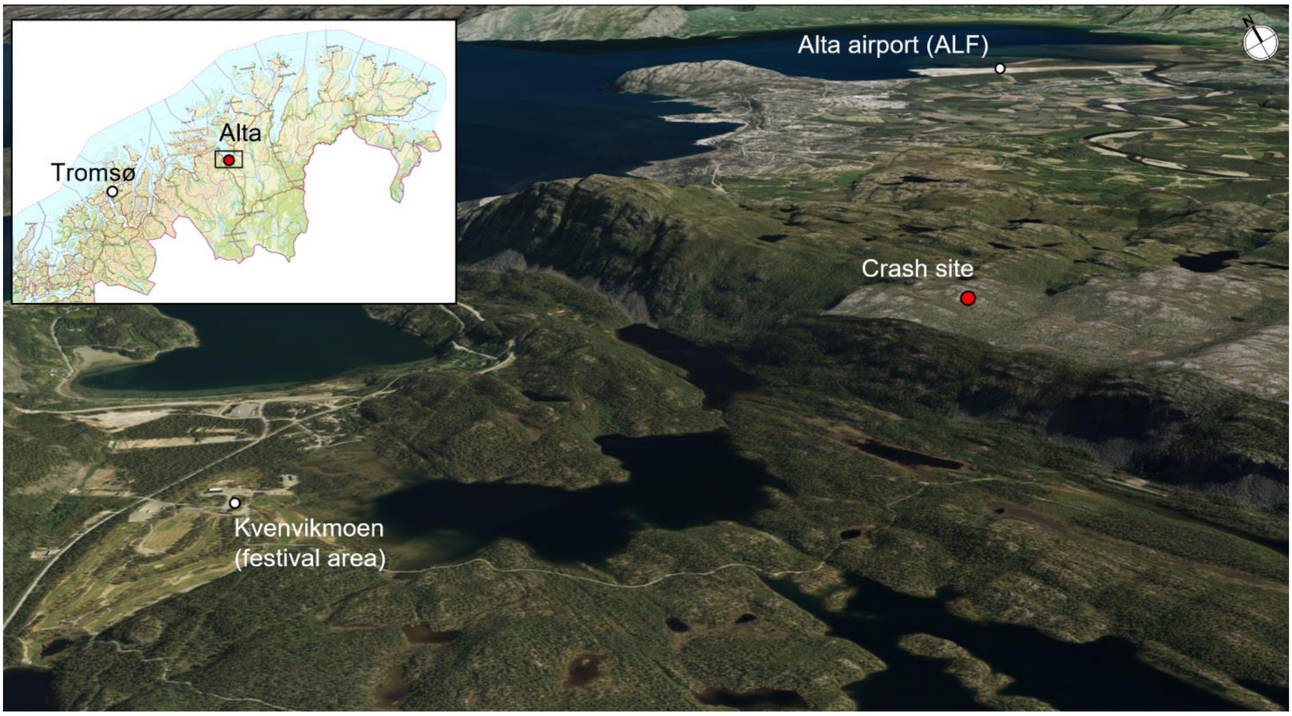

Figure 1: The crash site in the Skoddevarre mountains south-west of Alta. Map: © The Norwegian Mapping Authority. Illustration: NSIA

Summary

On Saturday 31 August 2019, an Airbus Helicopters AS 350 B3, registered LN-OFU, crashed in the Skoddevarre mountains near Alta. The helicopter was operated by Helitrans AS and was carrying one pilot and five passengers. The helicopter was consumed by fire shortly after the crash. All six on board died.

The passengers were participants in the Høstsprell festival and had signed up for a sightseeing flight departing from the festival area at Kvenvikmoen. The sightseeing flight on which the accident occurred was the second flight that day. The first sightseeing flight had also carried five passengers and had lasted for about 10 minutes. The second flight lasted for about five minutes before the helicopter crashed. Weather conditions and visibility were good in the area of the flights.

The investigation into the accident has been challenging. Except for the tail boom, the helicopter wreckage was completely burnt out. It was impossible to retrieve recorded flight data or information from electronic components in the wreckage. Airbus Helicopters had on its own initiative equipped the AS 350 with a Appareo Vision 1000 recorder, but the memory unit did not survive the fire. Furthermore, Snap Inc. has not provided the Norwegian Safety Investigation Authority (NSIA) access to a Snapchat video sent by one of the passengers immediately before the accident.

The helicopter's flight paths on both flights have been reconstructed with the aid of data from Flightradar24 and the helicopter operator's GNSS-based[3] tracking system. Data about the manoeuvres during the final minute prior to impact with the ground is missing due to the topography creating an ADS-B shadow. Hence the NSIA cannot draw an unequivocal conclusion as to how and why the accident occurred. Based on an overall analysis of all available information, the NSIA has been able to identify one probable sequence of events.

The NSIA has found no technical faults or irregularities relating to the helicopter that could have impacted the sequence of events. The accident occurred while the helicopter was in descent and in a slight right turn and at a low altitude. The helicopter was heavily loaded, and its speed was increasing. The NSIA believes the flight control hydraulic system may have reached its limit during the manoeuvring, and thereby triggered the servo transparency phenomenon[4]. The situation may have occurred unexpectedly for the pilot and based on the last available altitude data the helicopter probably had insufficient altitude above the terrain for the pilot to regain control in time.

The helicopter was almost new but was not equipped with a crash resistant fuel system. There are certified crash resistant fuel systems available for retrofit for the AS 350. Newly produced AS 350s are delivered with crash resistant fuel system as standard from October 2019. Under EU legislation, crash resistant fuel system is not required for helicopters whose type certificates were issued before 1994, such as Airbus Helicopters AS 350 (Part 21.A.101 "Changed Product Rule") The accident cannot be described as a high energy accident. The survivability would have been significant had a fire not broken out shortly after the crash. A crash resistant fuel system would therefore probably have prevented this from becoming an accident in which all six persons on board died.

As a result of this investigation the NSIA submits 12 safety recommendations addressed to EASA, CAA-N and Helitrans AS, the helicopter operator. They concern measures to prevent servo transparency, training and safety of commercial sightseeing flights, survival aspects, including crash resistant fuel system and use of helmets, and requirements of lightweight flight recorders.

[3] Global Navigation Satellite System (GNSS) is a common term for systems that determine the position of an object on the Earth using satellites, such as for example GPS.
[4] Servo transparency is a term used when the aerodynamic loads, in connection with helicopter maneouvers, exceed the hydraulic assistance of the servo actuators.

About the investigation

Purpose and method

The purpose of this investigation has been to clarify what caused LN-OFU to crash and catch fire in the Skoddevarre mountains during the second sightseeing flight in the afternoon of Saturday 31 August 2019. The NSIA has also considered what can be done to improve safety and prevent the recurrence of similar accidents and fatal consequences in future.

The investigation was conducted in line with the NSIA's framework and analysis process for systematic safety investigations (the NSIA method[5]).

Sources of information and investigations

The investigation following the accident posed challenges. Except for the tail boom, the helicopter wreckage was completely burnt out. Therefore, it has not been possible to carry out complete technical investigations. It was impossible to retrieve stored flight data or information from other electronic components in the helicopter wreckage. Several witnesses made observations relating to the flight, but no witnesses had seen the helicopter crash.

Multiple examinations have been carried out of the helicopter's components and systems, including a number of fracture and metallurgical examinations. Information about the helicopter's position, altitude and speed has been obtained from Flightradar24 and the helicopter company's CelloTrack 3Y tracking device. Saved photos and videos sent from the mobile app Snapchat have also been obtained and analysed. The NSIA is also aware of one Snapchat video from the accident which it has not been possible to acquire.

The NSIA has interviewed the loadmaster who helped to plan and conduct the sightseeing flights, and the passengers who took part in the first sightseeing flight on the day of the accident. The NSIA has also received documents and transcripts of witness interviews conducted by the police and have conducted its own interview with four of these.

The NSIA has reviewed the helicopter's maintenance history, the preparations before the flights, and how the flights were carried-out on the day of the accident. The manufacturer's and the operator's programmes for pilot instruction and proficiency checks on the helicopter type, and the helicopter operator's and the sector's guidelines for sightseeing flights and training of helicopter pilots have also been investigated. The investigation also clarified survival aspects and factors that could have limited the consequences of the accident.

The investigation report

The first section of the report, Factual information, describes the history of the flight, associated data and information gathered in connection with the accident, and describes the NSIA's examinations and related findings.

The second section, Analysis, describes the NSIA's assessments and analyses of the sequence of events and contributing factors, on the basis of factual information and examinations carried out. Details and factors that are found to be less relevant in order to explain and understand the accident are not discussed in depth.

The report ends with the NSIA's conclusions and safety recommendations.

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[5] *See https://www.nsia.no/About-us/Methodology*

1. Factual information

1. Factual information

1.1 History of flight

1.1.1 INTRODUCTION

The helicopter operator Helitrans AS, based at Alta Airport, had every year since 2012 offered helicopter tours to participants at the Høstsprell festival at Kvenvikmoen in Alta.

On Saturday 31 August 2019, in connection with the 2019 Høstsprell festival, it had been agreed that an Airbus Helicopters AS 350 B3 would land at the festival area at 15:00 and offer sightseeing flights up until 18:00. The festival participants were offered local sightseeing tours from Kvenvikmoen against payment.

The afternoon was sunny with scattered cloud cover, the temperature was 16 °C and there was almost no wind in the area.

1.1.2 PLANNING AND PREPARATION

Two persons from Helitrans AS planned the sightseeing flights from the festival area. One had the role of pilot in command and the other that of loadmaster. Both were licensed pilots and employed by the helicopter operator. The loadmaster had started out that morning on a sling-load operation for another customer. The sling-load operation was conducted with LN-OFE, another AS 350 helicopter operated by the same operator. The loadmaster had more experience of working as a pilot for the operator and he carried out the whole operation alone. While the sling-load operation was in progress, the pilot who would fly the tour on which the accident occurred had two hours and forty-five minutes in which to relax so as to be rested and ready for the sightseeing flights in the afternoon.

LN-OFU was readied by the loadmaster removing cargo equipment, and by removing the flight controls on the left-hand side[6]. The loadmaster has explained that it was the pilot in command who prepared the operational flight plan, carried out mass and balance calculations, kept the technical log, conducted the pre-flight inspection and topped up the fuel tank with 404 litres of fuel.

1.1.3 THE FLIGHT FROM ALTA TO THE FESTIVAL AREA

The first flight was the transfer (ferry flight, see Figure 2) from Alta Airport to the festival area at Kvenvikmoen. The pilot in command flew the helicopter while the loadmaster was seated in the passenger seat. LN-OFU took off from Alta Airport (ENAT) at 16:05 and landed at Kvenvikmoen seven minutes later. The loadmaster has informed the NSIA that everything worked as normal on board the helicopter during the flight to Kvenvikmoen.

1.1.4 FIRST SIGHTSEEING FLIGHT

Once the helicopter had landed in the festival area, the engine was switched off and the passenger list prepared for the first sightseeing flight. The loadmaster organised the passengers and checked whether anybody was unfit to be a passenger, before ensuring that they were all properly secured in their seats.

[6] The loadmaster had received training and company approval to perform this work. The work was not signed for in the aircraft technical logbook.

There were five passengers on the first flight, several of whom had never been in a helicopter before. One passenger was seated in the cockpit, to the left of the pilot. The other four were seated in the cabin behind.

As a response to a general question from the NSIA the passengers stated that they were not given any specific safety information before the flight. According to their statements, the pilot asked them whether they wanted to fly any particular route. He told them he would fly smoothly. Each passenger donned a headset (earphones and microphone).

The helicopter took off at 16:40. The route initially took them in the direction of Alta town, before making a wide turn to the right east of Øvre Alta and continuing towards the Skoddevarre mountains (see Figure 2, Flight 1). One passenger has told the NSIA that the pilot said he would fly closer to the ground to give them a better sense of speed.

One passenger estimated that the lowest altitude above the ground in the vicinity of what later became the crash site was just over 50 metres. The passengers stated, however, that they felt safe and did not experience any drama or discomfort. They sent both photos and video recordings to friends and family during the flight.

Returning from the first tour, the helicopter landed at Kvenvikmoen at 16:50. The passengers who were going on the second tour were not quite ready to board the helicopter, so the pilot switched off the engine.

1.1.5 THE ACCIDENT FLIGHT

When the passengers were ready, and the loadmaster had made sure that everybody was fit to join the tour, the passengers found their seats in the helicopter and donned their headsets. As on the first tour, one passenger sat in the front seat while the remaining four occupied the aft seats. The loadmaster checked that they were all properly secured in their seats.

The pilot started the engine and took off at 16:59. The loadmaster has told the NSIA that the plan was to make a slightly shorter flight than the first time around, i.e. less than 10 minutes' flight time.

GPS data from the helicopter operator's tracking system CelloTrack 3Y and data obtained from Flightradar24 show that the accident flight largely followed the same route as the first sightseeing flight. After taking off from Kvenvikmoen, the helicopter flew along the eastern side of the Kvenvika inlet towards Alta Airport, before turning right towards Elvestrand and heading south-west towards the Skoddevarre mountains and the festival area (see Figure 2).

Figure 2: Illustration showing parts of the ferry flight from Alta Airport to the festival area, the first flight (flight 1) and the accident flight (flight 2) carrying passengers, and the crash site and positions of eight witnesses. Data is not available close to the festival area due to lack of ADS-B coverage. Source: Google Maps and Flightradar24. Illustration: NSIA

Just over three minutes after take-off from the festival area, one of the passengers on the accident flight sent a Snapchat photo to a friend (see Figure 3). The photo was taken from the back row in the cabin looking in the direction of the instrument panel and front windows and shows a descent in the airspace above Hjemmeluftbukta.

It is estimated that the photo was taken some time between 17:02:05 and 17:02:15. The photo shows that, at that moment, the indicated helicopter speed was approx. 90 kt and the fuel tank was 80% full. The photo also shows a leftward roll (rotation around the longitudinal axis) of approximately 10° and a downward nose angle (pitch) of approximately 30°, between 77% and 79% on the first limit indicator (FLI)[7] and that the bleed valve[8] was open (see Figure 3).

[7] The First Limit Indicator (FLI) monitors the three key parameters which limits the thrust supplied by the engine and displays the value of the parameter which first reaches its upper limit if the engine thrust on the main rotor increases.
[8] The bleed valve bleeds surplus air from the engine's compressors so as to stabilise the air flow.

Figure 3: Descent above Hjemmeluftbukta. Photo: Passenger on board/NSIA

Information from Flightradar24 shows that the descent started at 1,525 ft[9] and lasted for 12 seconds. The ground speed increased from 70 to 110 kt, the highest sink rate was 2,432 ft/min.[10], and the helicopter levelled out at 1,250 ft after a total descent of 275 ft (see Figure 4).

[9] The aircraft altimeter was found with the QNH set to 1002 hPa, and this would give and indicated altitude indicated altitude that is 150 ft lower than the real pressure altitude. For more information see appendix B.
[10] Sink rate = negative vertical speed, while lift rate = positive vertical speed.

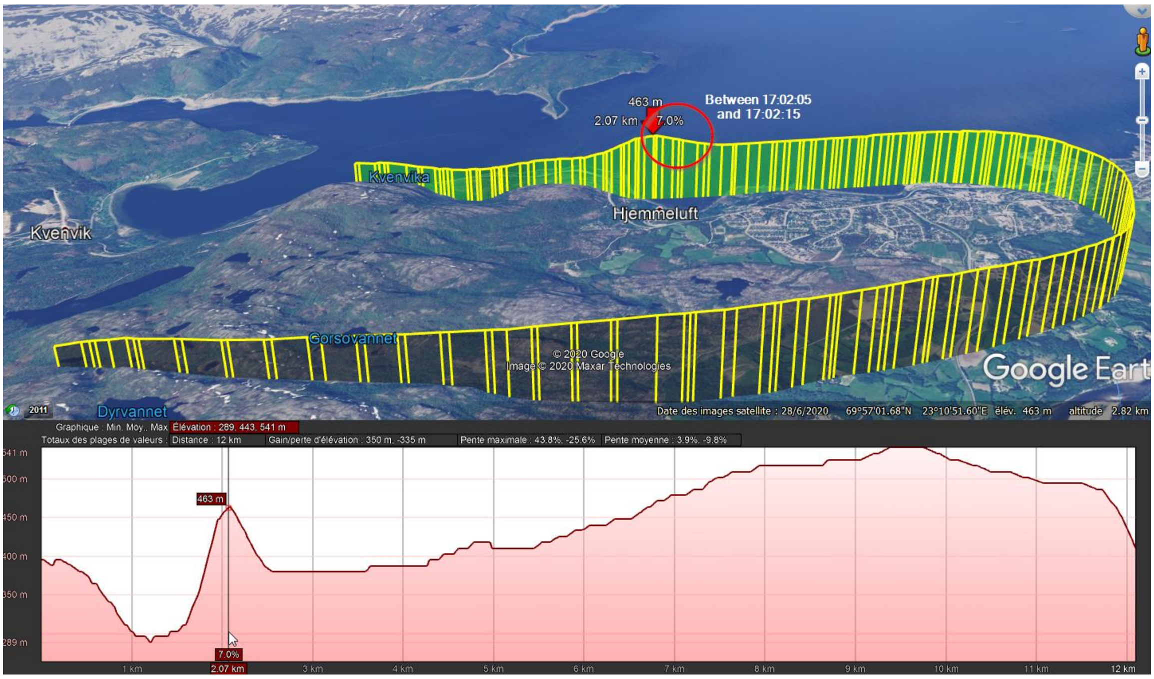

Figure 4: Vertical profile of flight path at the time when the photo above Hjemmeluftbukta was taken. The graph shows the helicopter's altitude above ground level. Illustration: Flightradar24/BEA/NSIA

On both sightseeing flights, there were limited periods with great variation in altitudes and speeds. The accident flight included two such periods while the first flight included three such periods.

The first and final periods of wider variations were conducted over the same geographical areas on both tours. The photo from the accident flight shown in Figure 3 was taken near the end of the first period. Corresponding variations were made on both flights in the vicinity of what became the accident site; see Figure 5.

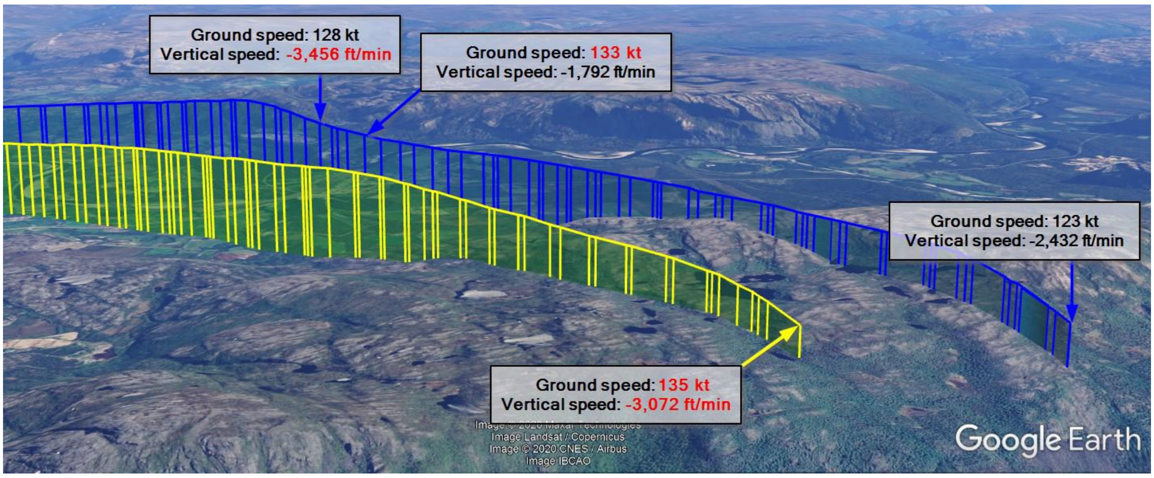

Figure 5: Comparison between the final part of the first flight and the final part of the accident flight. The first flight is indicated in blue while the accident flight is indicated in yellow. The values highlighted in red are the highest values. Source: Google Earth/BEA/NSIA

Flightradar24 shows that the helicopter's sink rate was increasing and had reached 1,728 ft/min. when the horizontal distance to the accident site was 400 m. At that time, the helicopter's altitude above ground level was 485 ft. The sink rate increased towards the end, and the last recorded sink rate was 3,072 ft/min. At the same time, the helicopter made a slight right turn from 247 to 251 degrees, and its ground speed increased from 125 to 135 kt.

The loadmaster has stated to the NSIA that a person approached him about five minutes after the helicopter had taken off. The person was worried and asked if he had heard a loud bang, which he said he had not. The person then asked the loadmaster to follow along to a place where smoke could be observed to emanate from somewhere up the hillside. The loadmaster has stated that he observed flames and thick black smoke just south of the Skoddevarre mountains in a direction north of Eidby on the hillside running down to Kvenvik. This person and the loadmaster are referred to as respectively witnesses 2 and 3 in Figure 2.

At that point in time, the loadmaster did not believe that this had anything to do with the helicopter, but he stayed in the area because he wanted to continue observing. After some minutes of not hearing any helicopter sound, he contacted Helitrans' air traffic centre, the police, the JRCC and the air traffic service at Alta Airport. The air traffic centre, which kept an overview of where the operator's helicopters were at all times, saw that the tracking of LN-OFU had stopped at 17:08.

A rescue operation was initiated immediately (see section 1.15). Shortly after LN-OFU was reported missing, the crew of a Bell 205 helicopter from Heli-Team AS discovered the wreckage engulfed in flames.

1.1.6 WITNESSES

1.1.6.1 Introduction

Several witnesses heard and observed the helicopter while it was flying, but no witnesses had seen the helicopter crash. The NSIA has also received documents and transcripts of witness interviews conducted by the police and have conducted own interview with four of these. These are witness 1, 3, 5 and 8.

These witnesses were in different locations, as shown in Figure 2. Witnesses 2 and 3 are mentioned in section 1.1.5. The witness descriptions of the other witnesses are referenced in more detail below.

There was normally a lot of helicopter traffic in the Alta area. The witnesses have stated that, for that reason, they normally did not look skywards on hearing the sound of a helicopter. Some witnesses have stated, however, that they looked skywards on this particular occasion because they heard what they perceived to be an uncommon sound from the helicopter. Others have stated that they heard abnormal variations in the helicopter's sound pattern.

Research has proved that witnesses are some of the least credible sources of information. The memory of humans is far from perfect and is heavily influenced by everyone's subjective interpretation of the situation. Witness statements are still an important source of information especially if there are other corroborating information.

1.1.6.2 Witness 1

At the time of the accident, witness 1 was jogging, along a gravel path that runs between Kvenvannet and Sennavannet lakes, approximately 1.5 km south-west of the accident site. The witness first heard the sound of a helicopter, but the sound disappeared after a while. At around 17:00, just after the witness had turned right onto the road leading to Kvenvikmoen, the sound of the helicopter returned. The witness told the NSIA that it could not see the helicopter. The witness described the sound as if the helicopter was about to land or stood still in the air with an increasing rotor speed, which according to the witness lasted for up to 5 seconds. When the witness also heard a brief metallic scratching sound followed by a bang, the witness turned around and ran a few hundred metres back along the route. The witness then saw flames and smoke emanating from the hillside in the direction of the Skoddevarre mountains.

1.1.6.3 Witness 4

Witness 4 made observations from outside their house, roughly 5 km from the accident site. The witness explained that helicopters from Alta Airport regularly flew over his house. This particular helicopter made a very different sound from what the witness usually heard. The witness also stated that the helicopter flew at a lower altitude and speed than on the first sightseeing flight, and that it sounded like a helicopter with only two rotor blades rather than an AS 350. The witness was quite familiar with the sounds made by the different helicopter types that frequented the area. The witness stressed that the unusual sound did not come from a Robinson helicopter or from the red Bell helicopter from Heli-Team AS that arrived at the accident site shortly after the accident.

1.1.6.4 Witness 5

Witness 5 was roughly 10 km accident site. He was out fishing in a boat, just east of Alta Airport. The witness worked at the airport and was familiar with the sound of Helitrans' helicopters. The witness spotted a helicopter and noted the unusual sound, which the witness described as hard and metallic. The witness was surprised by this because the witness heard the sound from this helicopter type on a daily basis and the sound pattern was normally very soft when the helicopter was in the air. Shortly afterwards, the helicopter disappeared behind Komsatoppen, but the sound persisted. The sound pattern then changed to what the witness described as variations the engine noise, before the witness heard a 'thump', as when something heavy drops to the ground.

1.1.6.5 Witness 6

Just before 17:00, witness 6 was sitting on the terrace outside Øytun folkehøyskole together with a friend. The terrace, about 4 km from the accident site, faced the Skoddevarre mountains. The witness saw a helicopter in the air, and the witness thought that it was flying at a slightly lower altitude and following a slightly different route from the one normally taken by helicopters that frequented the area. The witness saw the helicopter disappear over Garsovannet lake (see Figure 2). 30 to 60 seconds after the helicopter disappeared the witness believes he heard a brief "iiii"-sound, or a high frequency engine noise which he later connected to the helicopter. The friend he was with did not react to the sound, and it was not a topic of conversation.

1.1.6.6 Witness 7

At 17:00 on the afternoon in question, witness 7 was sitting on their terrace, 6 km from the accident site. The witness did not observe the helicopter that crashed. The witness did not usually pay attention to helicopters, as there were so many of them in the area. The witness had worked with the Bell 212 on Svalbard. While sitting on the terrace, the witness had heard an extremely powerful rotor noise, and the witness remembered thinking: 'that helicopter is carrying something that is way too heavy and had to drop the load'. The witness described the sound as a roar lasting for about three to five seconds. The witness stated that the sound probably did not come from the Bell helicopter that arrived at the accident site shortly after the accident. After a few minutes, the witness observed thick, black smoke rising from the Skoddevarre area.

1.1.6.7 Witness 8

At the time the accident occurred, witness 8 was on hole 6 at Alta golf course near the Kvenvik festival area, when the witness first became aware of the helicopter. The distance between the witness' position and the accident site was approximately 2 km, and the witness' position was approximately 300 metres lower than the accident site. The witness gave a statement to the police shortly after the accident. In the statement, the witness described having seen the helicopter about 1 minute before the accident. The witness continued to play golf, before again turning attention to the helicopter when it hit the ground.

In a new statement to the NSIA two years after the accident, the witness has provided more details about the period immediately before the helicopter crashed, and about some unusual noises from when the helicopter crashed. The witness has described seeing the left side of the helicopter at an angle from behind, and that the nose of the helicopter was pointing downwards just before it crashed. From the position of the witness, the helicopter briefly appeared to have little or no horizontal speed, and the witness believed that the helicopter did not suddenly hurtle downwards. The witness described the noises as being like when rotor blades come into contact with vegetation or trees but was uncertain about this. The witness then observed black smoke and flames rising from the accident site. After a while, the witness heard four or five bangs that sounded like small explosions. According to the statement, the witness did not see the actual sequence of events that led to the helicopter crashing.

1.2 Injuries

The deceased passengers were in the age 19–22.

Table 2: Injuries

Injuries	Crew	Passengers	Total
Dead	1	5	6
Serious			
Minor/none			

1.3 Damage to aircraft

The helicopter was completely destroyed (see section 1.12.2.1).

1.4 Other damage

There was fire damage to approximately 50 square metres of terrain surrounding the crash site.

1.5 Personnel information

The pilot was a 27-year-old male. He was issued with a Swedish commercial pilot licence CPL(H) on 15 December 2016. Table 3 shows the pilot’s hours of flight time on all helicopter types and on Airbus Helicopters AS 350 B3.

Table 3: Hours of flight time, pilot

Flight time	All helicopter types	Airbus Helicopters AS 350 B3
Last 24 hours	1	1
Last 3 days	2	2
Last 30 days	16	13
Last 90 days	42	15
Total	256	17

The pilot was first employed by Helitrans AS as a pilot on a seasonal contract on 9 May 2017, at which time he had completed proficiency checks and had experience of flying the helicopter types Robinson Helicopter Company R22, R44 and Airbus Helicopters EC 120B. For Helitrans AS, he worked as a pilot on two different seasonal contracts in 2018: a short-term contract for four days in January, followed by a longer-term contract from 13 March to 30 October.

He completed technical course and type rating on the AS 350 B3 (H125) helicopter type at Airbus Helicopters in Marignane in France, between 15 and 25 May 2018. He received instruction in the form of a theory course and flight training, and, on conclusion of the course, he passed a theoretical exam and type rating on the relevant helicopter type. In order to pass the theoretical exam, 75% of the candidate's answers must be correct, and in this case, the pilot's answers were 96% correct. He also passed the flight tests in all disciplines. The training also included a demonstration of and familiarisation with the servo-transparency phenomenon, a known manoeuvring limitation in the helicopter type. The phenomenon is discussed in more detail in section 1.6.8. A full flight simulator was not used during the training, as was not strictly required (see section 1.18.2).

The pilot was employed on a seasonal contract for Helitrans AS for the period 1 April to 30 November 2019. At the time of the accident, he held a valid company approval for commercial flight with passengers, and he had flown a total of 50 hours with passengers up until 31 August 2021. All of these were flown with the EC 120 and the AS 350.

He had passed the following proficiency checks at the operator Helitrans AS:

- An Operator Proficiency Check (OPC) on the helicopter type was conducted on 16 August 2018 with an instructor from Helitrans. Servo Transparency was a theoretical verbal topic on this OPC. After this OPC the pilot was under a limitation that he could not fly alone (LIFUS, Line Flying Under Supervision).
- An OPC on the helicopter type was conducted on 28 February 2019 with an instructor from Helitrans. Servo transparency was included as a theoretical verbal topic in the operator proficiency check.
- A proficiency check (PC) on the helicopter type was conducted on 8 April 2019, with a flight examiner from CAA-N. Servo transparency was not covered in this PC, and this was also not a requirement.
- An operator test to qualify for commercial flight with passengers was conducted on 20 April 2019 with an instructor from Helitrans, who was also the loadmaster in connection with the accident. Servo transparency was not covered in this check (See Appendix D).
- An OPC on the helicopter type was conducted on 19 August 2019 with an instructor from Helitrans. Servo transparency was included as a verbal topic in this OPC (See Appendix E).

The pilot had a valid Class 1 medical certificate without restrictions. No information has come to light to suggest that the pilot in command was medically unfit, or suffered from reduced alertness, impaired judgement or any other health problems at the time of the accident.

Helitrans has documented that the pilot had passed all necessary checks and exams up until the day of the accident and has stated that he was still in the process of gaining experience. Commercial sightseeing flights were seen as a less complex task by Helitrans, and hence suitable for accumulating hours of flight time on the helicopter type.

When interviewed by the NSIA, leading personnel at the operator have described the pilot as a meticulous, structured, calm and cautious person. They also stated that there was no indication that he performed the service in an unsafe manner. Several of his colleagues have also stated that they saw him as a cautious person and not one to seek out risk.

1.6 Aircraft information

1.6.1 GENERAL INFORMATION

The AS 350 B3 is a light, single-engine helicopter with three main rotor blades and a conventional tail rotor. The main rotor rotates clockwise seen from above. Parts of the helicopter are built from composite materials, including most of the main rotor.

The fuselage has two doors on either side: two forward doors to the cockpit and two rear doors to the cabin. LN-OFU had seats for six persons – one in each front seat in the cockpit, and four next to each other at the rear of the cabin. When the flight controls are mounted on the left side of the cockpit, the helicopter can be flown from both front seats. The minimum crew is one pilot in the front right seat.

LN-OFU was configured as shown in Figure 6. The pilot occupied the right-hand seat in the cockpit. There were no partitions separating the cabin from the cockpit or the passenger in the cockpit from the pilot.

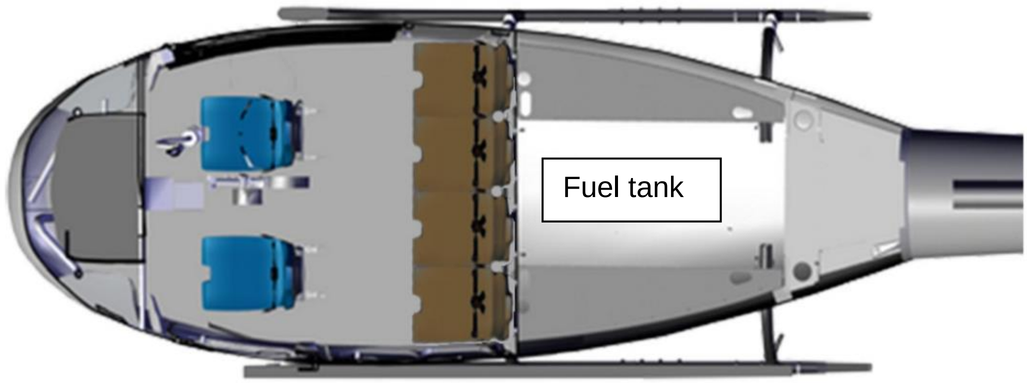

Figure 6: Position of seats and fuel tank in helicopter. Source: Airbus Helicopters/NSIA

The front seats are designed and made of composite material with two shock-absorbing seat sliders that extend when exposed to vertical forces, for example in the event of a hard landing or vertical impact with the ground. The rear seats are mounted on a joint tubular steel frame that runs under the forward edge of the seat pads.

The landing gear consists of skids connected by two cross tubes. Steps are mounted on the cross tubes. The cross tubes support the helicopter fuselage. Emergency pop-up floats were attached to LN-OFU's skids.

According to the operator, LN-OFU was equipped in accordance with Helitrans' specifications for sightseeing flights. Among other things, this entailed removal of the load basket, removal of unnecessary cargo from the cargo hold, and removal of the flight controls on the left-hand side of the cockpit.

1.6.2 DATA FOR LN-OFU

Manufacturer:	Airbus Helicopters, France
Type designation:	AS 350 B3
Serial number:	8721
Nationality and registration:	Norwegian, LN-OFU
Build year:	2019
ARC[11] date:	12 June 2019
Total flight time / landings:	Approx. 72.5 hours / 234 landings
Flight time since last inspection:	Approx. 22 min. since 100-hour inspection.
Engine:	One Safran Helicopter Engines Arriel 2D serial number 53371
Fuel:	Jet A-1
Empty mass:	1,340 kg
Maximum take-off mass:	2,250 kg
Never-exceed speed (V_{NE}):	155 KIAS[12], 3 kt reduction for every 1,000 ft above sea level

Figure 7 and Figure 8 show AS 350 B3 and dimensions.

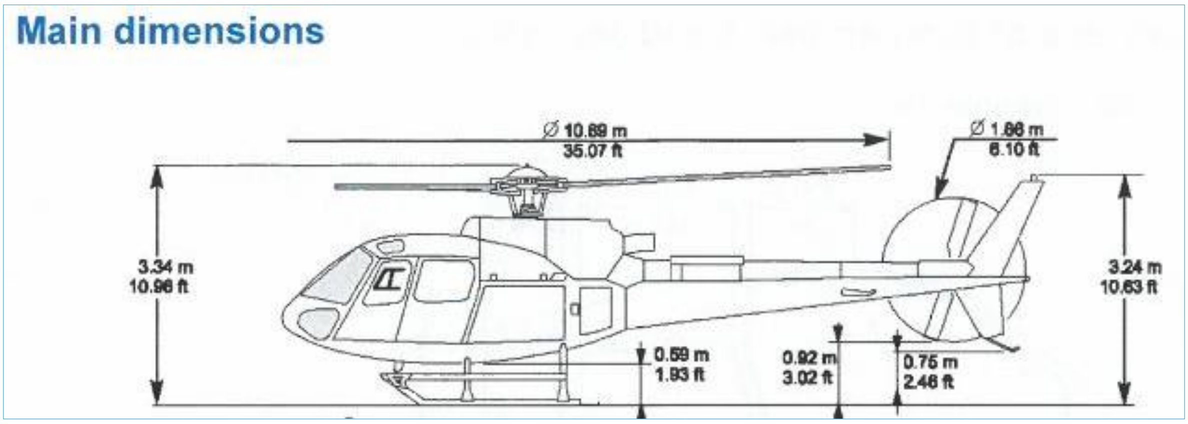

Figure 7: The main dimensions of helicopter type AS 350 B3. Drawing: Airbus Helicopters/NSIA

[11] *Airworthiness Review Certificate, issued by CAA-N.*
[12] *Knots-indicated airspeed, i.e., the speed indicated on the aircraft's instruments.*

Figure 8: Airbus Helicopters AS 350 B3, LN-OFU. Photo: Helitrans AS

1.6.3 ENGINE

The helicopter engine was an Arriel 2D, manufactured by Safran Helicopter Engines (SHE). Arriel 2D is a gas turbine engine made up of the following five main modules (see Figure 9):

- Module M01, hollow transmission shaft from a reduction gearbox with a freewheel clutch (sprag clutch).
- Module M02, low-pressure axial compressor.
- Module M03, high-pressure gas generator turbine with compressor and combustion chamber.
- Module M04, power turbine (PT).
- Module M05, reduction gearbox.

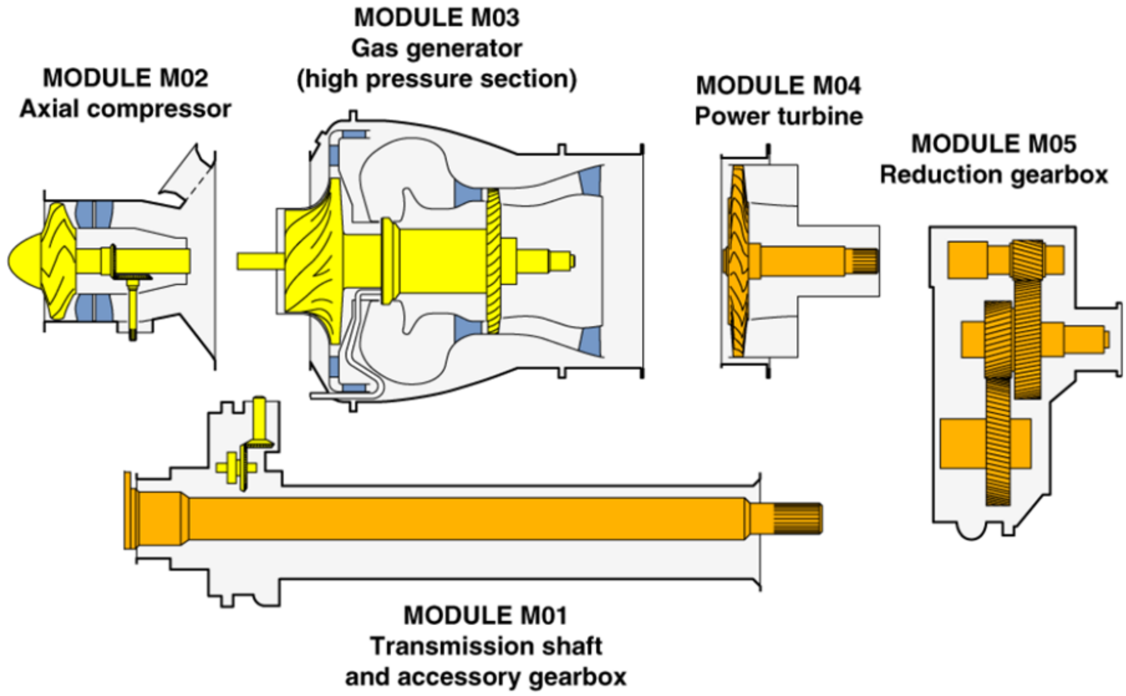

Figure 9: The five main modules of SHE's Arriel 2D engine. Illustration: Safran Helicopter Engines/NSIA

The engine consists of a gas generator and a power turbine. The gas generator has a high-pressure turbine that powers a compressor. The gas generator supplies the gas for the power turbine. The power turbine is a free turbine that operates both the main rotor and tail rotor via the reduction gearbox and transmission shaft. The input drive for the reduction gearbox is connected to the gear shaft by a threaded connection. When installed, the drive nut and gear shaft are marked to ensure alignment (see Figure 67). The direction of the torque is tightening. Overloading of the shaft connection can cause displacement of the alignment marks. The reduction gearbox rotates the transmission shaft at 6,000 rpm at 100% rotor rpm.

A digital engine control unit (DECU) provides full authority digital engine control (FADEC), which includes monitoring and control of gas generator rpm and power turbine rpm. The DECU controls the engine so as to keep the rotational speed of the main rotor constant at near 100% during flight, corresponding to 386 revolutions per minute.

Information about rotational speed is provided by three sensors referred to as the N2A, N2B, and N2C sensors (see Figure 64). The N2A signal is sent directly to the cockpit while N2B and N2C are used by the DECU. The DECU also uses the torque sensor to monitor the power turbine for overspeed, which is an uncontrolled increase in power turbine rpm.

The DECU has redundancy in that it has two identical channels that monitor each other. Built-in automation is intended to ensure transfer of control to an operative channel at all times. The DECU controls the fuel supply by means of a hydro-mechanical unit (HMU). The schematic drawing in Figure 10 provides an overview of the most important components of the engine's fuel system. In this figure the DECU is called FADEC.

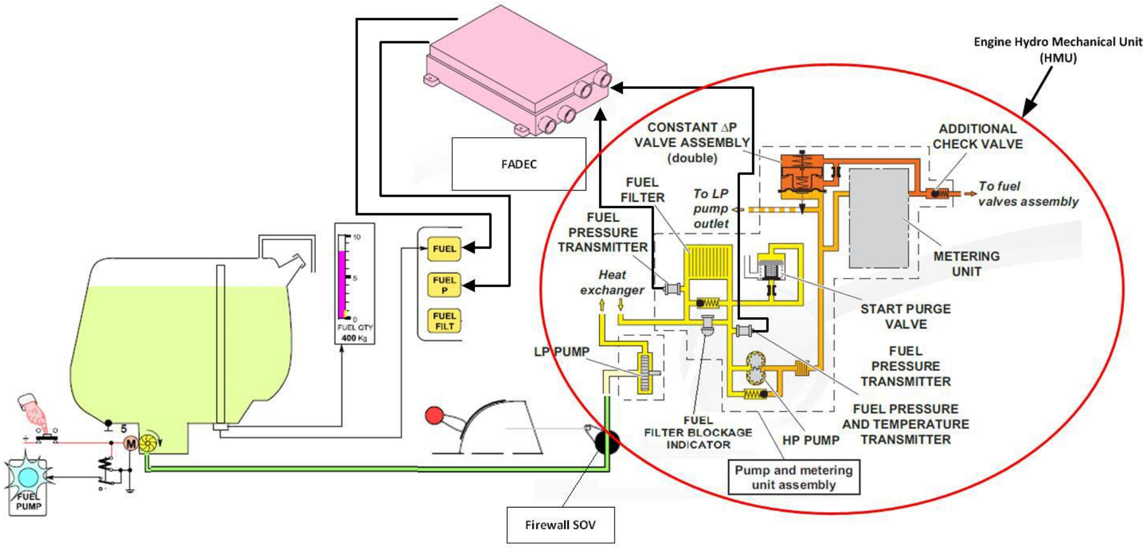

Figure 10: Simplified overview of the most important components of the helicopter's fuel system. Illustration: Airbus Helicopters/Safran Helicopter Engines/NSIA

In the event the DECU should not be able to control the fuel flow, the rotational speed of the rotors will automatically be maintained by an engine backup control auxiliary unit (EBCAU).

The engine in LN-OFU was almost new, tested and approved on 16 January 2019 at Safran Helicopter Engines in Bordes in France. The engine logbook showed that the acceptance criteria for all performance parameters were met at delivery.

1.6.4 THE ENGINE'S ROTATIONAL SPEED LIMITATIONS

N1 denotes the rotational speed of the engine's gas generator, while N2 denotes the speed of the power turbine (PT). An overview of the most important speed thresholds (safety barriers) for N2 is provided in Figure 11.

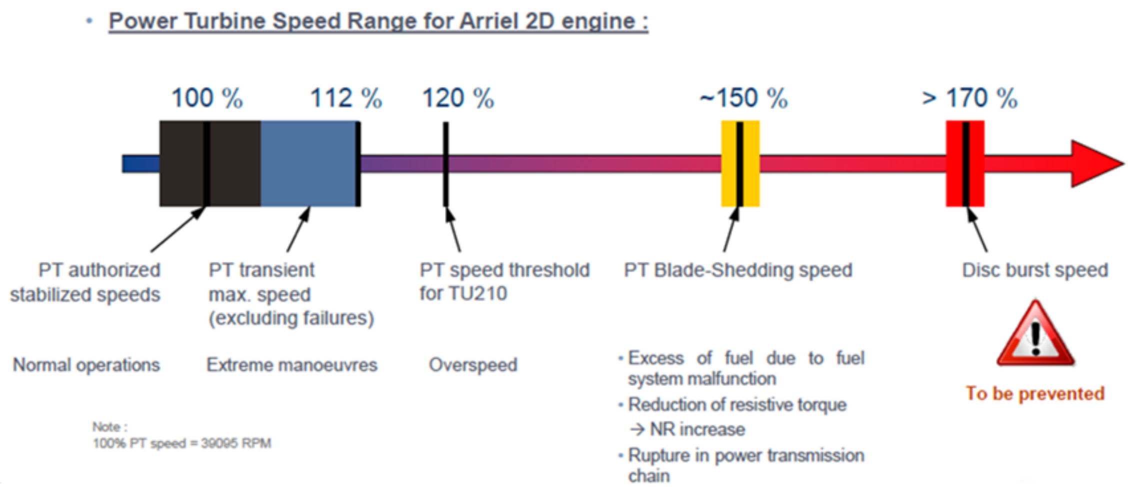

Figure 11: Rotational speed thresholds for N2 in SHE's Arriel 2D engines. Illustration: Safran Helicopter Engines/NSIA

The DECU will control the gas generator to keep N2 near 100% and limit N2 to a maximum of 112%. In the event of an uncontrolled increase in N2 (overspeed), the turbine rotor disk can theoretically burst, possibly resulting in extensive mechanical damage. The phenomenon is referred to as power turbine disc burst and will according to Safran occur from an N2 of around 170%.

When the engine is supplying power, an uncontrolled increase in rotational speed can occur if the engine is supplied with too much fuel because of a fault in the control system. It can also occur in the event of loss of engine resistance as a result of a rupture in the mechanical connection to the rotor system. Examples include a rupture in the reduction gearbox (Module M05), transmission shaft (Module M01) or the shaft between the power turbine and reduction gearbox or rupture or separation of the power transmission shaft between the engine and the helicopter's main gearbox.

In order to prevent a theoretical power turbine disc burst, the turbine blades are designed with a notch at the root of the blades (see Figure 12). This will cause the blades to be shed when N2 exceeds approximately 150%, which is referred to as the blade shedding speed.

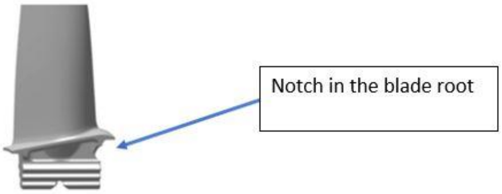

Figure 12: The arrow shows the notch at the root of the turbine blades, which is constructed to break if the rotational speed exceeds 150%. Illustration: Safran Helicopter Engines/NSIA

Blade shedding is a built-in barrier against power turbine disc burst, but also a source of overheating and potential fire. Airbus Helicopters and Safran have therefore developed a modification (TU210). The main component of this modification is an electrically operated stop valve (Stop Electro Valve – SEV) that cuts off the fuel supply when the rotational speed of the power turbine reaches 120%. The SEV is controlled by the DECU based on rpm signals from the N2B and N2C sensors, and torque signals from the torque sensor in the transmission shaft (Module M05). All three sensors must register an rpm of 120% or higher at the same time before the SEV cuts off the fuel supply and thereby stops the engine. Figure 13 shows the details of the TU210 modification.

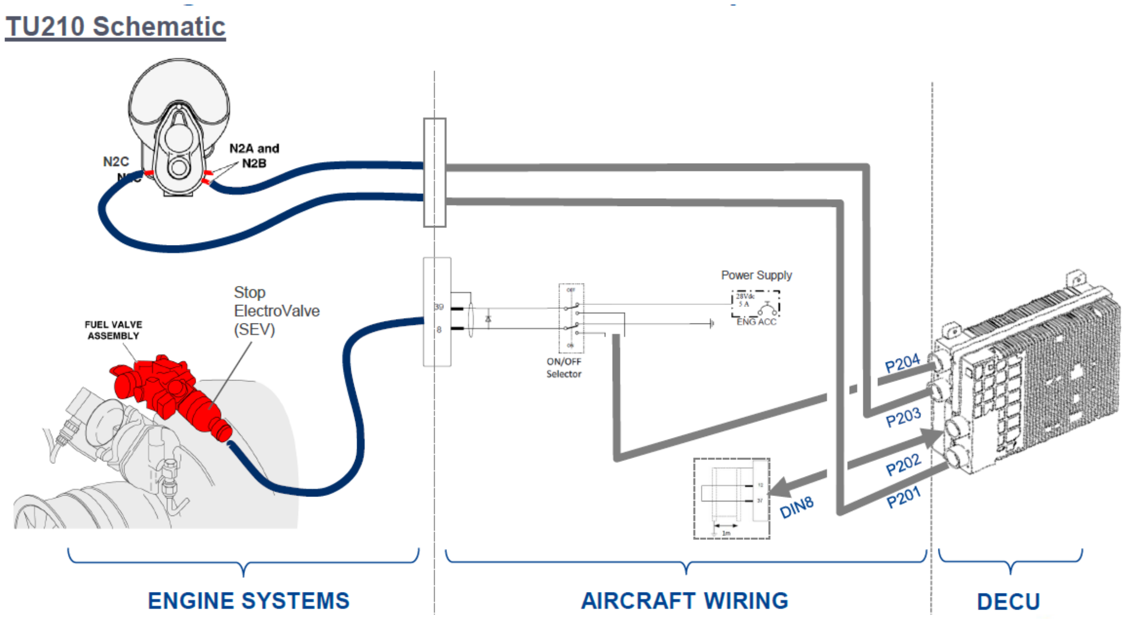

Figure 13: Schematic drawing showing the position of the N2 sensors in the engine system, as well as the fuel valve, the SEV and digital engine control unit (DECU). Illustration: Safran Helicopter Engines/NSIA

1.6.5 DRIVE TRAIN FROM TRANSMISSION SHAFT TO ROTOR SYSTEM

The drive shaft for the rotor system runs through the hollow transmission shaft in Module M01. A one-way freewheel clutch is mounted between them, allowing the transmission shaft to transmit torque to the rotor system, but not vice versa. The purpose of the clutch is to disconnect the power turbine, reduction gearbox and transmission shaft from the rest of the drive train should the engine be desynchronized (see Figure 66). It enables the pilot to establish autorotation or controlled descent without resistance from the engine.

The drive train from the transmission shaft to the main gearbox (MGB) is illustrated in Figure 14 and Figure 15.

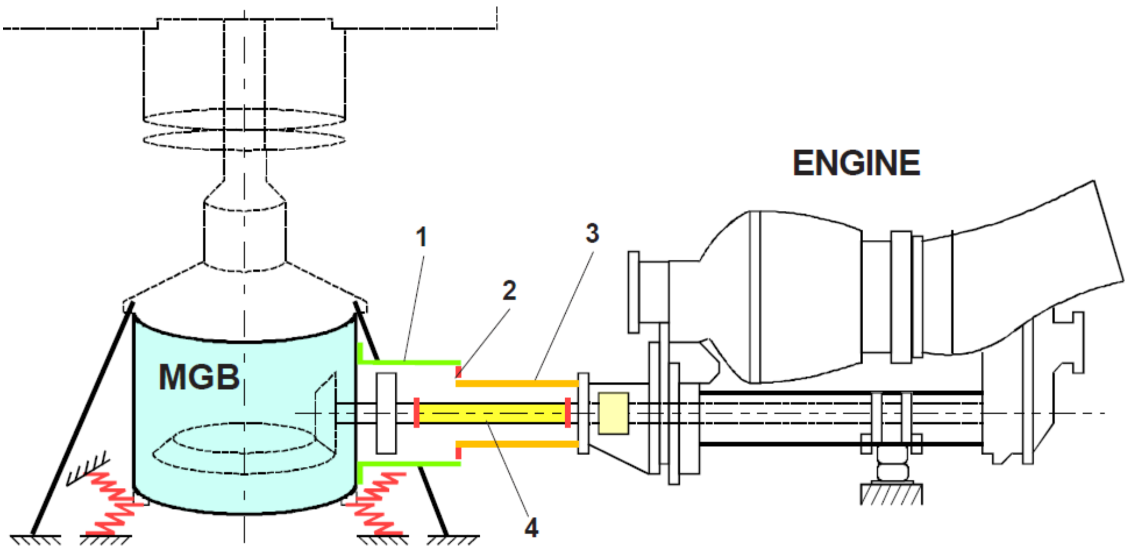

Figure 14: Connection between engine and main gearbox. Illustration: Airbus Helicopters/NSIA

The connection consists of the following components:

- A connecting casing (1) attached to the main gearbox and a coupling tube (3) attached to the engine.
- A gimbal ring (2) connecting the pipe to the flange connection.
- A drive shaft (4) transmitting engine power to the main gearbox via the input drive gear.
- The drive shaft (4) has flex couplings at both ends, marked in red.
- The main gearbox is attached to the fuselage with suspension bars and shock absorbers to absorb low-frequency oscillation during flight.

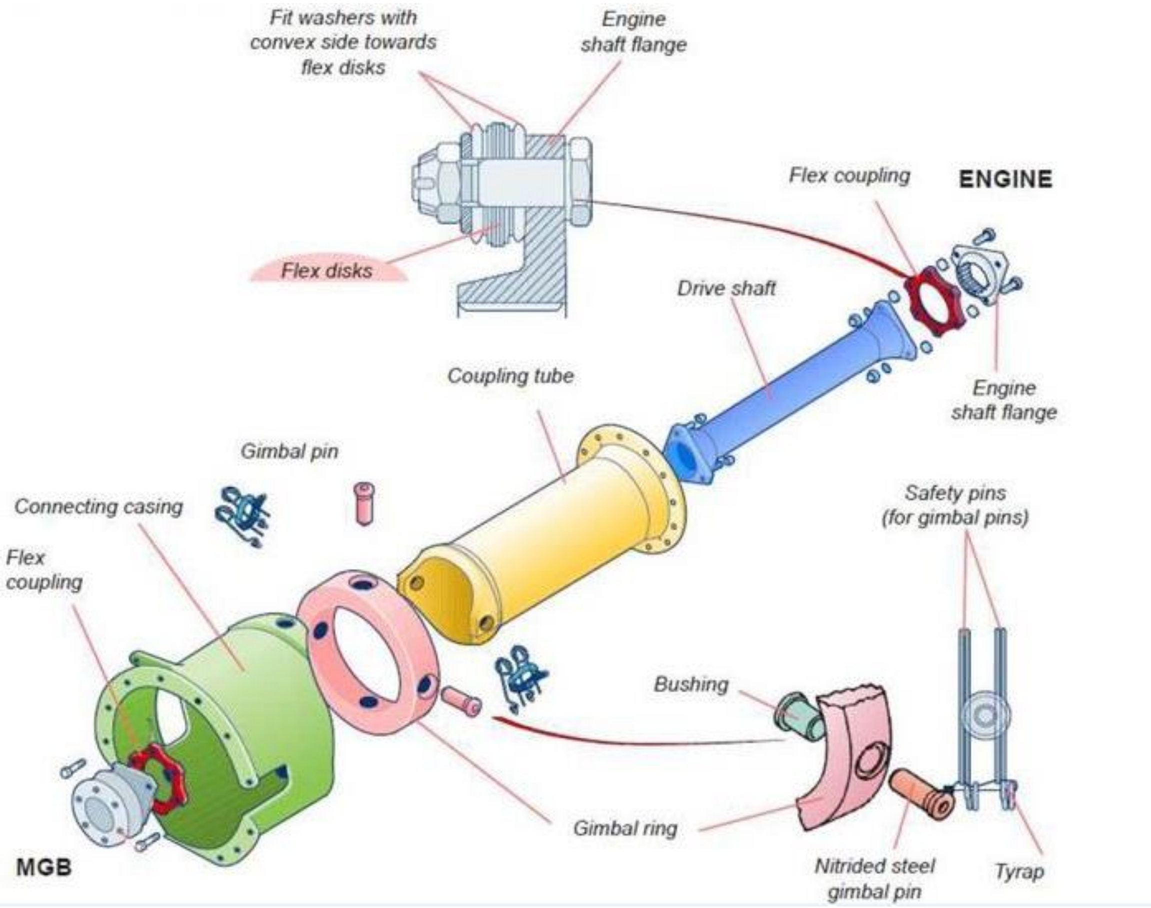

Figure 15: On the drawing, the drive shaft for the main gearbox is marked in blue and the flexible couplings at either end are marked in red. Illustration: Airbus Helicopters/NSIA

1.6.6 MAIN ROTOR SYSTEM

Airbus Helicopters has given the name Starflex to one of its main rotor heads. The rotor head consists mainly of composite material. Each rotor blade is mechanically attached to two sleeves. Between the sleeves, a Starflex arm is inserted between a thrust bearing and into the end of a frequency adaptor. The three arms form a unit and are referred to as the Starflex hub. The arms will typically fracture at 45°, as marked in Figure 16, if a rotor blade is exposed to a sudden braking force as when it hits the ground, a tree or other fixed object while rotating.

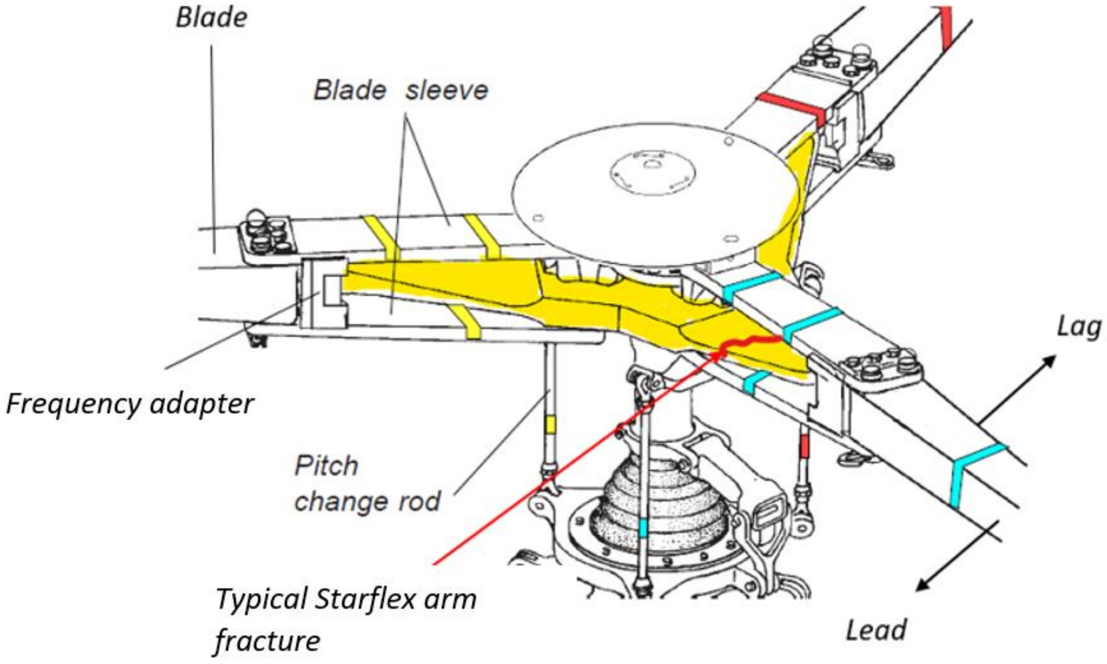

Figure 16: The Starflex hub with Starflex arms are marked in yellow. The arms will typically fracture as indicated in red. The fracture can also go in the opposite direction. Illustration: Airbus Helicopters/NSIA

1.6.7 FLIGHT CONTROLS AND RELATED HYDRAULIC SYSTEM

The cyclic control changes the direction of travel by changing the angle of attack (pitch) of the main rotor blades cyclically during rotation (cyclic pitch control), while the collective control increases or decreases the pitch throughout the rotational plane (collective pitch control). Stability and rotation around the vertical axis is controlled via the tail rotor.

The helicopter type is equipped with conventional flight controls, which means that the cyclic and collective pitch controls are connected to the main rotor by rods and a swashplate assembly. The pedals in the cockpit are connected to the tail rotor blades via a flexible ball-type sliding control and rods.

The swashplate assembly on the rotor mast transmits the flight control movements to the main rotor blades; see Figure 17. It has a non-rotating swashplate that is connected to the flight controls and a swashplate that rotates together with the main rotor and is connected to each rotor blade by a rod. The flight controls change the swashplate angle and height, and, in turn, the rods change the pitch of the main rotor blades.

When a helicopter flies in a horizontal direction, the resultant speed of the main rotor blades varies through the rotation depending on whether they are moving forwards or backwards in relation to the flight speed. It is necessary to compensate for changes in speed by changing the pitch. The main rotor of the AS 350 rotates clockwise (seen from above). In order to maintain equal lift on both sides when the helicopter is flying in a forward direction, the blades must have a greater pitch when moving towards the rear on the right-hand side than when moving towards the front on the left-hand side.

When the pitch of a rotor blade is changed in order to change the lift it provides, the control system must overcome the aerodynamic forces acting on the blades. The helicopter is equipped with hydraulic servo actuators to facilitate moving the flight controls and prevent transfer of aerodynamic forces to the flight controls. There are three servos for the main rotor and one servo for the tail rotor.

The three servos that control the pitch of the main rotor blades are located between the main gearbox and the swashplate assembly. The servos receive signals from the flight controls via the rods and transfer the movement to the rotor blades. This means that the pilot does not have to apply much force to adjust the pitch, and it is normally very easy to move the cyclic stick and collective lever on the AS 350.

A hydraulic pump supplies system pressure of 624 psi (43 bar) to the servos. Each servo has an accumulator that can maintain the pressure for a short period seconds in the event of loss of pressure from the pump. According to the design specifications, this is sufficient to be able to land from a hover, or to establish the recommended speed for further flight.

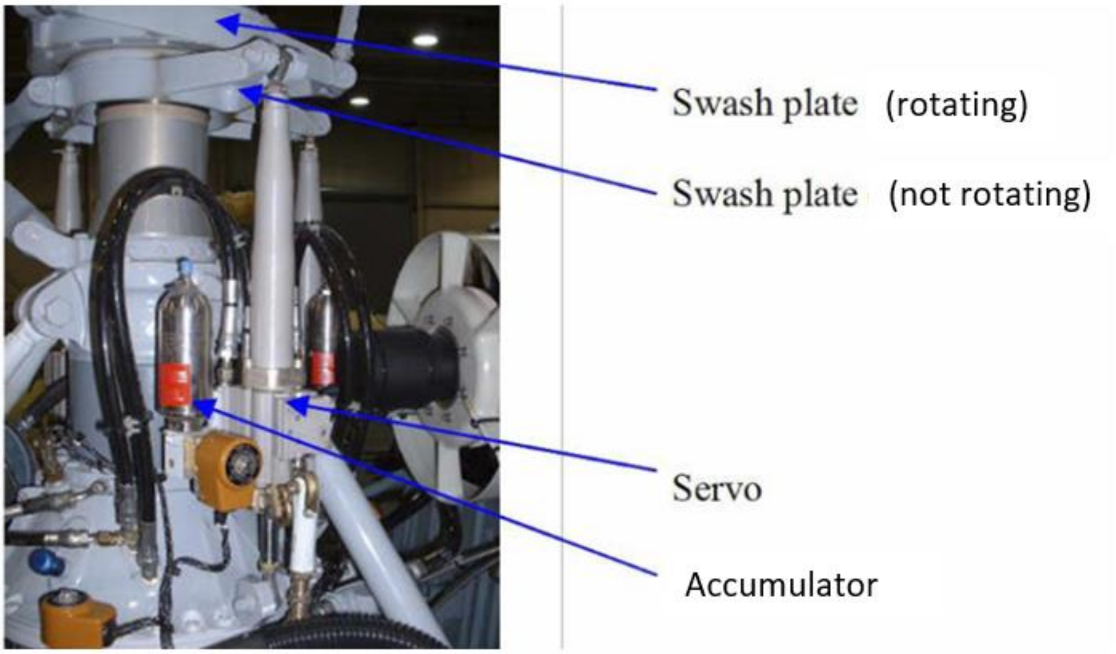

Figure 17: Rotor mast with hydraulic servos, accumulator and swashplate assembly. Photo: NSIA

When the hydraulic pressure drops, the flight controls become heavier to operate. If the system pressure drops below 30 bar, a red HYD light is illuminated on the master caution panel, and a warning sound is activated in the cockpit. Learning to fly with loss of hydraulic pressure is a mandatory part of the training for AS 350 pilots.

1.6.8 SERVO TRANSPARENCY

1.6.8.1 About the servo transparency phenomenon

To prevent overloading of the main rotor system, the maximum force that the servo actuators can produce is set to 193 daN[13]. Any additional force that is required must be transferred manually by the pilot by means of the flight controls. This puts an excessively high load on the hydraulic system, a form of overloading referred to as servo transparency or jack stall.

[13] 1 daN equals the weight of a mass of 1 kg.

The total load on the main rotor, and hence the probability of servo transparency, increases under the following conditions:

- High speed
- High collective pitch
- High mass
- High G load
- Increasing density altitude, i.e.:
    - Increasing flight altitude
    - Increasing temperature
    - Increasing humidity.

Combinations of these factors above can give rise to servo transparency even if the limit value for any one factor has not been exceeded. The helicopter type has no indicator to warn the pilot that the helicopter is about to enter servo transparency. There is no single limit that the pilot could observe to be sure to avoid the phenomenon.

The load on the rotor disk and on the hydraulic servo actuators increases when the helicopter is being manoeuvred. One factor that reduces the probability of servo transparency is to reduce the collective pitch before the total load on the rotor disk is exceeded.

The flight manual does not contain any diagram referring to what limitations apply for servo transparency under the prevailing conditions. Servo transparency is a result of interaction between the above-mentioned factors. Only when servo transparency occurs does it become clear that the factors have combined to exceed the limitations. This is illustrated in Figure 18.

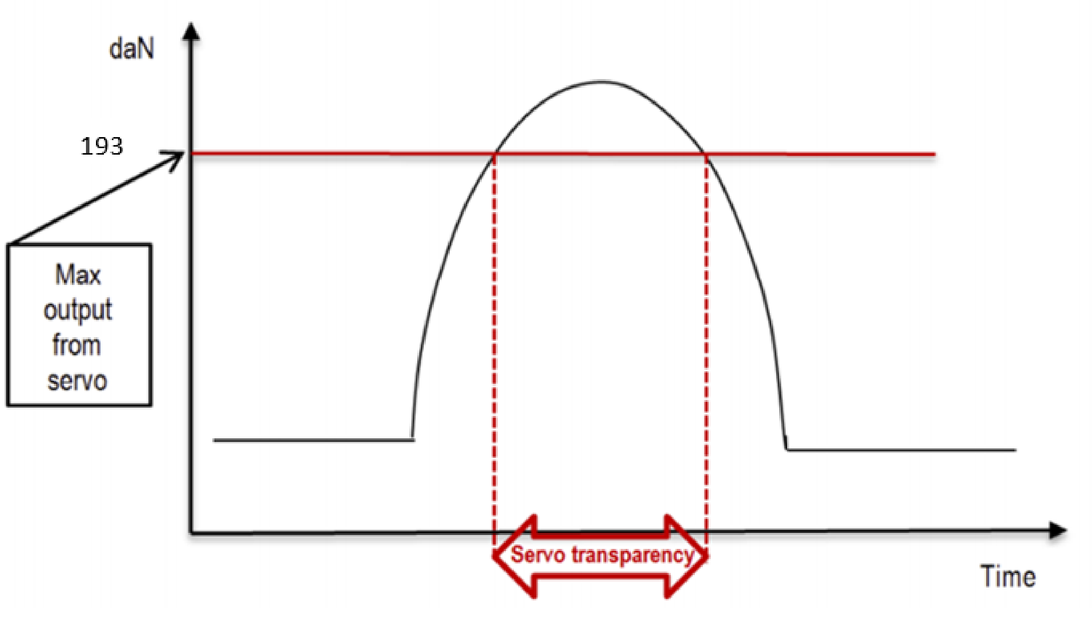

Figure 18: Illustration of servo transparency. The output needed exceeds the capacity of the servo actuators for the period between the red dashed lines. Illustration: NSIA

The aerodynamic forces required to achieve the correct pitch on the main rotor blades under the prevailing conditions may amount to, for example, 203 daN. In such cases, the pilot will have to overcome the exceeding forces manually. The pilot will experience an increase of 10 daN in stick output. This may startle the pilot and the flight controls can appear to be moving of their own accord or to be locked in position.

Servo transparency produces a right and aft cyclic load and a collective down displacement. Unless corrections are made by the pilot immediately, the helicopter's altitude and heading will change.

Figure 19 provides a description of how servo transparency can be avoided and how to act should the phenomenon occur. The description is taken from Airbus Helicopters' EASA Approved Flight Manual AS 350 B3, Flight Envelope Limitations, section 2.3 (dated December 2019).

6 MANEUVERING LIMITATIONS

- Continued operation in servo transparency (where load feedback is felt in the controls) is prohibited.

  Maximum load factor is a combination of TAS, Hσ and gross weight. Avoid such combinations at high values associated with high collective.

  Transparency may be reached during maneuvers, steep turns, hard pull-up or when maneuvering near VNE. Self-correcting, the phenomenon will induce an un-commanded right cyclic load and an associated collective down reaction. However, even if the transparency feedback loads are fully controllable, immediate action is required to relieve the feed back loads: reduce the severity of the maneuver, follow the aircraft's natural reaction, let the collective decrease naturally (avoid low pitch) and smoothly counteract the right cyclic motion.

  Transparency will disappear as soon as excessive loads are relieved.

- In maximum power configuration, decrease collective slightly before initiating a turn, as for this maneuver the power requirement is increased.
- In hover, avoid rotation faster than 6 sec. per full rotation.

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Figure 19: Excerpt of the AS 350 B3 Flight Manual 'Manoeuvring Limitations' relating to servo transparency, which also applied at the time of the accident. Source: Airbus Helicopters

In addition to the content in the flight manual, Airbus Helicopters released several publications to customers about servo transparency such as LS 1648-29-03 in 2003, SIN 3287-S-67 in 2018 and SIN 3093-S-001648 about flying close to VNE referring to LS 1648-29-03 in 2016.

1.6.8.2 Accidents/incidents involving AS 350 helicopters and servo transparency

Servo transparency is suspected to be a contributing factor in several accidents involving the AS 350. Most of these accidents have involved the loss of life.

Table 4: Some accidents/incidents involving Airbus Helicopters AS 350 in which servo transparency was suspected as a contributing factor.

Report no, investigation authority	Date and place of incident	Registration and brief description
Report 94-022, Transport Accident Investigation Commission of New Zealand	11 October 1994, Needle Rock, 10 nautical miles north-east of Whitianga, New Zealand	ZK-HZP: the pilot was entering a right-hand turn intending to fly around an island with a special rock formation. The altitude was too low for the pilot to regain control, and the helicopter impacted the water.

Report no, investigation authority	Date and place of incident	Registration and brief description
Report SL 2001/42, Accident Investigation Board Norway	15 January 2001, at Hunderfossen in Oppland County	LN-OAK: when transitioning from a horizontal flight to a right-hand turn, the pilot felt that the controls ‘froze’, which caused the helicopter to make 1.5–2 sinking (spiral) turns before the pilot was able to re-establish control of the helicopter. This report was published in Norwegian only.
Report NTSB/AAB-04/02 (pp. 33–35), National Transportation Safety Board, USA	10 August 2001, east of Meadview in Arizona, USA	N169PA: the pilot’s manoeuvring in combination with high density altitude caused high sink rate. The altitude above the terrain was too low for the pilot to regain control.
Report FTW02FA017, National Transportation Safety Board, USA	19 October 2001, near Roswell in New Mexico, USA	N111DT: the pilot initiated a right-hand turn at a vertical sink rate of approximately 200 ft and a speed of between 115 and 120 kt. The pilot realised that the turn was too steep but found that the cyclic stick was stuck. The pilot was unable to pitch up the helicopter even when using two hands.
Report A07W0138, Transportation Safety Board of Canada	23 July 2007, approx. 35 nautical miles north-east of Fort McMurray in Alberta, Canada	C-FHLF: the pilot initiated a rapid descent from 1,500 ft to just above the treetops, and lost control while attempting to level off. The helicopter rolled right, nosed down, struck the terrain and rolled over onto its left side.
Report EW/2007/09/06, Air Accidents Investigation Branch, UK	15 September 2007, Lanark, Scotland	G-CBHL: the pilot was manoeuvring at high speed and low altitude, and most probably initiated a turn. Findings were made indicating that the pilot may have been in the process of regaining control, but not sufficiently to avoid the crash.
Report SL 2012/13, Accident Investigation Board Norway	4 July 2011, Dalamot in Ullensvang, Hordaland County	LN-OXC: this accident is discussed in more detail in section 1.6.8.3.
Report 2265, Swiss Transportation Safety Investigation Board	1 July 2013, near the Kröntenhütte mountain hostel in Erstfeld, Switzerland	HB-ZMO: the pilot initiated a descent, following the terrain. The helicopter flew at high speed and low altitude while turning increasingly to the right. According to witnesses, the helicopter then nosed up and banked hard to the right before it crashed.
Report WPR16FA040, National Transportation Safety Board, USA	15 December 2015, near Superior in Arizona, USA	N74317: after passing over a ridge with about 30 ft clearance to the terrain, the pilot started to descend in a slight right-hand turn, while the ground speed increased to 148 kt. He increased the right-hand turn to pass through a saddle in the terrain. The helicopter nosed up and banked hard to the right, and the pilot was unable to regain control.
Report A16P0045, Transportation Safety Board of Canada	16 March 2016, approx. 82 nautical miles north-west of Smithers in British Columbia, Canada	C-FBLW: the pilot initiated a descent into a ravine and the helicopter’s speed increased rapidly. Moments later, the helicopter abruptly rolled to the right, pitched up, and collided with terrain on a steep snow-covered slope.
Report RA-07275, Interstate Aviation Committee, Russia	1 November 2016, Adler in Sochi, Russia	RA-07275: the helicopter was on a commercial sightseeing tour when it crashed right next to a house.

1.6.8.3 The accident with LN-OXC at Dalamot in Norway in 2011

The accident with LN-OXC at Dalamot in the Ullensvang[14] mountains occurred on the second flight, after having completed a first flight with five passengers. As the helicopter started the descent towards a cabin site in the mountains, the five passengers of the first flight witnessed the helicopter turning tightly to the right, before control appeared to be lost as the helicopter came down at a great sink rate and an estimated angle of bank of 60–90 degrees.

There were indications that the pilot was about to regain control, but that the helicopter had insufficient altitude for this to be possible. It appeared as if the helicopter was on the way of returning to wings-level flight, but it hit the ground at relatively high speed and immediately caught fire. All five persons on board died in the accident and the helicopter was destroyed.

The investigation team did not find any technical defects or irregularities that could have influenced the course of events. The extensive fire damage made parts of the helicopter unavailable for examination, but it was possible to establish that the engine was delivering power to the rotors when the accident happened. It was also possible to verify that key parts of the flight controls were intact up until the time of the crash.

According to the report, the investigation team found that the accident was most probably the result of an abrupt manoeuvring sequence giving rise to servo transparency. Control of the helicopter was lost, and the altitude was insufficient for the pilot to pitch up and level out in time.

Reference is made to safety recommendation SL 2012/09T submitted with the investigation report:

> *If servo transparency is encountered in a right turn, the associated uncommanded right roll and possible pitch-up have the potential to cause a significant deviation from the intended flight path, which, if encountered in close proximity to terrain or obstacles, could be hazardous.*
>
> *The Accident Investigation Board Norway (AIBN) recommends that EASA requires the type certificate holder Eurocopter to issue a warning of the particular hazard when encountering servo transparency in a right turn, preferably as a permanent note in the Flight Manual of the helicopter models in question.*

A similar recommendation was submitted by the Air Accidents Investigation Branch (AAIB) in the UK after the accident involving G-CBHL in Scotland in 2007[15]. In connection with the accident involving C-FBLW in 2016[16], the Transportation Safety Board of Canada wrote that Airbus Helicopters disagreed with these recommendations. Airbus Helicopters argued that the flight manual's description of the servo transparency phenomenon was already sufficiently explicit. Hence Airbus Helicopters did not take any steps to comply with the safety recommendations. The recipient of the safety recommendations, EASA, has not ordered Airbus Helicopters to clarify the matter in its flight manual.

After the accident with RA-07275 in Russia in 2016 however, Airbus Helicopters started the process to change the flight manual to accommodate the safety recommendations. The change was approved by EASA in December 2021, just over 2 years after the accident with LN-OFU.

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[14] https://www.nsia.no/Aviation/Published-reports/2012-13-eng
[15] AAIB (2009): Eurocopter AS350B2 Squirrel, G-CBHL, 15 September 2007
[16] TSB (2018): Aviation Investigation Report A16P0045

1.6.9 MASS AND BALANCE

The helicopter's maximum authorised mass was 2,250 kg. It had a maximum fuel capacity of 540 litres, corresponding to 432 kg. The fuel level is stated on the Vehicle and Engine Multifunction Display (VEMD) as a 0–10 graduation and as quantity in kg.

The NSIA has received the pilot's mass and balance calculations from the helicopter operator. The calculations cover the period from the first sightseeing flight on the festival. The pilot used standard mass values for the pilot and the passengers, see Table 5.

According to the pilot's calculations, the helicopter had a total mass of 2,241 kg when taking off for the first sightseeing flight. The helicopter operator has estimated the fuel consumption for the first sightseeing flight, including two start-ups to be approx. 28 kg.

After the accident the helicopter operator have stated that the helicopter was loaded with 90% fuel at the take-off from Alta Airport, which is 389 kg. At the time of the accident they estimated the helicopter to have 80% fuel left, which is 345 kg. This corresponds with Airbus Helicopters' analysis of the instruments in the Snapchat photo taken by one of the passengers approximately three minutes before the accident occurred (see section 1.1.5).

The NSIA has received the actual weight of the six persons who were on board when the accident occurred. The NSIA has also used a fuel quantity of 80% when calculating the helicopter's mass and balance at the time of the accident; see Table 5. The calculations indicate that the actual total mass at the time of the accident was close to the maximum mass of the helicopter type, which was 2,250 kg.

The NSIA has received documentation from Helitrans that show that the helicopter was within balance limits during all flights.

Table 5: The pilot's mass calculations based on standard values, and the NSIA's mass calculations for the accident based on the received mass of all persons on board and estimated fuel volumes. The NSIA has used a value of 0.8 kg per litre fuel.

	The pilot's mass calculations at the start of the first sightseeing flight based on standard mass values	The pilot's mass calculations extrapolated to the accident	NSIA's mass calculations at the start of the first sightseeing flight based on standard mass values	NSIA's mass calculations at the start of the first sightseeing flight based on real mass values	NSIA's mass calculations for the accident based on real mass values
Equipped Empty Weight	1 340 kg	1 340 kg	1 340 kg	1 340 kg	1 340 kg
Emergency Pop-Out Floats	64 kg	64 kg	64 kg	64 kg	64 kg
Pilot	85 kg	85 kg	85 kg	88 kg	88 kg
Five passengers	450 kg (based on standard mass of 90 kg)	450 kg (based on standard mass of 90 kg)	450 kg (based on standard mass of 90 kg)	393 kg (based on real mass)	393 kg (based on real mass)
Fuel	302 kg	268 kg (302 kg - 34 kg)	379 kg (389 kg - 10 kg / 90% - ferryflight)	379 kg (389 kg - 10 kg / 90% - ferryflight)	346 kg (80%)
Total mass	2 241 kg	2 207 kg	2 312 kg	2 264 kg	2 231 kg

1.6.10 MAINTENANCE

LN-OFU was almost new when it crashed. The only modification carried out after it was delivered to Helitrans AS was the installation of a Donaldson filter in the air inlet for the engine approved per EASA STC[17] 10017072. It was installed on 28 June 2019 after 19 hours and 45 minutes of total flight time. On 3 July 2019, after 20 hours of total flight time, the engine oil type was switched to Mobil 254.

The inspection interval for the Donaldson filter in the air inlet is 100 hours. In accordance with the helicopter operator's maintenance system, a 100-hour inspection was therefore carried out at the operator's base in Alta on the day of the accident. The helicopter's total flight time was then 72 hours and 11 minutes. Helitrans has informed the NSIA that the inspection was carried out after only 72 hours' flight time for practical reasons to do with order volume, activity level and available resources. According to Airbus Helicopters' maintenance programme for the helicopter type, the helicopter was due for its first inspection ('150-hour inspection') after 150 hours.

The 100-hour inspection was a visual inspection which was signed for as completed at 13:30, only a few hours before the fatal flight (Work Order: WO OFU-15). The aircraft technician who conducted the inspection has demonstrated and described in detail how this was done. It included an inspection of the engine's air intake filters and of the condition of the drive shaft between the engine and main gearbox, including the flexible connections with bolts, nuts and lock pins.

The only fault that was found during the inspection was a small oil leakage in the gasket around the input shaft to the main gearbox. The aircraft technician stated that it was a minor leakage, that the oil was wiped up and that this was a relatively normal occurrence. The inspection was completed without annotations in the helicopter's maintenance documentation.

The helicopter had no further maintenance history.

1.6.11 CRASH RESISTANT FUEL SYSTEM FOR LN-OFU AND AS 350 B3 IN GENERAL

1.6.11.1 Introduction

When LN-OFU was ordered and at the time of the accident, there were two different crash resistant fuel system options available for the AS 350 B3. One system, called CRFS, was produced by Airbus Helicopters and the other, called CRFT, was produced by a subcontractor (Standard Aero). Both were approved for installation and had a valid STC and certified in accordance with CS 27.952. Only CRFT was certified for use with underbelly equipment installed.

Neither CRFS or CRFT was ordered or delivered with LN-OFU. Nor were these installed in any other AS 350 helicopters in Norway at that time. The systems were available for both production line installation and retrofitting. LN-OFU was to be delivered with cargo swing. For this configuration, only CRFT was certified in accordance with CS 27.952. During the contract process for LN-OFU Airbus Helicopters specified and priced a crash resistant fuel system. The chosen solution by the buyer, with a conventional fuel tank was highlighted as a note in the purchasing contract.

1.6.11.2 Development, certification, and requirements for crash resistant fuel system

In 1994, the US and European certification specifications for helicopters were updated to include requirements for crash protection of fuel systems FAR/JAR 27.952. In the USA it is the Federal Aviation Administration (FAA) which is the certifying body, while in Europe it was the Joint Aviation

[17] Supplemental Type Certificate.

Authorities (JAA[18]). The certification did not apply retroactively, and thus only applied to helicopters which received their type certificate after 1994.This means that the requirement does not apply to the AS 350 B3.

Airbus Helicopters initiated a crash resistant fuel system development project in 2011. In 2012, it was certified compliant with CS 27.952 as CRFS. It was implanted as a standard for the EC130T2 as a newly certified aircraft.

Then, CRFS while not certified compliant with CS 27.952 for AS 350 B3 was installed as standard on AS 350 B3 delivered in the USA. It became a pre-selected option for other customers in Airbus Helicopters' commercial offers to be manually deselected by the customer in case they did not wished it installed.

From 2016, it was also available for retrofit in older AS 350 B3 and B2 helicopters (SB N.AS 350-28-10-0). CRFS was certified compliant with CS 27.952 without underbelly cargo swing installation and so proposed for retrofit. In 2017 CRFT, offered by Standard Aero (Then Vector Aerospace), was certified in accordance with CS 27.952 with underbelly cargo swing installation. In 2019, CRFS was certified fully compliant with CS 27.952 with and without underbelly cargo swing installation and so became a standard for all AS 350 B3e. Airbus Helicopters issued a Safety Information Notice (SIN) 3281-S-28 to all operators strongly recommending modifying the fuel system in existing helicopters to make the system crash resistant.

In March 2016, the NTSB submitted a safety recommendation report on crash resistant fuel systems in helicopters produced by Airbus Helicopters. The report was the result of an investigation into two accidents with post-crash fires. A video recording was available of one of the accidents, and it showed the helicopter crash and also how the fuel spilled out from the fuel tank and later caught fire. These accidents had in common that post-crash fires were potential factors in the death of people aboard the helicopters.

NTSB addressed three safety recommendations to FAA and one to EASA. It is stated in the report that the NTSB investigated at least 135 accidents involving various models of certified helicopters between 1994 and 2013, in which fires broke out as a result of the accidents. Only three of the helicopters involved had a crash resistant fuel system. As of November 2014, only 15% of a total of 5,600 helicopters in the USA with a production data after 1994 had a crash resistant fuel system installed. On that basis, the NTSB issued a safety recommendation to FAA that all new-build helicopters be equipped with a crash resistant fuel system in accordance with FAR 27.952 or FAR 29.952, regardless of their type certification date. As a result, US Congress passed the FAA Authorization Bill which includes an amendment to require all newly manufactured helicopters delivered to the USA after May 2020 to be equipped with crash resistant fuel system.

The NTSB also urged both FAA and EASA to prioritise certification of a crash resistant fuel system for retrofitting, as well as to inform owners and operators of AS 350 B3 and similar helicopters variants of what systems were approved and available and urge them to install such systems. This was subsequently done by EASA on 27 September 2017 (Safety Information Bulletin (SIB) 2017-18) and by FAA (Special Airworthiness Information Bulletin (SAIB) SW-17-23R2).

On 5 September 2019, an AS 350 B2 helicopter collided with a power line in Sobrado in Valongo in Portugal. The Portuguese investigation authority investigated the accident and published a report. The accident was caught on video. The helicopter was not equipped with a crash resistant fuel system, and it caught fire immediately after impact with the ground. The Portuguese investigation authority issued the following safety recommendation (14 July 2020):

[18] *JAA was the predecessor of the European Aviation Safety Authority (EASA).*

It is recommended that EASA follow its Rotorcraft Safety Roadmap publication principles, producing rulemaking documentation requiring retroactive application of the current improvements in fuel tank crash resistance for rotorcraft certified before the new certification specification for type design entered into force. Helicopters used for Commercial Operations shall be subject to this additional airworthiness requirement for operations.

The following is the response from EASA per 13 October 2021:

This safety recommendation will be taken into account in the frame of rulemaking task RMT.0710 "Improvement in the survivability of rotorcraft occupants in the event of a crash". This task is part of the European Plan for Aviation Safety (EPAS) 2020-2024. It will consider options for retroactive application of fuel tank crash resistance requirements. Further information will be provided when the project is launched with the publication of its terms of reference.

On 15 May 2019, EASA issued a revised version of the same SIB (SIB No 2017-18R1). It repeats that the installation of a crash resistant fuel system will reduce the risk of a post-crash fire and thus increase the time for escaping if the accident is otherwise survivable.

Measures implemented after the accident with regards to crash resistant fuel system is described in 1.18.4.2.

1.7 The weather

1.7.1 INTRODUCTION

The Norwegian Meteorological Institute has provided the following information about the weather situation in the area at the time of the accident.

1.7.2 THE WEATHER SITUATION IN GENERAL

The afternoon of 31 August 2019 started with a period of showers over the western coast of Finnmark. By 16:00, the showers had moved east, leaving only few clouds in the sky above the Alta area (see Figure 20). There was little wind, with wind speeds never exceeding 10 kt at the airport or at the Komsatoppen peak (elevation: 700 ft.). The wind direction alternated between variable and north-westerly winds. The temperature at the airport reached +18 °C at 16:50, and the freezing level (zero-degree isotherm) was at 8,000 ft.

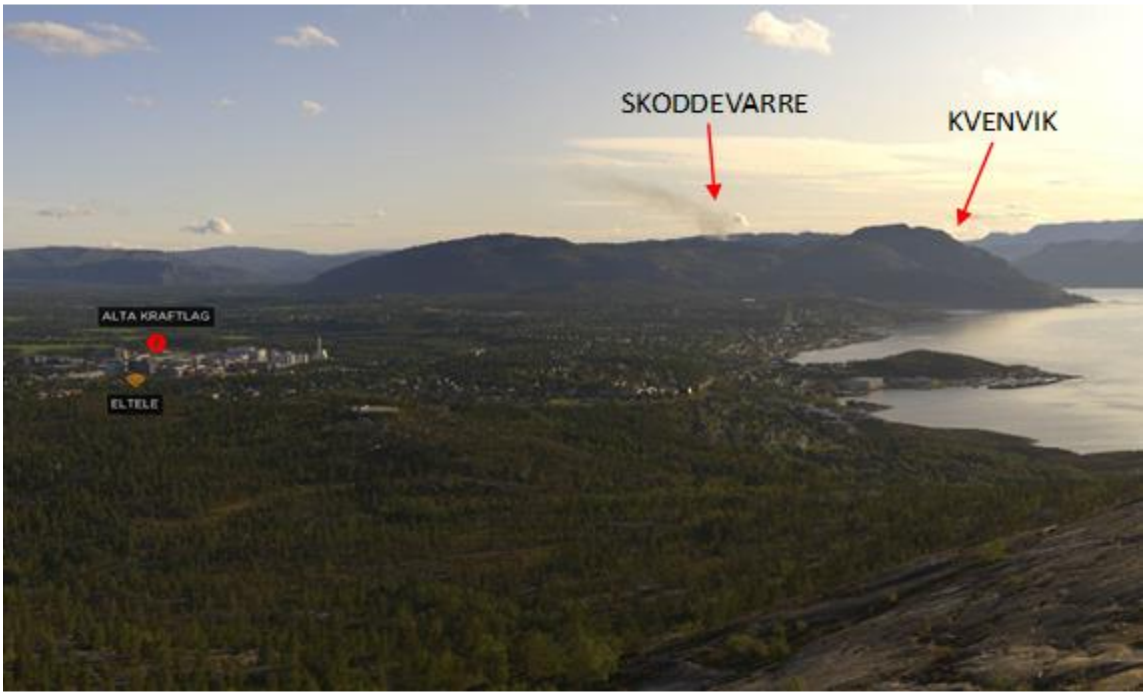

Figure 20: Webcam photo taken at 17:15 from the Komsatoppen peak, 2.5 km west of Alta Airport. The webcam faces south-west in the direction of Kvenvik and the Skoddevarre mountains. Smoke from the accident site can be seen in the photo. Source: Norwegian Meteorological Institute. Illustration: NSIA

The aviation meteorologist on duty received no request for weather data from the LN-OFU pilot.

1.7.3 METAR ALTA AIRPORT ENAT AT 16:50

AUTO 00000KT 9999// BKN072/// 18/12 Q1007 RMK WIND 700FT 33007KT=

1.7.4 WARNINGS OF RISK OF ICING OR TURBULENCE

No warnings of icing or turbulence had been issued for the relevant area or time period, though the IGA forecast predicted local light to moderate turbulence.

1.7.5 IGA FORECAST

Weather forecast for general aviation in Finnmark from 14 UTC to 24 UTC

WIND SFC............: SW/05-25KT, STRONGEST COT. BECMG VRB/05-10KT INLAND

WIND 2000FT.........: SW-W/15-35KT. LATE SW-W/10-25KT, VRB/05-10KT FINNMARKSVIDDA

WIND/TEMP FL 050....: 200-260/15-30KT, LCA 35KT COT N PART/PS05-PS08

WIND/TEMP FL 100....: 240-270/25-35KT, LATE OCNL 40-45KT COT W PART/MS03-MS00

WX..................: SCT SHRA COT, BECMG NIL. RISK BR/FG FINNMARKSVIDDA

VIS.................: +10KM, RISK 0,2-5KM IN BR/FG

CLD.................: FEW/BKN 1000-4000FT, LCA BKN/VV 0200-1000FT IN BR/FG. ISOL EMBD TCU/CB 1200-2000FT COT/FJORDS EARLY

0-ISOTHERM..........: FL080-100

ICE.................: LCA MOD IN TCU/CB

TURB................: LCA FBL/MOD

OUTLOOK FOR TOMORROW: SE-S/05-20KT, LATE OCNL 25KT W PART. MAINLY NIL.

1.8 Aids to navigation

The flight was based on visual navigation. A digital map system was available in the helicopter, but whether it was used is uncertain.

1.9 Communications

The air traffic service at Alta Airport ENAT was not staffed at the time of the flight. Recording of the radio frequency was activated and the audio log shows that no distress message (MAYDAY or PAN) was received before the helicopter crashed.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

1.11.1 INTRODUCTION

Helicopters in this weight class are not required to have an approved cockpit voice recorder (CVR) or flight data recorder (FDR) permanently installed. Nor was the helicopter equipped with such recorders; see 1.11.3.

On its own initiative, Airbus Helicopters chose to equip AS 350 helicopters delivered after 2013 with a Appareo Vision 1000 recorder. It is less resistant to fire and external impacts than recorders equivalent fulfilling EUROCAE ED155 or EUROCAE ED112 used in aircraft that are required to be equipped with such equipment.

There is no regulatory requirement, for helicopters with a maximum certificated take-off mass under 7,000 kg, to use data stored in lightweight flight recorders for analyses to find and implement continuous measures to increase flight safety. This is required for other branches of aviation through flight data monitoring (FDM) according to CAT.IDE.H.191 and SPO.IDE.H.146.

1.11.2 LN-OFU'S ELECTRONIC STORAGE DEVICES

LN-OFU had an Appareo Vision 1000 recorder installed in the ceiling above the aft seats. This recorder is equipped with GPS, inertia and accelerometer sensors. These allow the determination of aircraft position, altitude, heading, attitudes, vertical & horizontal speeds in relation with the ground and g-forces. It also made audio and image/video recordings. The video camera faces forward and should ideally film the vehicle and engine multifunction display (VEMD), the operation of switches and controls in the cockpit and the view ahead from the cockpit.

The audio recording if subjected to a frequency analysis, would reveal any faults in rotating components such as the engine, gearbox or rotor system. The unit could store up to 4 hours of video and audio recording and more than 200 hours of flight data. All information is stored both in a built-in memory module and on a separate SD card. The built-in memory module is encased in stainless steel so as to be more resistant to external impact; see Figure 21.

Figure 21: Appareo Vision 1000 in undamaged condition, and in severely fire-damaged condition as found in LN-OFU. The arrow points to the casing around the built-in memory module. Source: Appareo Systems, LLC and Airbus Helicopters

The SD card in the Appareo Vision 1000 unit was not found. The memory module was taken to BEA's laboratory, where the metal casing was removed. The severely fire damaged memory units inside the module were removed and X-rayed to ascertain their condition and the possibility of downloading their content. Several connections between the silicon dies and the pins proved to have melted away, however, rendering it impossible to download any data; see Figure 22. The units were then examined by Thales in France, with a view to possibly retrieving data directly from the silicon chips. That proved impossible.

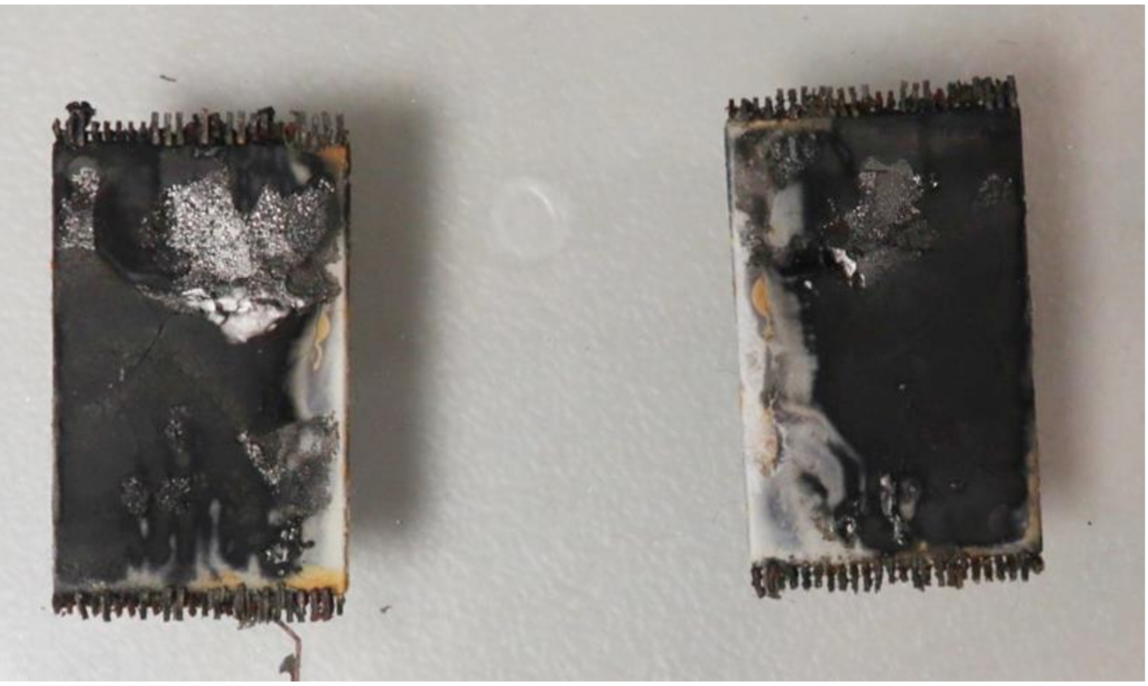

Figure 22: The memory units from the Appareo unit examined by Thales. Photo: BEA

Other units that stored information on board the helicopter, were the DECU, the engine data recorder (EDR), VEMD and Garmin Avionics GTN650. The DECU and EDR are electronic systems for providing optimum engine output, and for recording and storing engine data. The DECU is meant to store engine data with updates every second. If an engine fault is detected, the storage frequency increases to every 20 milliseconds. The EDR and DECU exchange data, and data from the EDR can be downloaded. The VEMD displays important information and is filmed by the

Appareo unit. It also stores flight information, fault messages and limit value exceedances. The Garmin Avionics GTN650 navigation unit can display and store GNSS[19] information.

All the helicopter’s electronic units for storing audio, image and video records and data were found to have been so damaged by the intense heat that it was impossible to retrieve information from any of them; see Figure 23. A photo of the instrument panel before the accident can be seen in Figure 3.

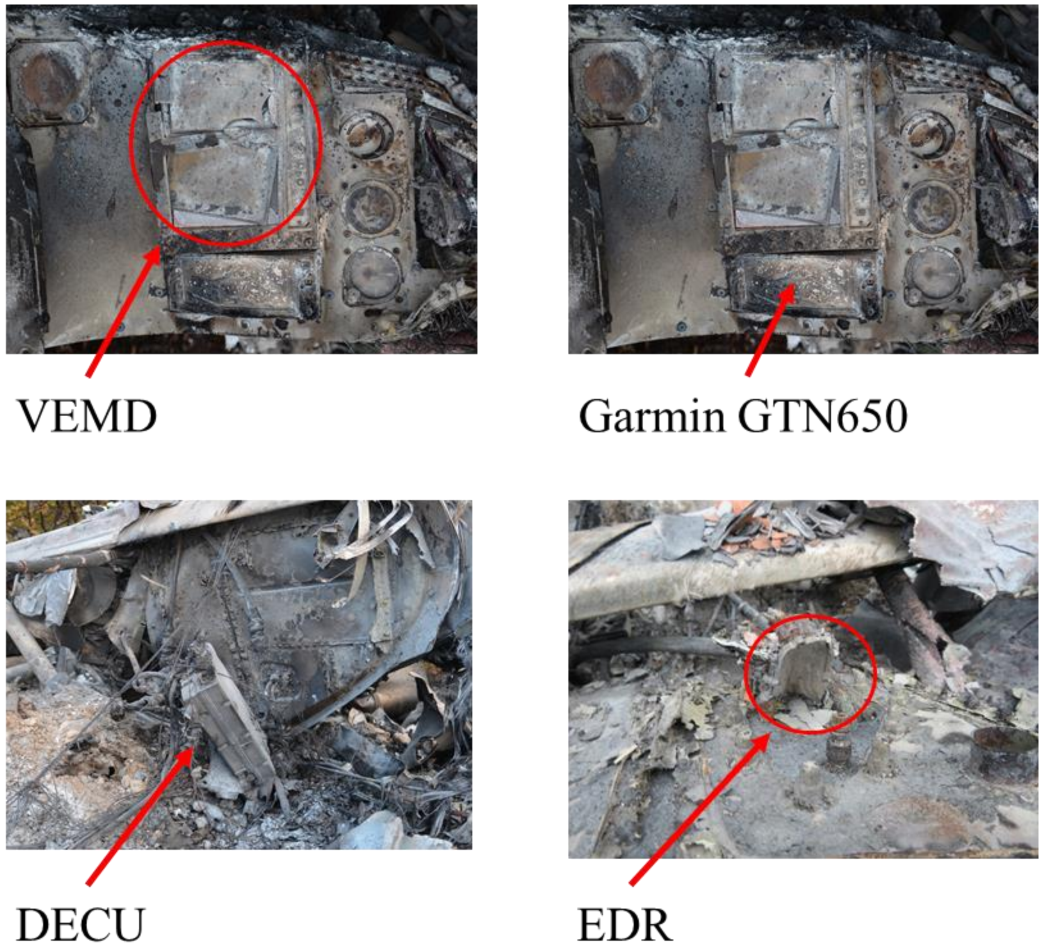

Figure 23: Burnt out electronic units with storage capability. Photo: NSIA/BEA

Mobile phones or parts of such phones that had been damaged by fire were found at the accident site. It proved impossible to retrieve data from any of them. A relatively undamaged iPad mini was also found, which the helicopter company had dedicated to the accident helicopter. The iPad had not been used on the day of the accident and it therefore did not contain relevant information.

1.11.3 REQUIREMENTS FOR FLIGHT RECORDERS FOR SMALL AIRCRAFT, INCLUDING LIGHT HELICOPTERS

Based on the investigation into the accident with LN-OXC at Dalamot, the investigation authority issued the following safety recommendation:

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[19] Global navigation satellite systems.

Safety recommendation SL 2012/10T.

A flight recorder is a useful tool for establishing what happened in an accident. The recordings can also be utilised for training and flight safety work in general under the right conditions. The technological development has advanced far enough to make the Accident Investigation Board believe that it is time for the aviation authorities to require suitable recorders for lighter aircraft as well, including light helicopters.

The Accident Investigation Board Norway (AIBN) recommends that EASA considers introducing requirements for flight recorders on more aircraft than those covered by the current regulations.

This safety recommendation, and several similar recommendations, were part of the background material when EASA in 2017 issued a Notice of Proposed Amendment (NPA 2017-03) to initiate a rulemaking process to define requirements for flight recorders in aircraft that were not already subject to such requirements. As a result, such requirements were adopted through Commission Implementing Regulation (EU) 2019/1387, SPO.IDE.H.146 and CAT.IDE.H.191 Lightweight flight recorder, with effect from 5 September 2022:

Turbine-engined helicopters with a maximum certificated take-off mass between 2,250 kg and 3,175 kg and manufactured on or after 5 September 2022 will be required to carry a flight recorder if they are used for commercial air transport or commercial specialised operations.

Flight recorders are subject to, among others, the following requirements:

- They shall be dedicated to recording and storing data and/or audio and/or images/video recordings.
- They shall be permanently installed.
- They shall record and store data continually from take-off to touch-down.
- The flight recorder is required to meet industry standards that include testing against impact shock, static crush and high temperature fire (refer to EUROCAE ED-155 or ED-112).
- The flight recorder shall record, by means of flight data or images, information that is sufficient to determine the flight path and aircraft speed

The visions and strategy for collecting more safety data for helicopter operations are described in EASA's Rotorcraft Safety Roadmap.[20]

Through Rule Making Task RMT.0271 and 0272, EASA has promoted voluntary installation in helicopters that fall outside the scope of the new regulations, and that more information can be stored on a voluntary basis.

[20] EASA's Rotorcraft Safety Roadmap is a strategy to reduce the number of accidents and incidents with helicopters in Europe.

1.12 The accident site and wreckage information

1.12.1 THE ACCIDENT SITE

The helicopter impacted the ground at 301 metres (988 ft) above sea level in an east-facing slope just east of Kvenvannet lake and just below the peak of Skoddevarre (see Figure 24), a mountain ridge between Alta and Kvenvik. There is an unobstructed view and a distance of approximately 2 km as the crow flies from the accident site to the nearest public road at Kvenvik.

The accident site was meticulously documented. It is a relatively small, flat area encompassed by steep terrain. The area consists of rocky ground with a cover of heather, moss and some independent mountain birches. Some areas in the vicinity are boggy and have small lakes.

The wreckage lay within a limited area, where the vegetation was charred. There was little fire damage to the vegetation in the immediate vicinity; see Figure 25. There were no signs that the heather or vegetation around the wreckage had been ignited by burning fuel.

Figure 24: The accident site. The photo was taken looking north-west. Photo: The police/NSIA

Figure 25: The accident site near Skoddevarre, viewed from an easterly direction, with the front of the helicopter in the foreground. The bushes on the far right in the photo had not been damaged by the main rotor. Tarpaulins have been deployed to protect the wreckage. The photo was taken after removal of the deceased. Photo: NSIA

The tops of two mountain birches in front of and to the right of the helicopter had been within the range of the main rotor and had downward-sloping cuts to the left seen in the direction of travel (see Figure 26).

Figure 26: The accident site, viewed from the south-east. The birch in the foreground was in front of and to the right of the wreckage. The tree on the upper right was damaged by fire only. Photo: NSIA

The main rotor had left three weak marks in the terrain. The two clearest marks were in front on the left and immediately in front of the wreckage, respectively, while the smallest mark was in front on the right. At the far end of the impression on the left, an end cap for one of the rotor blades was found (see Figure 27). The distance from the helicopter's main gearbox to the marks on the ground matches with the damage at the tips of at least two of the rotor blades.

Figure 27: Photograph showing the most visible mark after a rotor blade to the front and to the left of the wreckage. The birches to the left in the photo have been cut by rotor blades. The red arrow shows where the tip of a rotor blade has hit a rock. Photo: NSIA

1.12.2 WRECKAGE INFORMATION

1.12.2.1 The main wreckage

The position of the wreckage indicated that impact with the ground occurred while the helicopter was heading from west to east. The main part of the helicopter and its components lay in a concentrated area. The helicopter wreckage was severely damaged by fire (see further description in section 1.14).

Some components had been moved and also stepped on by the fire service while searching for deceased persons and putting out the fire. The fire service provided the NSIA with video records of the fire service's work at the accident site, so that the NSIA could get an overview of what, if anything, had been moved.

No traces of impact with external objects such as a drone or bird were found in the burnt-out wreckage. Neither were there any reports of birds or drones in the area at the time of the accident. There are no available satellite images, that could show birds or drones, of the Skoddevarre area for the period that is relevant to the accident.

The deceased persons were removed by the National Criminal Investigation Service the day after the accident, with the NSIA and local police present.

The wreckage was looked through, roughly sorted and transferred to Kvenvikmoen by helicopter three days after the accident. Parts that were to undergo further examination were sent on to the NSIA's premises, while the smaller remaining parts were transferred to Alta.

1.12.2.2 Main gearbox

The main gearbox housing was made of a magnesium alloy and was completely consumed by fire. Magnesium burns at a very high temperature. The suspension bars by which the main gearbox is attached to the fuselage were completely destroyed by heat. The four upper fastenings of the bars were still attached to the conical part of the gearbox housing, but only two of the four lower fastenings were initially found at the accident site. The remaining two were found when the collected parts of the wreckage were re-examined at a later date. No damage was observed in the form of destroyed gears or gear trains inside the main gearbox.

1.12.2.3 Seats

The two front seats in the helicopter were completely destroyed by fire and the frames were bent to the left. The two shock absorbing seat sliders on the left-hand side of each seat were extended by about 10 mm, while the two on the right-hand side had not been extended. The aft seats were without shock-absorbers. The seats were destroyed by fire and the tubular frame was damaged by fire, but not deformed.

1.12.2.4 Landing gear

The forward part of the landing gear skids had burnt up. A step was mounted above each of the skids, which protruded from the landing gear. The steps are made out of an aluminium alloy. The step on the left side had largely burnt up and there were no traces of the forward part, while the one on the right side was little damaged by the fire. It was only slightly compacted at its forward edge. The skids and steps lay more or less in the helicopter’s direction of travel. They had separated from both the forward and aft cross-tubes. Mounting shoes for the skids had been welded to either end of each of the tubes. In three of these four welds, there was a fracture in the welds heat-affected zone. The cross-tubes were not significantly deformed.

1.12.2.5 Main rotor and rotor blades

The main rotor blades lay together with the rest of the wreckage at the accident site. They were damaged by fire, and all had a clearly visible cross fracture near the middle of the blade. Two of the blades showed major impact damage at the tip of the blades; see Figure 28. The blades mainly consist of glass fibre with a foam core. Small parts of foam and glass fibre were found in the terrain in the immediate vicinity of the accident site. It is not uncommon to observe large quantities of foam in the terrain after a main rotor blade has impacted the ground with great force.

Figure 28: The three rotor blades. The blade tips are to the left in the photo. Photo: NSIA

The main rotor head sustained major damage in the fire after impact with the ground. One of the Starflex arms were found to have an overload fracture (45°), a typical consequence of impact with the ground. Another arm showed a 90° fracture, and the third arm was so damaged by fire that an eventual fracture could not be determined.

1.12.2.6 Tail section

The helicopter's tail section had separated from the main wreckage and was hardly damaged by the fire. It was found balancing at the edge of a crest with the aft end pointing south-westerly towards the lake Kvenvikvannet. One tail rotor blade was broken near the middle, while the other had only small scratch marks at the very tip of the blade. The horizontal stabiliser on the left-hand side of the tail boom was buckled upwards, and the lower part of the vertical fin was bent to the right. One tail rotor blade had been pushed against and through the fin without any sign of rotation of the tail rotor when this occurred.

The tail rotor and accompanying gearbox remained attached to the tail boom. The drive shaft for the tail rotor had broken between the tail boom and fuselage (see Figure 29). The part of the shaft which was connected to the tail rotor had left several scratch marks in the tail boom due to rotation.

Figure 29: The broken drive shaft for the tail rotor between the fuselage and tail boom, with typical rupturing of the flexible coupling. Photo: NSIA

1.12.2.7 The shaft transmission between engine and main gearbox

The drive shaft that transmits power from the engine to the main gearbox was found at the accident site. The shaft had separated from both the main gearbox and the engine, and all six bolts for the flexible couplings that had kept it in place were missing. Half a bolt was subsequently found in the wreckage that was transferred to the NSIA in Lillestrøm. Deformed and damaged remains of a total of 18 discs from the couplings were found and removed for further examination.

1.12.2.8 Engine

The engine was found in a central location in the wreckage. The rear torque link consisted of a cradle attached to the engine compartment floor, while two metal bands around module M01 held the engine in place in the cradle. The engine had been shifted forward in the impact, and had separated from the aft fastening, while the cradle was found bent forwards in the direction of flight and still attached to the engine compartment floor. Marks on the engine showed that the engine was fastened with the metal bands during the fire. Tube and hose connections for oil and fuel were identified and found to have been correctly connected.

The engine control systems in the cockpit were impossible to identify or severely damaged from the impact with the ground. It was thus impossible to determine the position of the controls at the moment of impact.

1.12.3 SEARCH FOR PARTS

Searches for parts were conducted three times, the first time immediately after the accident.

1.12.3.1 First search

A first search for possible helicopter parts was carried out in the area surrounding the accident site. A search party was formed of police and civil defence personnel on the instructions of the NSIA. The search party moved east from the accident site along the presumed flight route. Other than fragments of the main rotor blades near the accident site, no further findings were made.

1.12.3.2 Second search after six weeks

The second search was conducted after six weeks. The main purpose of the second search was to look for missing bolts from the drive shaft for the main gearbox (see section 1.6.5). The NSIA accompanied by defence and police personnel searched the area using metal detectors and powerful magnets. The search area was, in addition to the crash site, below and on both sides of the helicopter’s known flight path (see Figure 30).

Ten of total eleven missing bolts were found when magnets were used in a meticulous search of the accident site. One small bit of composite material from one of the rotor blades was also found. It is assumed that this bit had ended up where it was found during the NSIA's removal of parts from the accident site.

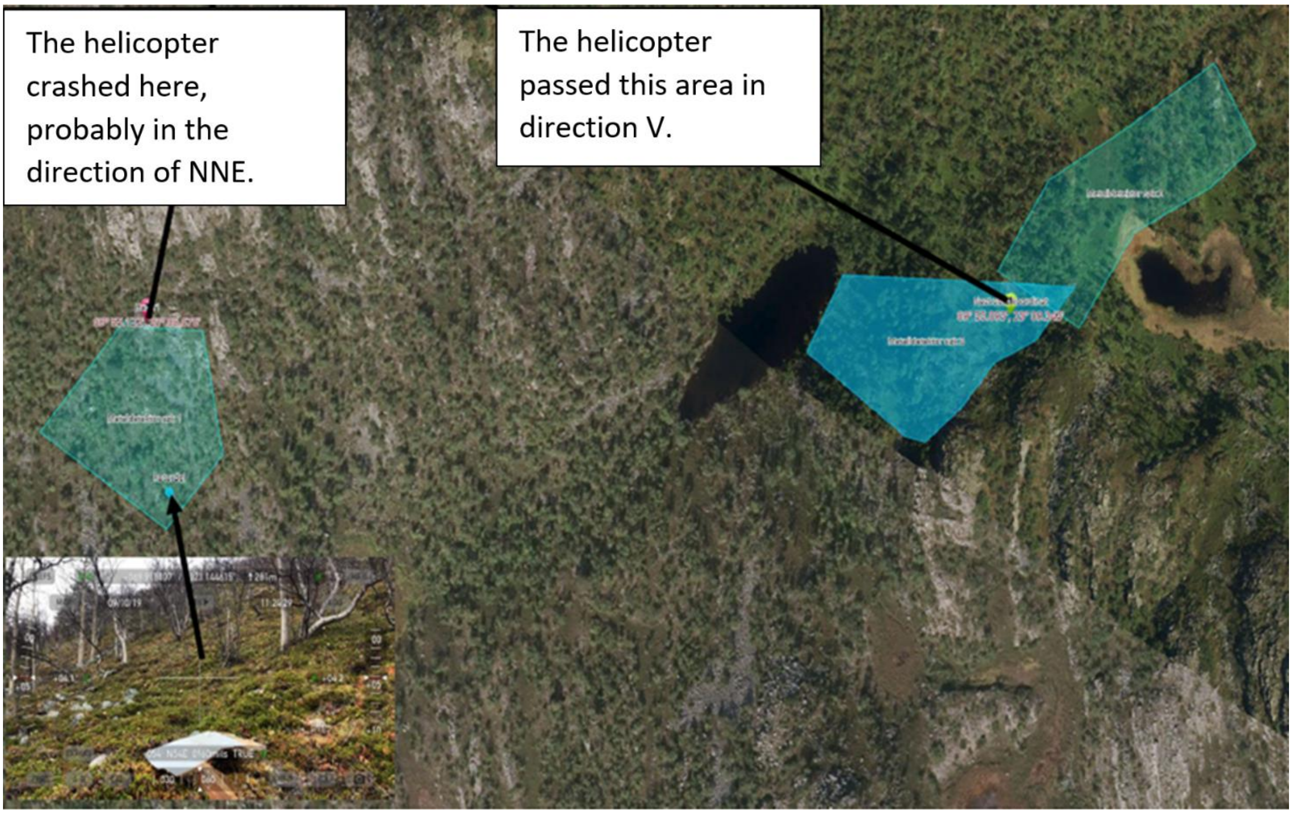

Figure 30: Area of second search. Source: NSIA

1.12.3.3 Drone search number one

The NSIA subsequently commissioned Geonord AS to conduct a detailed drone search of the terrain below and on both sides of the helicopter's flight path. The drone was an RTK multirotor drone equipped with a 24-megapixel camera. A total of 3,922 photos were taken within a distance of 300 meters to either side of the final part of the flight path as shown in Table 6 below, and within a 500 meters radius of the accident site. The photos were taken from altitudes of between 35 and 50 metres above the terrain (see Figure 31).

Table 6: Last seven registered flight path positions, where position no 7 is the accident site. Source: NSIA

1	69.91899 N	23.16106 E
2	69.91867 N	23.15903 E
3	69.91843 N	23.15745 E
4	69.91834 N	23.15672 E
5	69.91821 N	23.15571 E
6	69.91777 N	23.15218 E
7	69.91837 N	23.14478 E

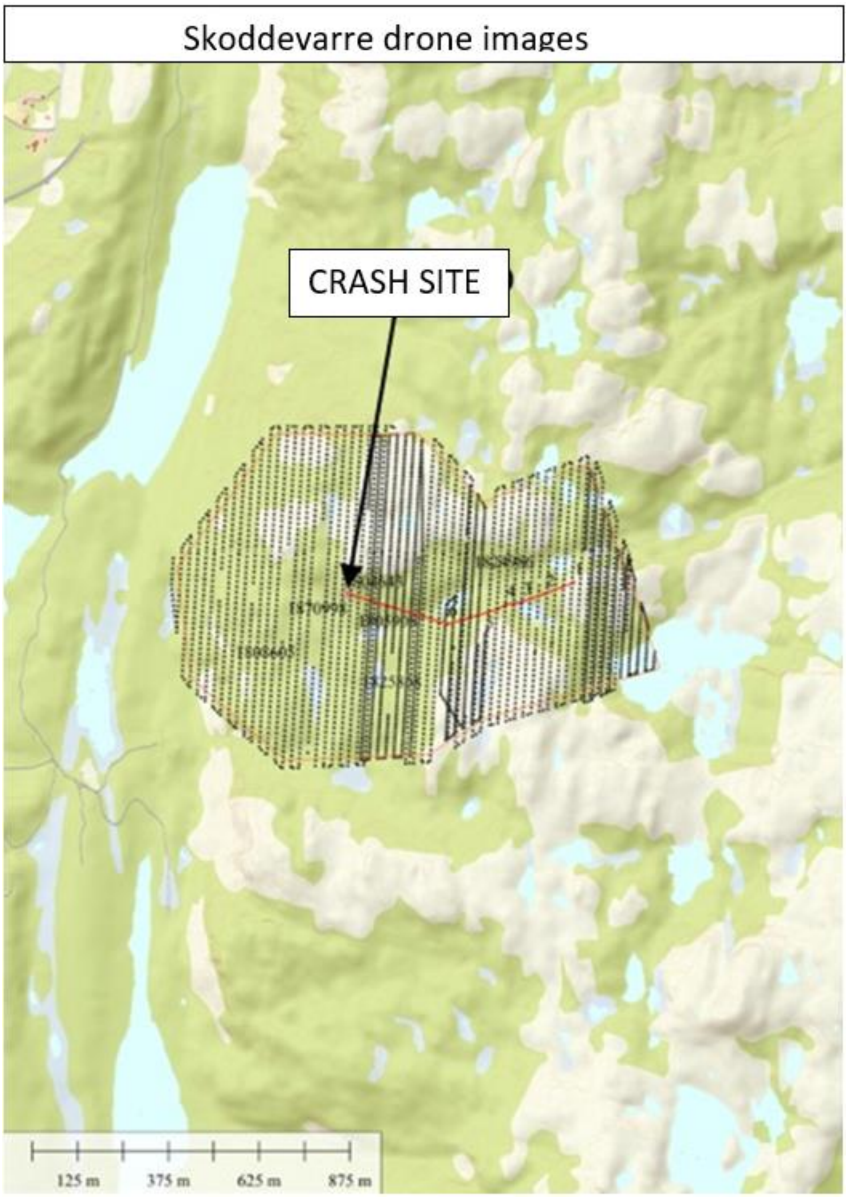

Figure 31: The red line marks the final part of the flight path. The black dots represent the 3,922 photo shots. Illustration: Geonord AS/NSIA

After a review of the photos, Geonord registered 170 findings. The findings were made on the basis of objects that stood out from the surrounding terrain on account of their shape, colour or contrast. The NSIA analysed these 170 findings immediately after receiving the photos in December 2020. None of the findings could be related to the accident.

1.12.3.4 Drone search number two

Based on new information autumn 2021 describing open flames in the terrain in the Nordtoppen area around the time of the accident, the NSIA decided to perform a new drone search in late September 2021 to map the area. Nordtoppen is close to the flight path the helicopter followed during the initial phase of the flight, see Figure 32 and Figure 33. The drone company Geonord AS was hired to photograph the terrain in the area where the flames had been observed.

The photos were reviewed in cooperation with Alta police station, and a total of nine points in the terrain were marked as particularly interesting. On 5 October 2021, Alta police station conducted an inspection of the search area to study the points more closely. The black points in the photos turned out to be wet rock, however, and no findings were made that could be linked to the accident.

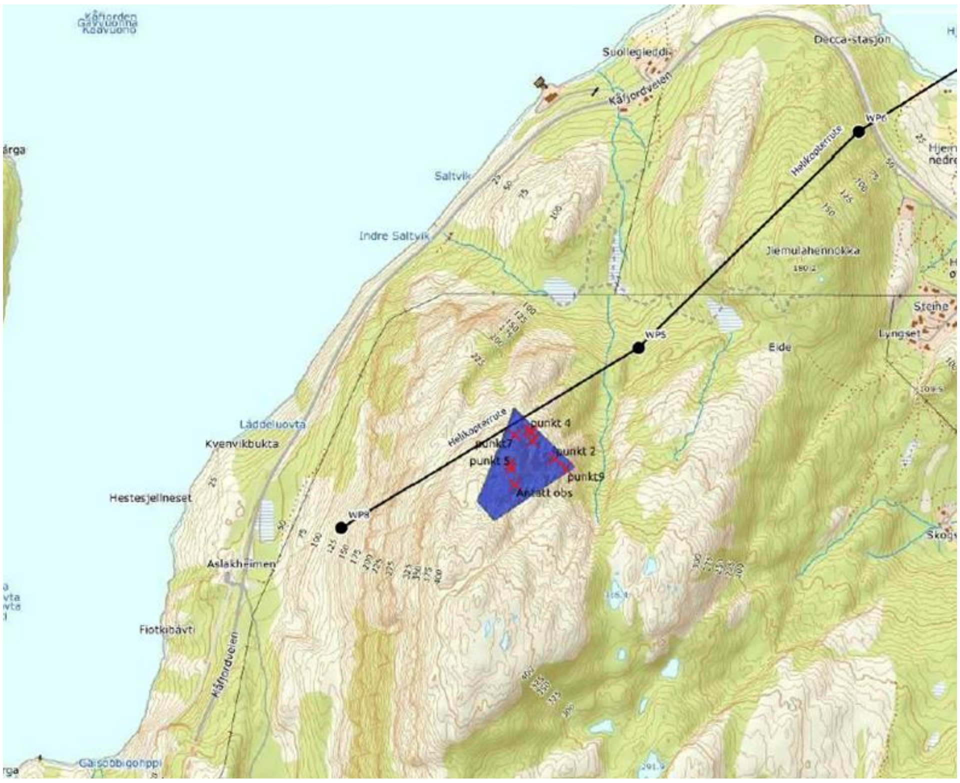

Figure 32: The blue field indicates the area photographed by the drone. The black line is the helicopter's flight path based on CelloTrack data. Illustration: © The Norwegian Mapping Authority, Geonord AS, the police and the NSIA

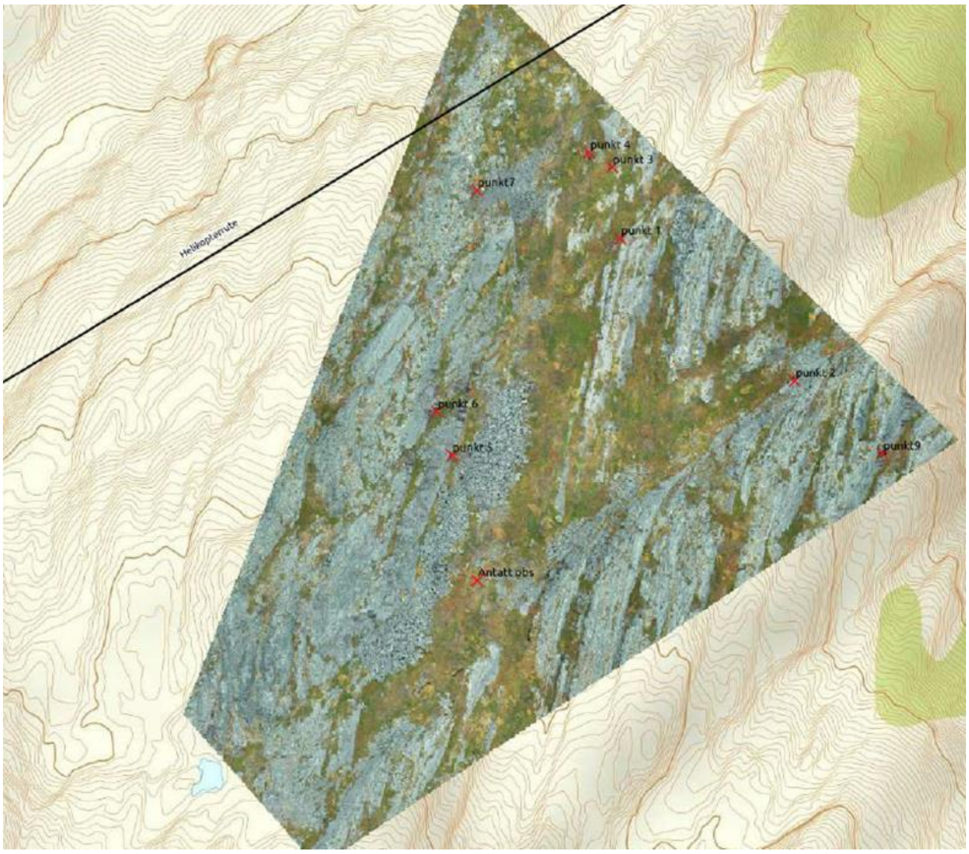

Figure 33:The same search area as in the figure above, but with a higher resolution. Illustration: © The Norwegian Mapping Authority, Geonord AS, the police and the NSIA

1.13 Medical and pathological information

Five of those who died were found in the helicopter wreckage, severely charred. The passenger occupying the seat on the far right in the cabin had managed to get out of the helicopter. He was found down a steep, rocky slope, approximately 50 metres from the accident site, by the Heli-Team helicopter crew who arrived on the scene shortly after the accident. At that time, the passenger was conscious and able to speak, but the conversation did not contribute to clarifying what had happened. He had severe burn injuries and died in hospital the following day as a result of these injuries.

A post-mortem examination was carried out of all six victims at the University Hospital of Northern Norway in Tromsø. The following findings are from the autopsy reports:

- The passenger who managed to exit the helicopter, had fracture of the spine and external head injuries. The head injuries were not deemed to be life-threatening.
- Two of the other passengers had neither pelvis nor spinal injuries. It was not possible to ascertain whether the two last passengers had corresponding injuries.
- The cause of death of the passengers is assumed to be extensive burn injuries.
- The pilot had fracture with misplacement in the spine, but no signs of pelvis fracture.
- The pilot is assumed to have died from a combination of head and burn injuries.
- No alcohol, medication or narcotic substances were found in either blood or urine samples from the pilot, while some of the passengers had been moderately under the influence of alcohol.

Pilots can be exposed to an acute medical condition during a flight that leave them incapable of operating an aircraft. The NSIA has not received any information or made any findings to suggest any loss of consciousness or sudden illness of the pilot. The autopsy gave also no indication of illness. It could be confirmed that he had eaten food.

1.14 Fire

At the time of the accident, the helicopter carried an estimated 346 kg (433 litres) of fuel and a smaller amount of hydraulic fluid and engine oil. With the exception of the tail boom, the helicopter body had been almost completely consumed by the fire. All fuel and combustible material were consumed by fire. Much of the aluminium had burnt up or melted. A metal fire had developed in the magnesium in the main gearbox.

The area of the fire was limited to the immediate vicinity of the helicopter wreckage. There had been no fire in the terrain in front of the point of impact. Much of the aluminium had burnt or melted. Bits of the helicopter's front part and windows were found just in front of the point of impact; see Figure 25. These had sustained only minor fire damage. Other main components, including the engine, steel parts of the main gear box, landing gear, parts of the main rotor, the controls, seat structure and instrument panel had been exposed to intense heat.

When the first search and rescue personnel arrived on the scene, the helicopter was completely burnt out.

1.15 Survival aspects

1.15.1 THE RESCUE OPERATION

The Joint Rescue Coordination Centre Northern Norway (JRCC N-N) is control centre for the rescue services' Cospas-Sarsat satellite-based communication system. The centre registered position and identification signals from the helicopter's emergency location transmitter (ELT 257/Norway/4793D5) at 17:06. The emergency location transmitter had been activated automatically. The JRCC was also notified of the accident by telephone. The emergency location transmitter stopped transmitting signals after a while. The emergency location transmitter was never found and is assumed to be consumed by the fire.

The JRCC N-N was in charge of the operation, and a Sea King SAR helicopter was notified and deployed to the scene of the accident. At 17:14, the JRCC N-N and air traffic control service in Alta agreed to establish an aviation safety zone with a 500-meter radius and extending to 2,000 ft above the accident site. The safety zone was kept free of all air traffic, with the exception of the SAR helicopter and a Bell 205 helicopter from Heli-Team.

The helicopter from Heli-Team was en-route from Banak to Kvænangen and passed over the accident site at 17:16. The helicopter crew notified of the accident and position by radio and circled the accident site to look for eventual survivors. They spotted the injured person not far from the accident site and landed nearby. The loadmaster on board then went over to the passenger and cared for him. The pilot has told the NSIA that he regarded the helicopter as consumed by fire when they arrived at the accident site, about 10 minutes following the accident.

After the Sea King SAR helicopter had arrived, emergency medical treatment was administered to the injured passenger. The SAR helicopter took off at 18:50 and flew the injured person to the University Hospital of Northern Norway.

Heli-Team later transported rescue personnel and necessary equipment to the accident site. The crew of a SAR helicopter stationed at Hammerfest Airport (ENHF) contacted the JRCC N-N and offered to help. The JRCC N-N concluded that there was no need for further helicopter resources, however.

1.15.2 HELICOPTER SAFETY EQUIPMENT AND USE

Helitrans has equipped all its helicopters with CelloTrack 3Y[21], a system that reports the position, altitude and ground speed of the helicopter in real time. The helicopter operator uses this information to facilitate efficient utilisation of the helicopter fleet. There is also an important safety aspect to the system in that it enables the operator to locate a helicopter that has performed an emergency landing or crashed. It had no bearing on the survival aspect in the accident under consideration, however.

The helicopter was equipped with an emergency location transmitter model Kannad Integra AP-H S1854501. This was installed in the rear luggage compartment right behind the fuel tank. The antenna was installed at the left-hand side of the airframe above the luggage compartment.

The helicopter was equipped with two energy-absorbing seats in the cockpit (see section 1.6.1). It was also equipped with floats in the event of an emergency landing on water.

[21] *In the following referred to as CelloTrack.*

The loadmaster has informed that, before take-off, he had checked that the seatbelts were correctly fastened. Both seats in the cockpit had 4-point seatbelts, while the four aft seats in the cabin had 3-point seatbelts.

Helitrans did not require helmets to be used during sightseeing flights. The pilot had his helmet available but chose not to wear it during sightseeing flights. Passengers are not commonly offered helmets on sightseeing flights; hence Helitrans had no helmets available for the passengers.

LN-OFU was not equipped with a crash resistant fuel system (see section 1.6.11).

1.16 Tests and research

1.16.1 FLIGHT PATH TRACKING

1.16.1.1 Introduction

The CelloTrack unit was not part of the helicopter's systems or formally certified for use in aircraft. CelloTrack has both an accelerometer and GNSS-based tracking and is set to transmit information over the GSM network to the operator for every kilometre flown. Helitrans has informed the NSIA that the unit in LN-OFU was programmed to enter sleep mode after one minute without movement. The CelloTrack system has information from the whole flight up until the second-to-last transmission registered at 17:05:00, when the helicopter was moving and 580 metres from the accident site. The final transmission places the unmoving helicopter at the accident site at 17:08:00.

Flightradar24 is an internet-based service based in Sweden. The service shows aeroplane and helicopter movements in real time. It includes tracking of aircraft, origins and destinations, and, if applicable, route numbers, aircraft types, positions, altitudes and speeds. It can also show previous tracks and historical data broken down by airline, aircraft, aircraft type, area or airport. It captures data from multiple sources, though mainly from Automatic Dependent Surveillance-Broadcasts (ADS-B) units on board aircraft. These units transmit signals about the aircraft's position based on ground-based and satellite-based information.

Flightradar24 records data more frequently than what is makes publicly available. For the purpose of optimum reconstruction of the helicopter's flight path, the NSIA therefore obtained more comprehensive data from Flightradar24 via the Swedish investigation authority. The data stored by Flightradar24 were analysed and then compared with the data from CelloTrack. The comparison showed that the position, altitude and speed data coincided; see Figure 34.

Both Flightradar24 and CelloTrack register ground speed. Ground speed does not necessarily correspond to the pilot's reading in the cockpit. As the wind speed was less than 10 kt from the north-west on the day of the accident, the difference will have been very small.

Flightradar24 had not received or recorded data from the initial and final period of the flight. The area lacking ADS-B data are the same for both flights, indicating the helicopter was outside ADS-B coverage. Data from the helicopter's CelloTrack system were therefore used to illustrate the altitude profile for these periods of the flight. The elevation of the terrain below each point was obtained from the Norwegian Mapping Authority.

Information from Flightradar24 about the helicopter's position at given times on 31 August 2019 has also been plotted onto the Norwegian Mapping Authority's digital maps at norgeskart.no; see Figure 35.

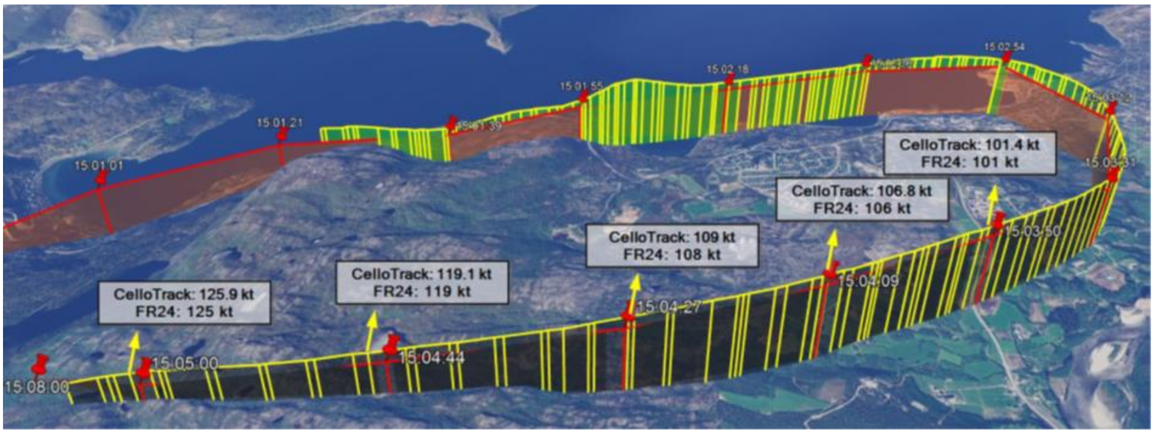

Figure 34: Comparison between data on ground speed and flight path from Flightradar24 (marked in yellow) and similar data from the CelloTrack unit (marked in red) carried by the helicopter on the accident flight. The comparison confirms the reliability of the signals. The accident site in the lower left corner is marked with a red pin and the time 15:08:00. Illustration: BEA/NSIA

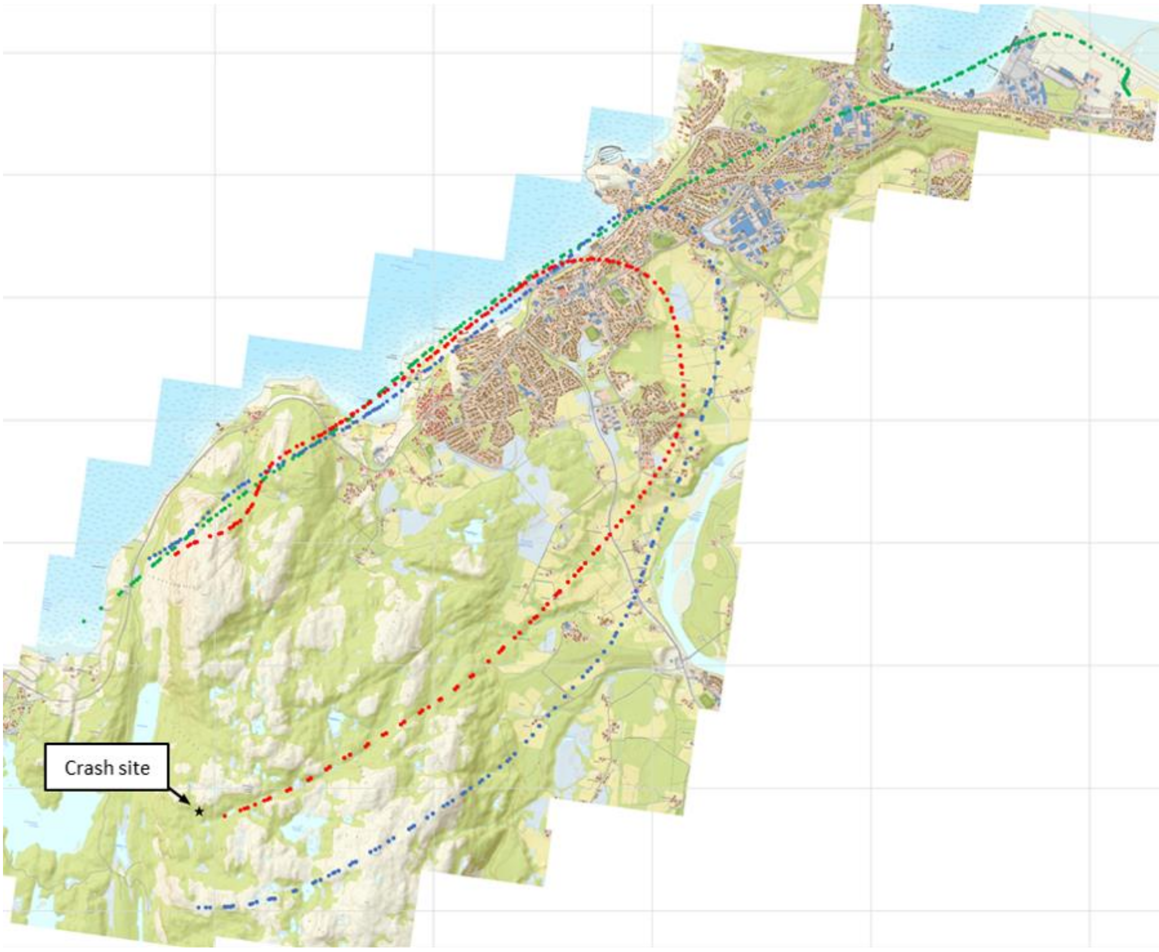

Figure 35: The ferry flight from Alta is marked in green, the first sightseeing flight is marked in blue, and the accident flight is marked in red. Map: © The Norwegian Mapping Authority. Markings: NSIA

1.16.1.2 The ferry flight from Alta

Figure 36 shows flight path data for parts of the ferry flight from Alta to the festival area. Flightradar24 recorded data for four minutes and nine seconds. No significant altitude or speed variations were registered during the flight.

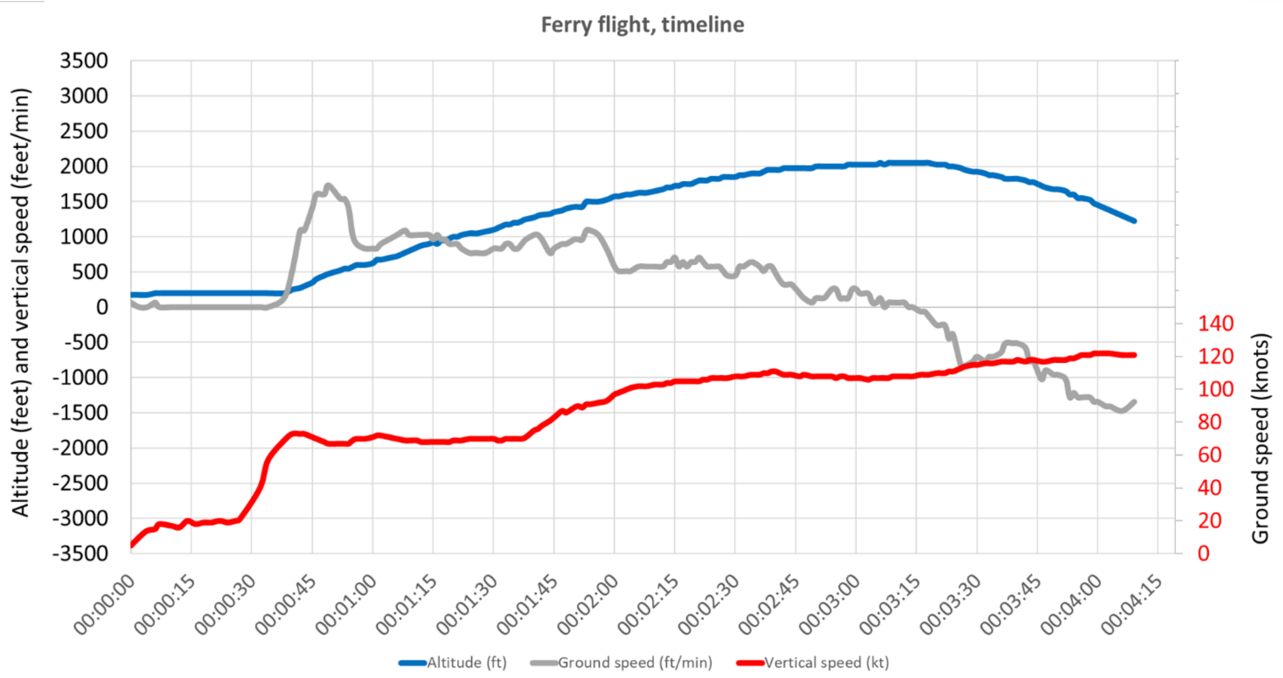

Figure 36: Flight path of parts of the ferry flight to the festival area, with reference to the timeline for the flight. The blue curve represents altitude and the grey curve vertical speed[22], with the values shown on the left axis. The red curve represents ground speed, with the values shown on the right axis. Source: NSIA

1.16.1.3 First sightseeing flight

The timeline for the first sightseeing flight is based on the reported take-off time at 16:40 Flightradar24 registered data from 03:13 minutes into the flight, and the last time at which data were registered was after 07:50. The timeline for the flight path is shown in Figure 37.

There were variations in altitude and speed during three periods of the flight. The first took place after 03:30 minutes and lasted until 04:28 minutes had passed. The next was from 06:28 to 07:10 minutes into the flight, and the final period was from 07:29 minutes into the flight until the final time at which data were recorded, 07:50 minutes into the flight.

The first and final periods concurred with corresponding manoeuvres on the accident flight. The second period was at high altitude above relatively flat terrain and does not warrant further description.

The first period concurs with the passage across the first mountain ridge, over partly mountainous terrain and onwards across Hjemmeluftbukta bay; see Figure 38.

[22] Negative vertical speed is also referred to as sink rate, while positive vertical speed is referred to as climb rate.

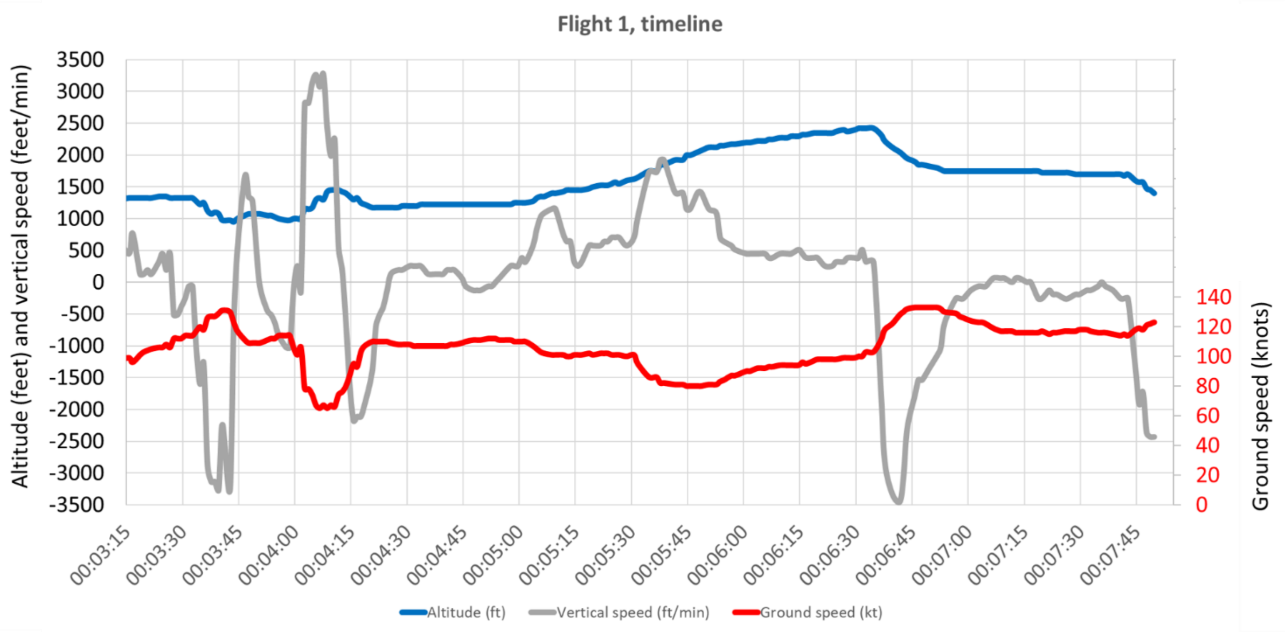

Figure 37: Flight path of first helicopter tour, with reference to flight timeline. The blue curve represents altitude and the grey curve vertical speed, with the values shown on the left axis. The red curve represents ground speed, with the values shown on the right axis. Source: NSIA

Figure 38: First period of first sightseeing flight. Map: © The Norwegian Mapping Authority. Markings: NSIA

The NSIA has obtained the terrain elevation profile along the flight path followed during this period from the Norwegian Mapping Authority. The terrain profile and flight path followed during the first period of the first sightseeing flight is shown in Figure 39. Error margins related to altitude data are described in more detail in Appendix B.

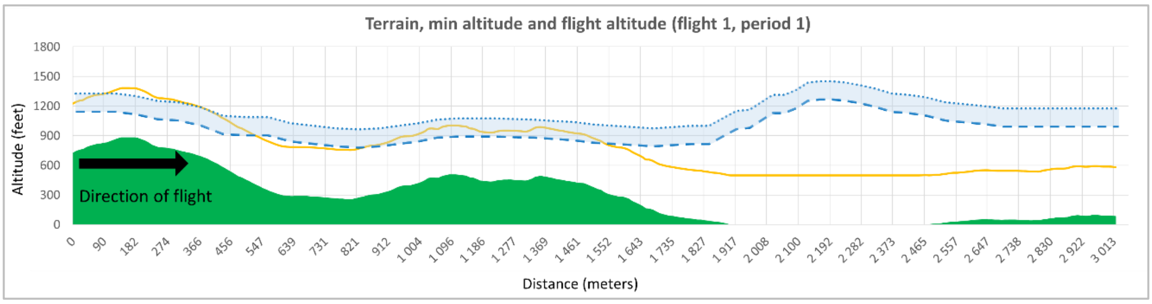

Figure 39: Altitude above the terrain during the first period of the first sightseeing flight. The green represents the terrain, the amber line shows the minimum altitude of 500 ft above the terrain, while altitude of the flight path is indicated in blue. The upper blue dotted line represents altitude data from Flightradar24, and the lower dotted line is the altitude of the flight path adjusted with data from CelloTrack. Note that the direction of flight is from right to left. Source: NSIA

The figure shows two flight path altitudes. The upper dotted line illustrates the flight path based on data from the transponder in the helicopter registered by Flightradar24. The lower dotted line is the flight path adjusted with the difference between the transponder altitude and altitude data from CelloTrack and represents the probable altitude. Data from CelloTrack contains fewer data points but corresponds with the elevations of the festival area and the accident site. The comparisons are expressed in more detail in Appendix B.

The flight path for the final period of the first sightseeing flight, which had variations in altitude and speed, is show in Figure 40.

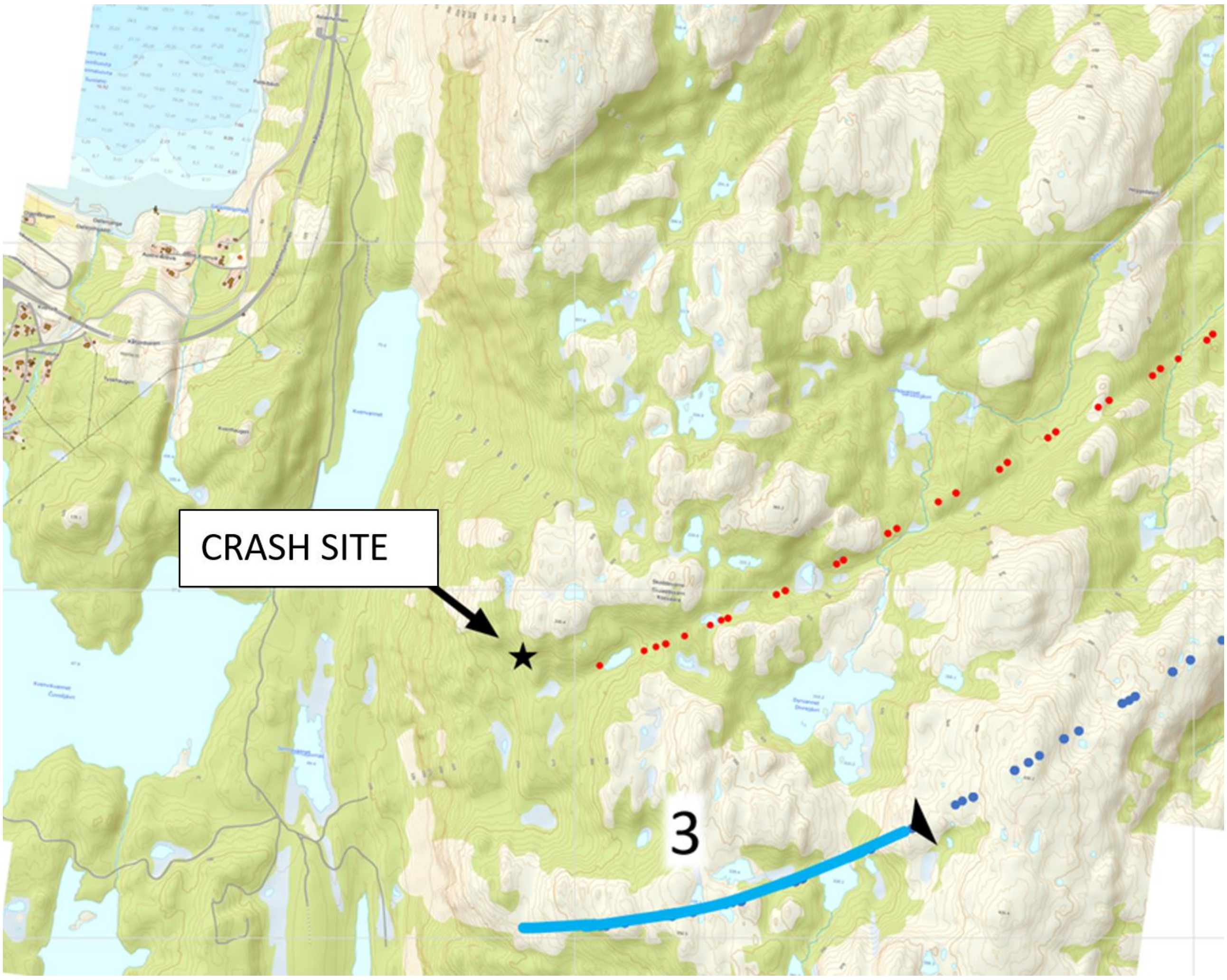

Figure 40: The final period of the first sightseeing flight is marked with a blue line. The last registered part of the accident flight is marked in red. Map: © The Norwegian Mapping Authority. Markings: NSIA

The last registered data point on the first sightseeing flight shows an altitude of 1,400 ft and a vertical speed of -2,432 ft/min. One of the passengers on the sightseeing flight stated that, after that, the flight descended along the mountainside in the direction of the festival area. The terrain profile and the flight path for the last period of the first flight are illustrated in Figure 41.

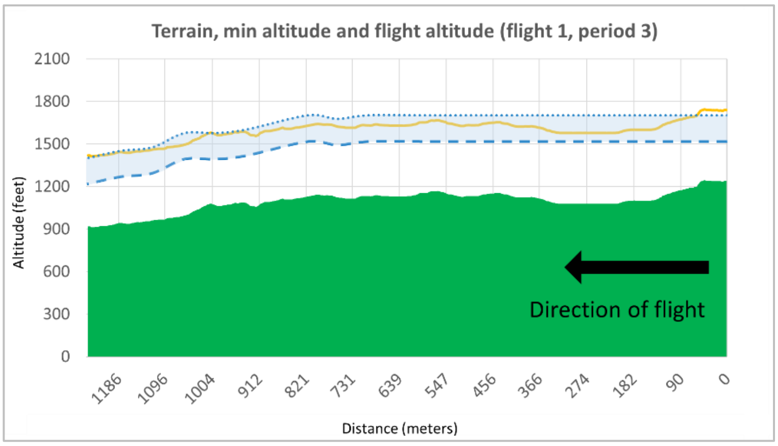

Figure 41: Altitude above the terrain during the last period of the first sightseeing flight. The green represents the terrain, the amber line shows the minimum altitude of 500 ft above the terrain, while altitude of the flight path is indicated in blue. The upper blue dotted line represents altitude data from Flightradar24, and the lower dotted line is the altitude of the flight path adjusted with data from CelloTrack. Source: NSIA

1.16.1.4 The accident flight

The timeline for the accident flight is based on the reported take-off time at 16:59. Flightradar24 registered data from 02:25 minutes into the flight, and the last time at which data were registered was after 06:10. The timeline for the flight path is shown in Figure 42.

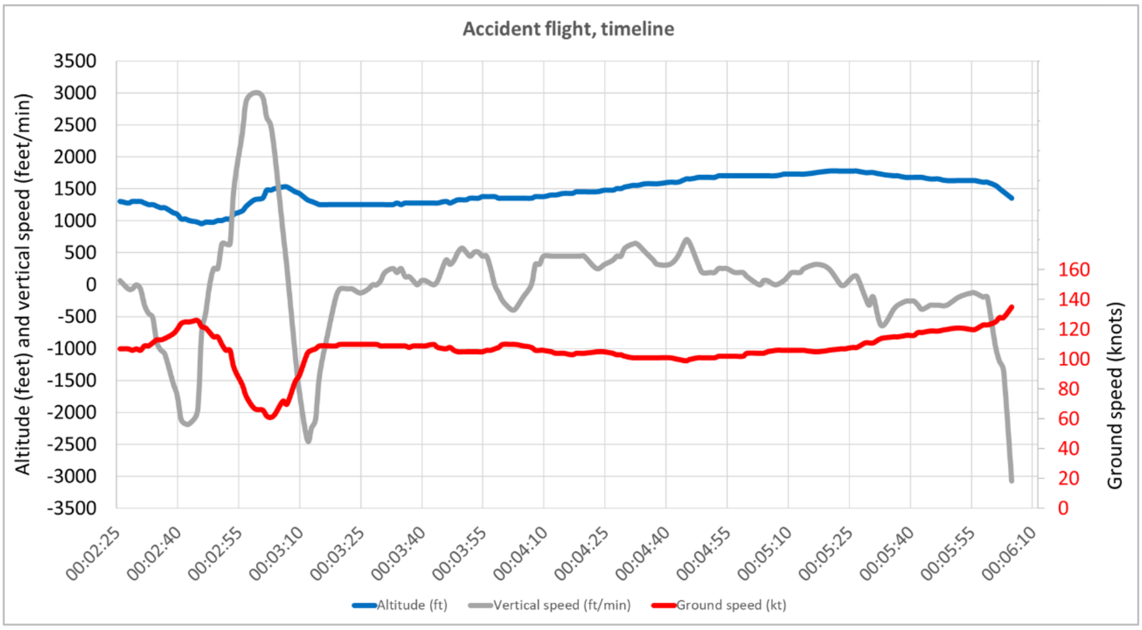

Figure 42: Flight path of the accident flight, with reference to the flight timeline. The blue curve represents altitude and the grey curve vertical speed, with the values shown on the left axis. The red curve represents ground speed, with the values shown on the right axis. Source: NSIA

There were variations in altitude and speed during two periods of the accident flight. The first took place after 02:28 minutes and lasted until 03:22 minutes had passed. The last period was from 05:40 to the last registered data point at 06:50.

The flight path followed during the first period of the accident flight is illustrated in Figure 43. The terrain profile and flight path followed during the first period of the accident flight is shown in Figure 44.

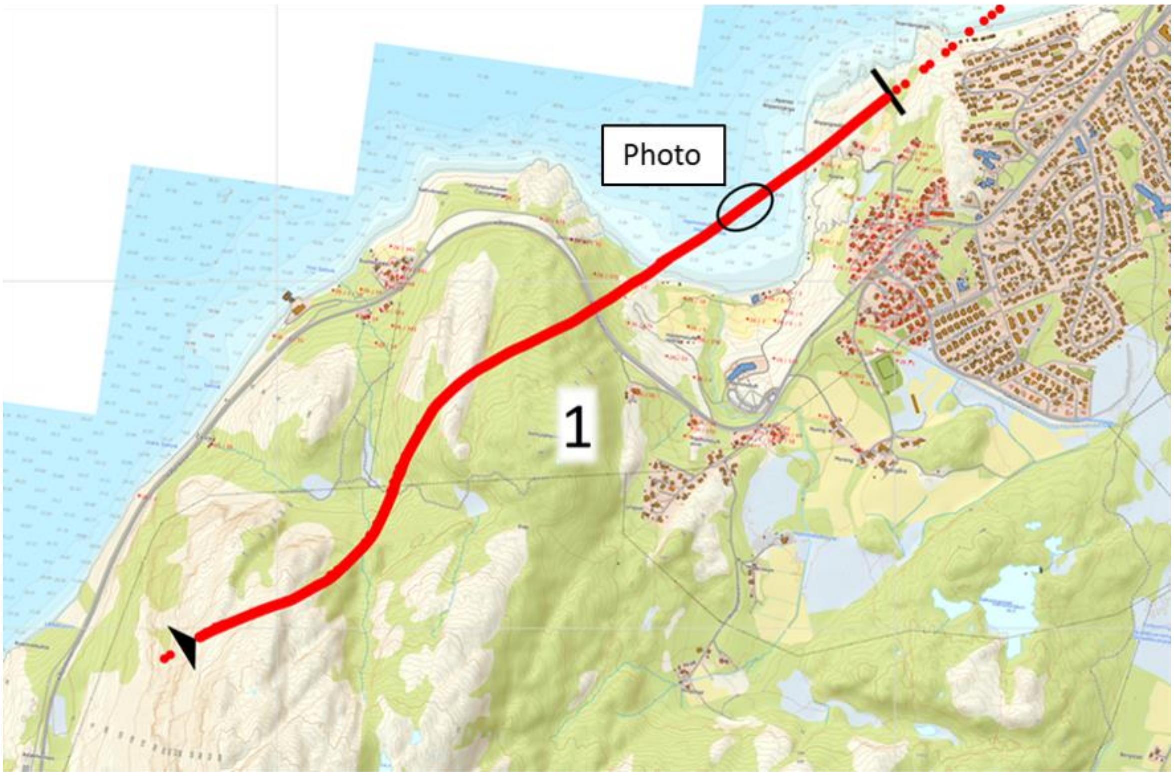

Figure 43: The first period of the accident flight. The area where the photo in Figure 3 was taken is marked. Map: © The Norwegian Mapping Authority. Markings: NSIA

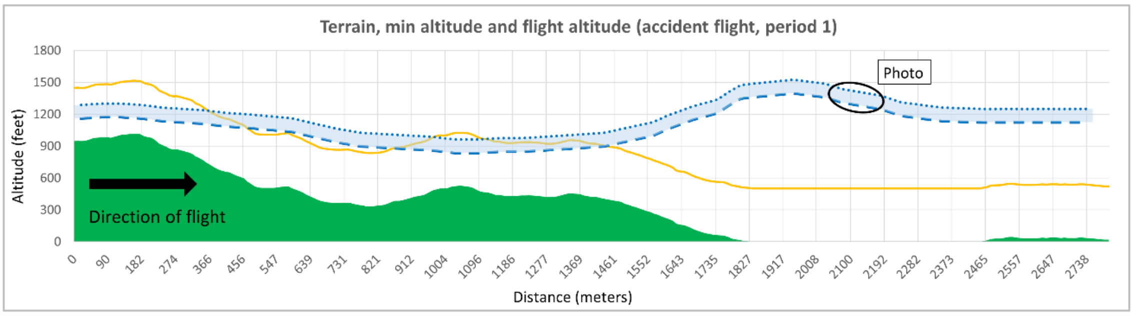

Figure 44: Altitude above the terrain during the first period of the accident flight. The green represents the terrain, the amber line shows the minimum altitude of 500 ft above the terrain, while altitude of the flight path is indicated in blue. The upper blue dotted line represents altitude data from Flightradar24, and the lower dotted line is the altitude of the flight path adjusted with data from CelloTrack. The area where the photo in Figure 3 was taken is also marked. Note that the direction of flight is from left to right. Source: NSIA

The flight path followed during the final period of the accident flight, which had variations in altitudes and speeds, is shown in Figure 45. The terrain profile and flight path for the last period of the accident flight are illustrated in Figure 46.

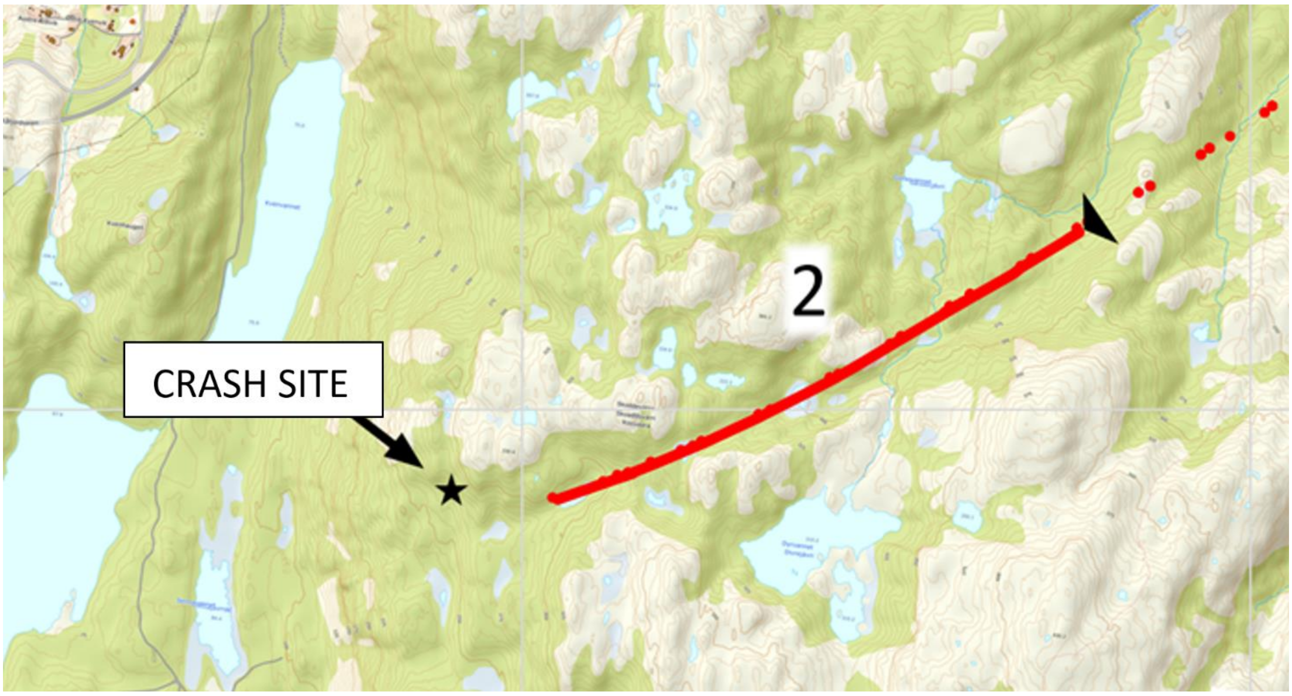

Figure 45: The final period of the accident flight. Map: © The Norwegian Mapping Authority. Markings: NSIA

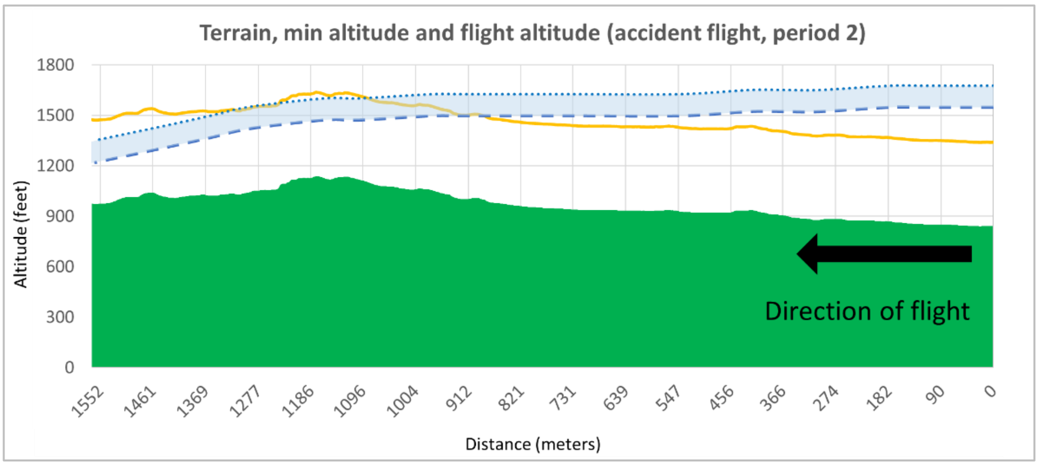

Figure 46: Altitude above the terrain during the final period of the flight leading up to the time of the accident. The green represents the terrain, the amber line shows the minimum altitude of 500 ft above the terrain, while altitude of the flight path is indicated in blue. The upper blue dotted line represents altitude data from Flightradar24, and the lower dotted line is the altitude of the flight path adjusted with data from CelloTrack. Note that the direction of flight is from right to left. Source: NSIA

1.16.2 ANALYSIS OF VIDEO AND AUDIO RECORDINGS

Several of the passengers on both sightseeing flights made brief video recordings and sent them to friends and acquaintances during the flight. The video recordings have been analysed for the purpose of extracting both operational and technical information. The time of the recordings could be determined by comparing the surroundings with information about the flight path (see Figure 47).

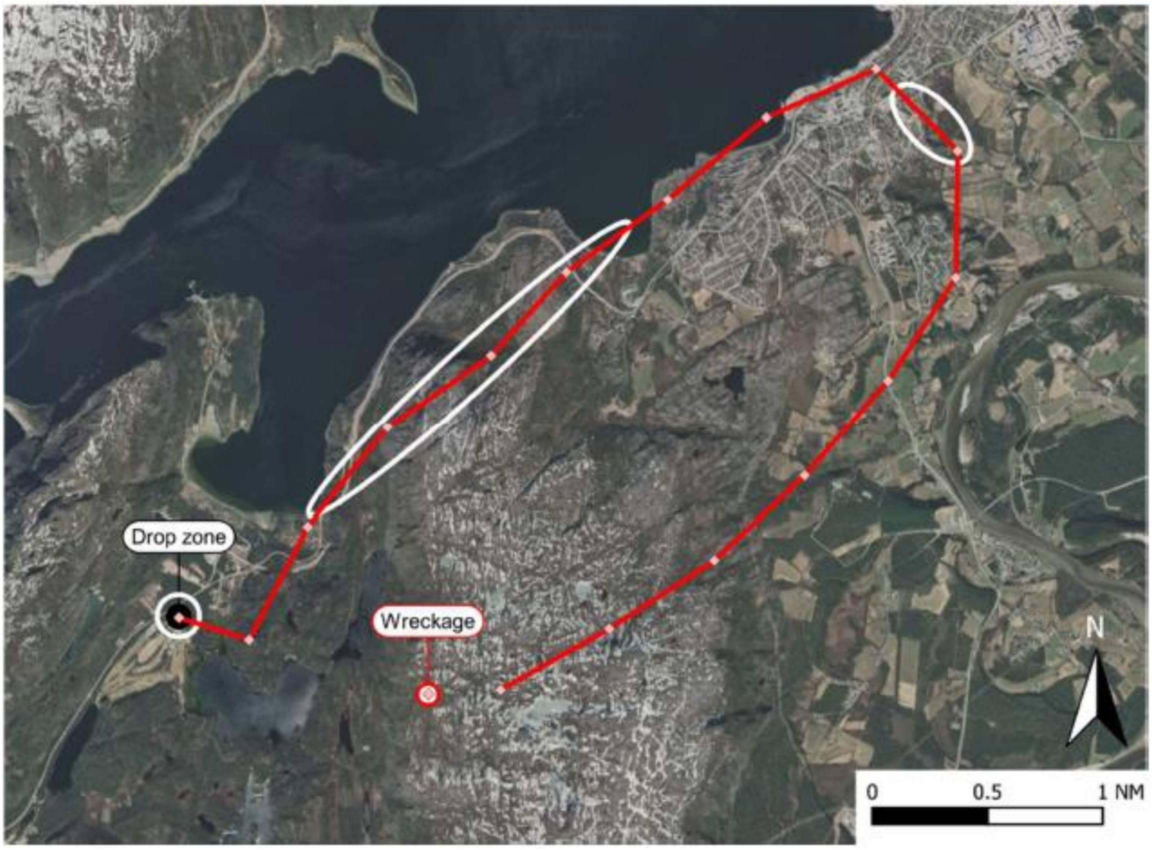

Figure 47: The flight track is marked in red and based on information from CelloTrack. The NSIA has received several videos that were taken during the flight. The white circles show where during the flight these were filmed. Source: Google Maps/BEA/NSIA

Frequency analyses of the videos can be used to identify possible technical faults in any of the helicopter's rotating components. BEA analysed a total of four Snapchat videos of 8-, 40-, 48- and 76-seconds' duration, respectively. With the exception of the shortest recording of 8 seconds, the duration and quality of the recordings were sufficient to enable good analyses.

The sound analyses did not detect any anomalies in the rotating components (engine, drive shafts, gears in the gearbox and rotors). The rotor and engine speeds appeared to be nominal.

The video recordings did not indicate any anomalies in the helicopter.

1.16.3 ACCESS TO SNAPCHAT VIDEO

Early on in the investigation, the NSIA learnt of the existence of a video recording from the final phase of the flight. One of the passengers had snapchatted with a friend for a period of time. The recipient has estimated that the video was of up to three seconds' duration, and it was taken in the forward direction from the same aft seat position as the photo in Figure 3.

According to the recipient, the video recording showed woodland and no sky, and the helicopter was in fast descent without rotating. The recipient could neither recall seeing anything unexpected or out of the ordinary to indicate that the helicopter was faulty, nor remember hearing any unusual helicopter sounds.

The recipient stated that, during the final part of the video, there was an exclamation from one of the passengers indicating that he or she was unhappy about the situation.

The recipient immediately responded by asking what was happening but received no reply. Between 17:07 and 17:10, the recipient then made five unanswered calls to the person who had sent the Snapchat video.

The video is no longer available, as it was only sent to a friend and she did not save it. The National Criminal Investigation Service contacted Snap Inc. in the USA on behalf of the police and was able to secure the account belonging to the person who sent the Snapchat video for a period of 12 months.

In parallel with the police's work to obtain access to the video, the NSIA contacted the National Transportation Safety Board (NTSB) in the USA, requesting assistance to obtain the video. The NTSB considered that it did not have the requisite authority and stated that any request to possibly obtain information from Snap Inc. would have to be routed via the judicial authorities.

It is clear from Snap. Inc.'s website that the company has a very restrictive policy for disclosing information to third parties. The following are examples of what is required:

> *Inform us that your case involves child exploitation, or the threat of imminent death or bodily injury, and provide a sufficient legal and factual basis for us to make this determination.*

In cooperation with the Norwegian Police, judicial authorities in Norway and the USA have sought to gain access to the video. It has not been possible to gain such access, however, or to get confirmation from Snap Inc. that the video recording has been stored. The NSIA contributed to the process by explaining in writing how access to the video could possibly help prevent future accidents with this frequently used helicopter type.

The NSIA also contacted Ibas Ontrack AS to find out whether it was possible to retrieve the video from the recipient's mobile phone and was told that this was not possible.

1.16.4 GENERAL INFORMATION ABOUT THE TECHNICAL EXAMINATIONS

The NSIA was assisted by a team of experts from the French investigation authority BEA, the helicopter manufacturer Airbus Helicopters and the engine manufacturer Safran Helicopter Engines (SHE) both during technical examinations at the accident site and during subsequent examinations in the NSIA's premises.

When the wreckage arrived at the NSIA's premises, the components were examined and positioned in a simplified reconstruction. It was primarily the tail section, and the remains of the main rotor, engine and steel components that were available for detailed examinations. Engine controls and other components made of aluminium alloys had melted in the fire together with parts of the flight controls and transmissions to the rotor system. The largest chunks of melted aluminium were X-rayed with regards to detect possible parts without making any findings of importance to the investigation.

The engine and the engine's systems for controlling the fuel supply were carefully examined. The drive shaft between the engine and gearbox, the flexible couplings with fastening bolts, and the free turbine were sent to DNV GL to undergo fracture- and metallurgical examinations. Both NSIA and Airbus Helicopter participated in these investigations.

A more detailed description of the various examination results and observations is provided in the sections below.

1.16.5 EXAMINATION OF THE DRIVE SHAFT FOR THE MAIN GEARBOX

The drive shaft with flanges in both ends, the gimbal coupling, that encircles the drive shaft and the flexible coupling for the main gearbox, were examined. Rotation damage was found in the flanges between the drive shaft and main gearbox, as well as inside the gimbal housing.

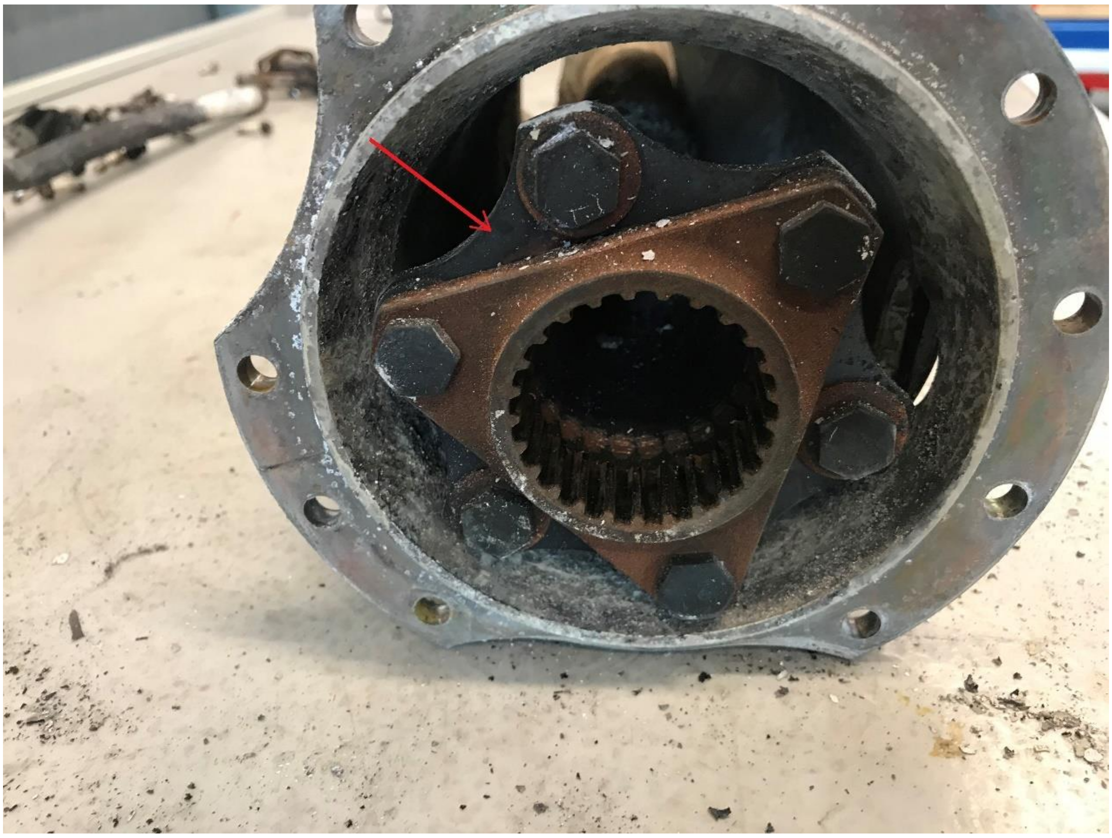

Figure 48: The drive shaft between the engine and main gearbox seen from the engine side. The flexible coupling, see red arrow, appears to be undamaged. Photo: NSIA

Figure 49: Drive shaft between engine and main gearbox with flange for connection to the gearbox. The flange shows rotation damage in several places and no remains of the flexible coupling. The gimbal coupling in the background is severely damaged by heat and also shows signs of rotation damage. Photo: NSIA

The shaft between the engine and main gearbox has a flexible coupling at either end, which had come off at the gearbox side. Figure 48 shows the engine side of the shaft and a virtually undamaged flexible coupling. When broken, the flexible coupling would be expected to look like the photo in Figure 29. As shown in Figure 49, there were no remains of the flexible coupling on the flange, and the same was true on the main gearbox side. Because of the unusual appearance and the fact that no unbroken bolts were found, it was considered important to map the fracture propagation and thus determine whether it could have happened while the helicopter was in the air or was a result of the impact with the ground.

The flexible coupling consisted of 18 x 0.2 mm steel discs held together by steel sleeves. Each disc had six holes. There is a flange at the gearbox end of the shaft and a corresponding flange on the gearbox side. Each of them has three lugs with holes for inserting a bolt. The coupling was kept together by six bolts with washer and castle nuts. The castle nuts were locked with cotter pins through the hole at the tip of the bolt. Each bolt is identified by a part number and a production serial number, but Airbus Helicopters has not established any system whereby production serial numbers can be linked to individual aircraft.

Figure 50: All the bolt halves that were found. For reference purposes, two unbroken bolts with nuts are shown in the lower part of the photo. Photo: DNV GL/NSIA

In total 11 of 12 bolt halves were found (see Figure 50): six with nuts attached and five with bolt heads. Thus, the NSIA had at least one fracture surface from each of the six bolts available for metallurgical examination. The metallurgical examination was carried out by DNV GL. No deviations from specified chemical composition, hardness or tensile strength were found in the tests performed.

Helitrans contributed with bolts removed from other AS 350 helicopters that served as references during the examinations. NSIA received the technical requirements specifications from Airbus Helicopters. Some of the reference bolts had fewer flight hours than LN-OFU. Measurable wear was found on the unthreaded part of all these bolts, and the cadmium coating had been worn away. This is mentioned as an observation, unrelated to the accident.

DNV GL’s examinations showed that all the fractures in the bolts were the result of tensile and shear overloading (see Figure 51 and Figure 52). There were no signs that fatigue cracks had occurred prior to the accident.

Figure 51: The fracture surfaces of one of the bolts. The sleeve that is inserted through the discs can be seen on the right by the nut. Photo: DNV GL/NSIA

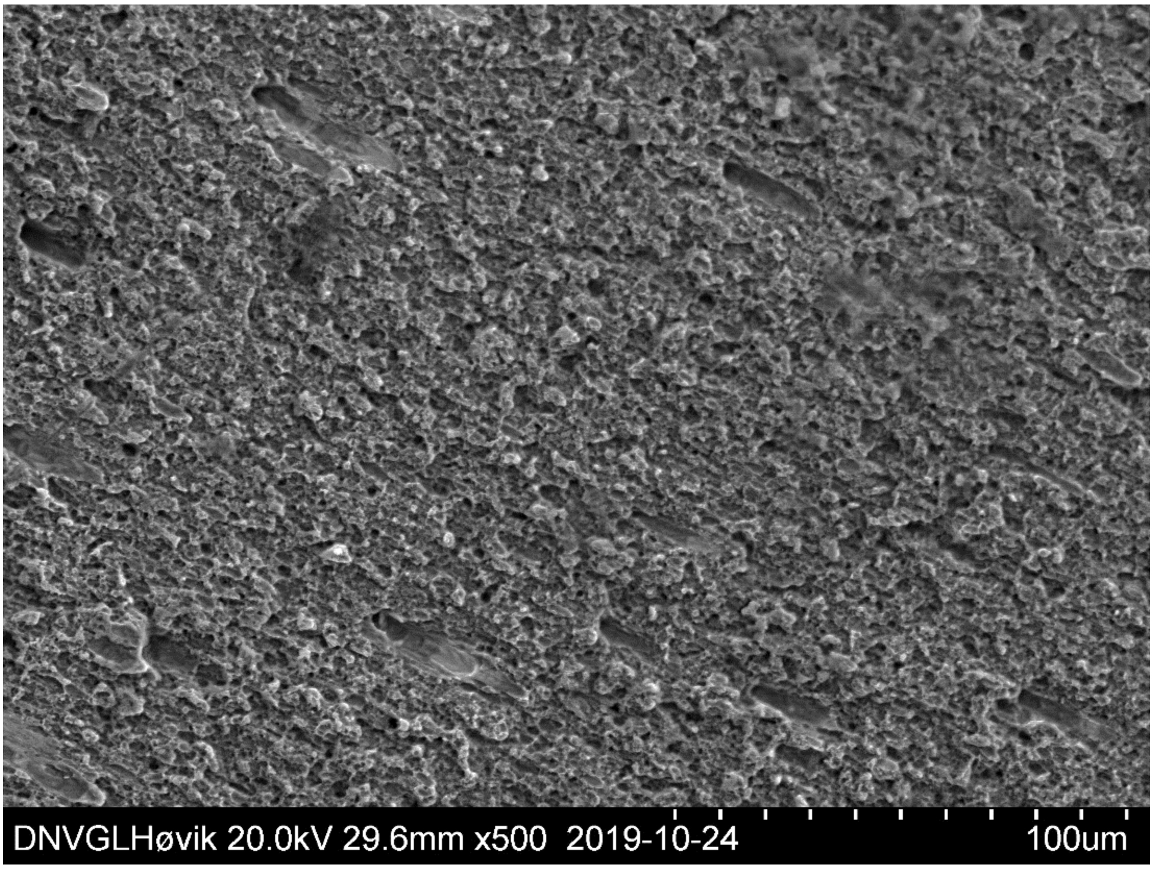

Figure 52: The fracture surface of the bolt in the previous figure, magnified 500 times. The dimples in the fracture surface are evidence of a ductile overload fracture. Photo: DNV GL/NSIA

A great number of segments of various sizes of discs which constitute the flexible coupling were found at the accident site. The 18 discs in the coupling had a total of 108 holes, and the remains of discs with a total of 104 holes were found. Most of the discs were twisted and bent (see Figure 53). Four segments were found with five holes intact, while the majority of segments had only one hole.

Figure 53: Disc segments from the flexible coupling. Photo: DNV GL and NSIA

All the fractures in the discs were analysed by DNV GL with participation from Airbus Helicopters. They were assessed as being largely ductile overloading fractures, propagated as a result of tensile loading or shear stress. No deviations from specified chemical composition, hardness or tensile strength were found in the tests.

To understand the damages to the disc segments of the flexible coupling Airbus Helicopters made an animation. The animation showed the load at different angles of misalignment and rotation between the drive shaft and the main gear box. Still pictures from the animation is shown in Figure 54 and Figure 55. The animation shows that there must be a significant angle of misalignment to explain the damages. A disc from LN-OFU is shown for comparison in Figure 55.

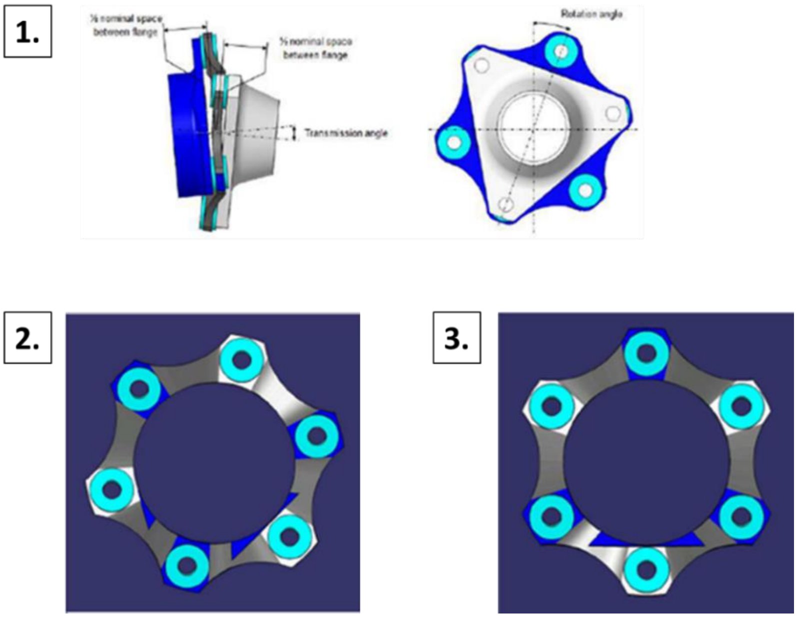

Figure 54: The illustration from the animation shows how the damages to the flexible coupling discs can be created after contact with the drive shaft due to misalignment between engine and main gear box. Source: Airbus Helicopters/NSIA

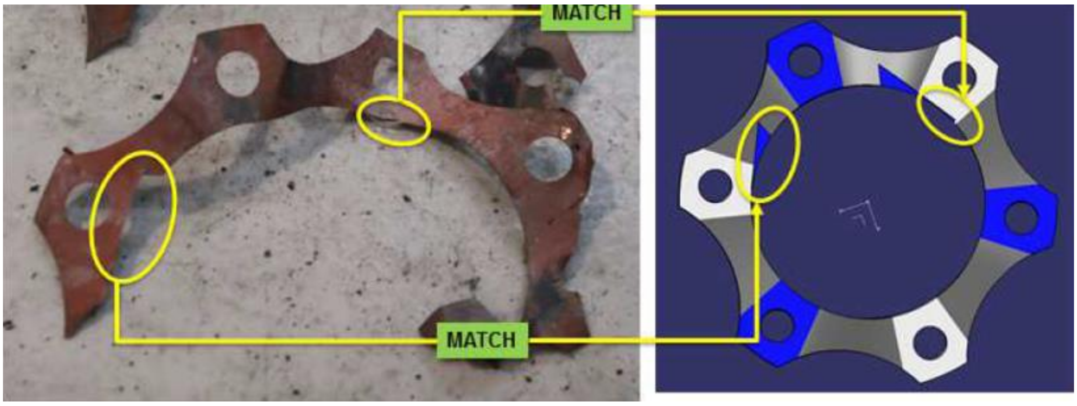

Figure 55: Comparing the damages to the actual disc segments of LN-OFU and typical damages to the disc segments due to misalignment of the driveshaft it was found that they were close to identical. Source: Airbus Helicopters/NSIA

1.16.6 EXAMINATION OF THE ENGINE

1.16.6.1 General information

The engine and external components were relatively undamaged; see Figure 56. The engine was examined by the NSIA and Safran Helicopter Engines. The plugs for the wiring to the EBCAU and torque sensor were broken. Large parts of the wiring for the DECU had burnt up completely (see section 1.6.3 for a description of the engine and relating systems).

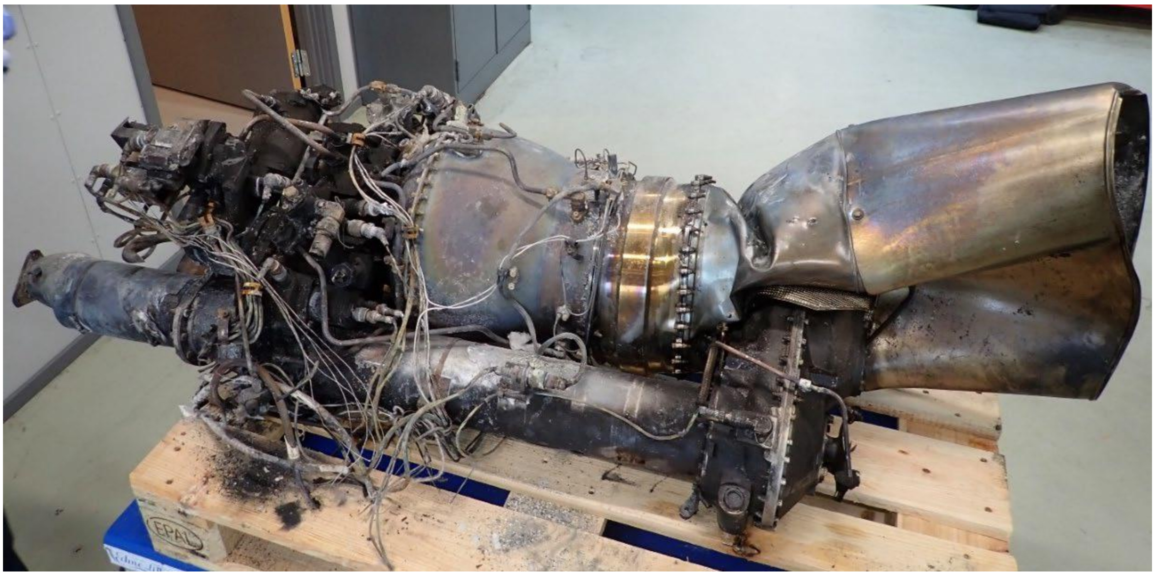

Figure 56: The engine before it was disassembled in the NSIA's premises. Photo: Safran Helicopter Engines/NSIA

Rotation marks on the conical surface at the centre of the compressor and notches in the compressor blades are indications that foreign bodies had entered the air inlet while the gas generator was in highspeed rotation. Molten aluminium had run down the engine at different angles, which indicates that the engine had changed position while the fire was in progress.

To start with, the following components were removed from the engine and examined:

- Fuel filter: visually inspected and found to be uncontaminated.
- Engine oil filter: visually inspected and found to be uncontaminated.
- Magnetic oil plug, Module M01: no particles worth mentioning were found.
- Magnetic oil plug, Module M05: some minor particles found; see Figure 57. Safran Helicopter Engines considered the particles to have come from the gearbox in connection with the increase in rotational speed and the damage to the power turbine.
- Magnetic plug for return oil: visually inspected and found to be uncontaminated.

Figure 57: Magnetic oil plug in Module M05. Photo: NSIA

A borescope inspection of the interior of the gas generator showed some minor damage from foreign bodies in the compressor. The inside was sooty, but no further interior damage was found (see Figure 58).

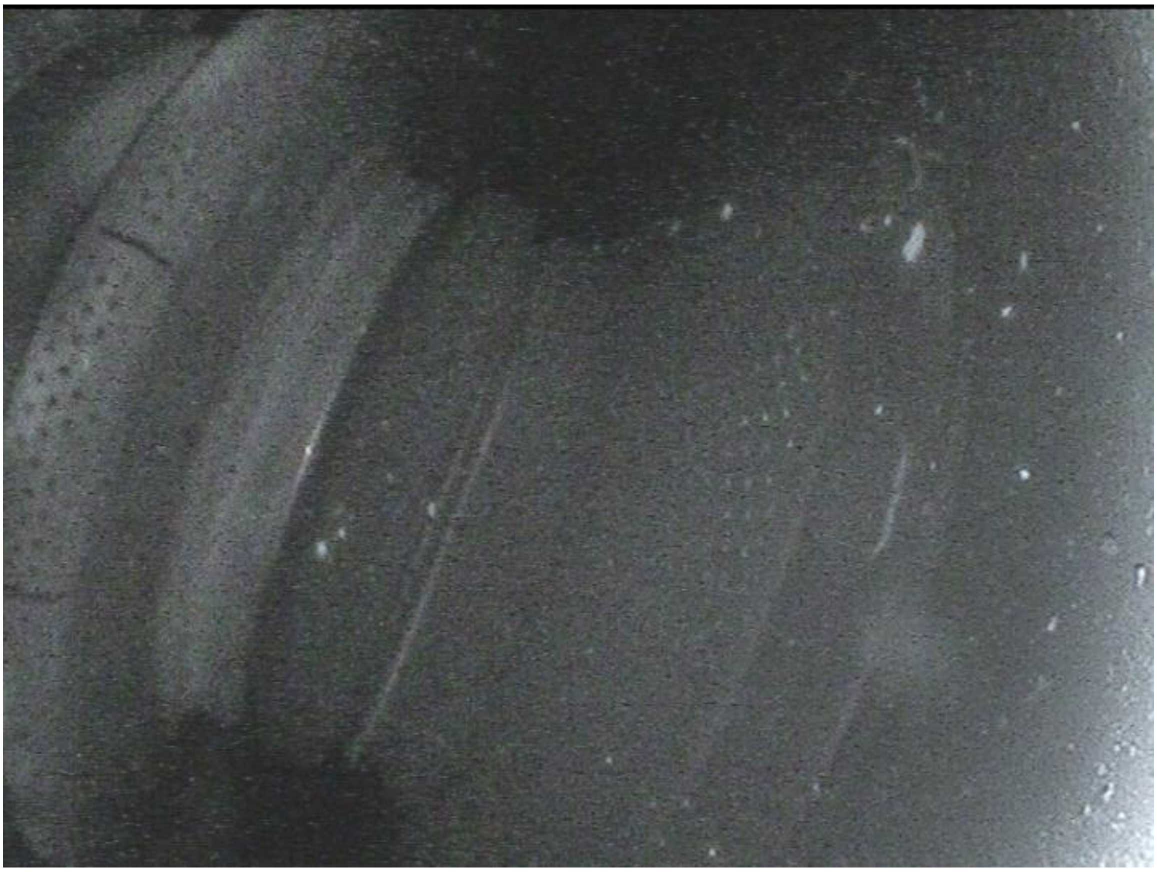

Figure 58: Photo of combustion chamber taken with a borescope camera. The area was undamaged, but covered in soot. Photo: NSIA

1.16.6.2 Power turbine

As mentioned in section 1.6.4, the turbine blades are designed with a notch at the root of the blades to prevent a theoretical power turbine disc burst. The power turbine had shed all 37 blades; see Figure 59. The roots of all the blades were left in the turbine disc grooves, while fragments from only a few blades were found on disassembling the engine. No recognisable fragments of turbine blades were found at the accident site.

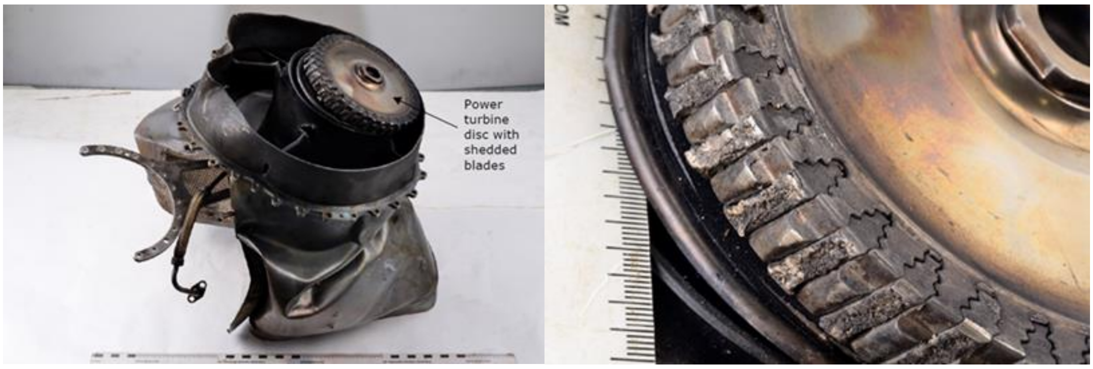

Figure 59: All 37 blades on the free turbine had just about identical fracture surfaces at the root of the blade. Photo: DNV GL/NSIA

The turbine disc without blades, the shaft and the bearings were undamaged, but had become misaligned relative to the centre of rotation. This had caused the turbine disc to come into contact with the turbine housing during rotation, whereby the fracture surfaces had largely been destroyed.

DNV GL examined the various fractures on the turbine blades. All 37 blade roots were removed from the turbine disc grooves and examined. The examination showed that all fractures were largely ductile fractures and had occurred at the notch. There were no signs of fatigue. One brittle dendritic structure was found in a limited area but was not deemed to have contributed to the fracturing.

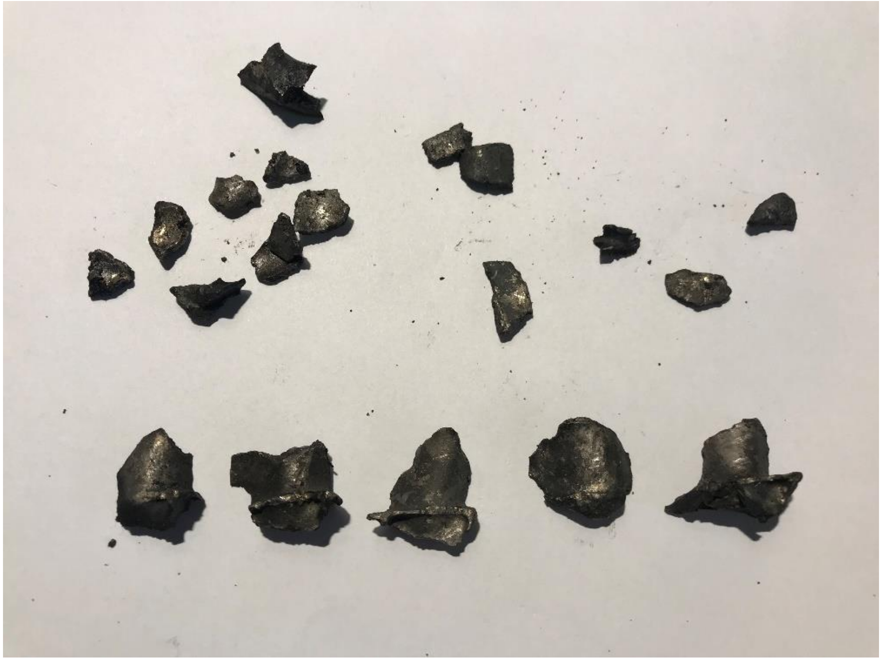

Figure 60: Turbine blade fragments found during engine disassembly. Photo: NSIA

1.16.6.3 Hydro-mechanical fuel control unit

The hydro-mechanical unit (HMU) showed little heat damage. The back-up control unit (EBCAU) was removed from the HMU and it was established that the shaft between the HMU and the EBCAU had retained its normal position; see Figure 61.

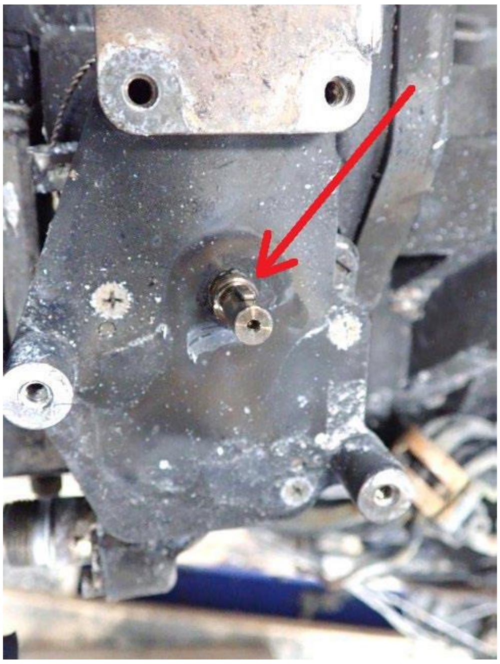

Figure 61: The arrow points to the locking finger on the shaft between the HMU and the EBCAU. When it points straight upwards, the EBCAU has not taken over control of the engine. Photo: Safran Helicopter Engines

The fuel pump was disassembled and examined. There was heat damage to some internal gaskets, but both pump stages were otherwise undamaged. The first stage is shown in Figure 62.

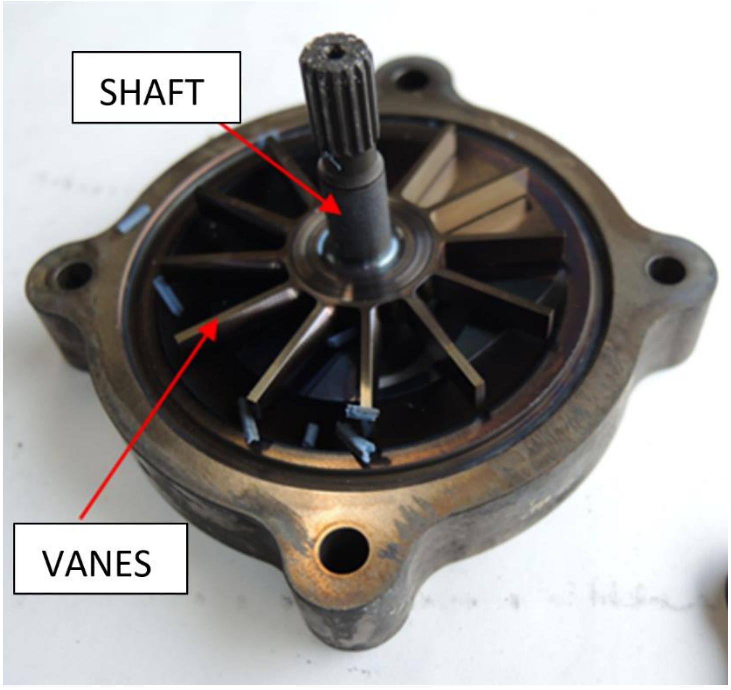

Figure 62: The vanes and shaft in the low-pressure part of the fuel pump. Small bits of the interior blue gasket were further fragmented and fell off during disassembly. Photo: NSIA

1.16.6.4 The power turbine's overspeed protection system

The power turbine's overspeed protection system is described in section 1.6.4. The stop electro valve (SEV) on the fuel supply is controlled by DECU based on rpm signals from the N2B and N2C sensors and the torque sensor. Overspeed must be detected by both N2 sensors and the torque sensor for the SEV to be activated.

The SEV normally remains in the most recently commanded position. The valve was taken to Aerospace Industrial Maintenance Norway AS (AIM) at Kjeller to be X-rayed so as to determine its position. The NSIA and Safran Helicopter Engines assessed the X-ray images and concluded that the valve was most probably in the open position (see Figure 63). This indicates that the fuel valve intended to shut of the fuel flow at 120% had not been activated by the DECU.

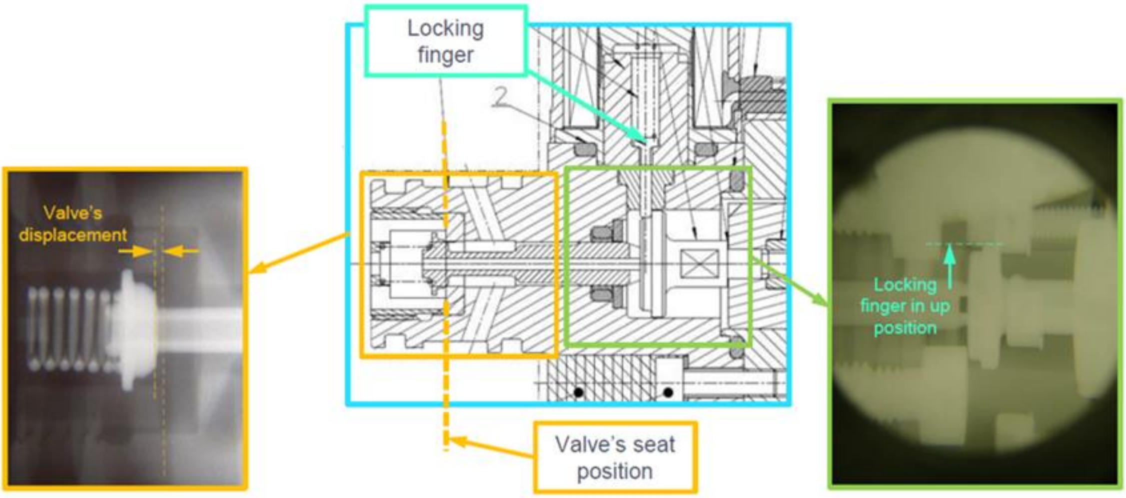

Figure 63: X-ray images of the SEV showed that it was found in the open position and had not been activated. Illustration: Safran Helicopter Engines. X-ray images: AIM/NSIA

When the sensors were removed, it became evident that the connecting plug for the torque sensor had been destroyed by crash forces. The sensors were sent to France to be inspected for damage. The work was conducted by Safran Helicopter Engines under the auspices of the French investigation authority (BEA). The N2 sensors were found to be undamaged, while a small contact mark was found on the pickup part of the torque sensor (see Figure 64). No malfunction was found when the sensors were tested.

Figure 64: The torque sensor with contact mark on the pick-up part, the damaged connecting plug and the three undamaged N2 sensors. Photo: Safran Helicopter Engines/NSIA

In order to determine the cause of the contact mark, the engine's transmission shaft (Module M01) was examined. The examination revealed a bent tooth and another tooth that was marked by contact with the torque sensor (see Figure 65).

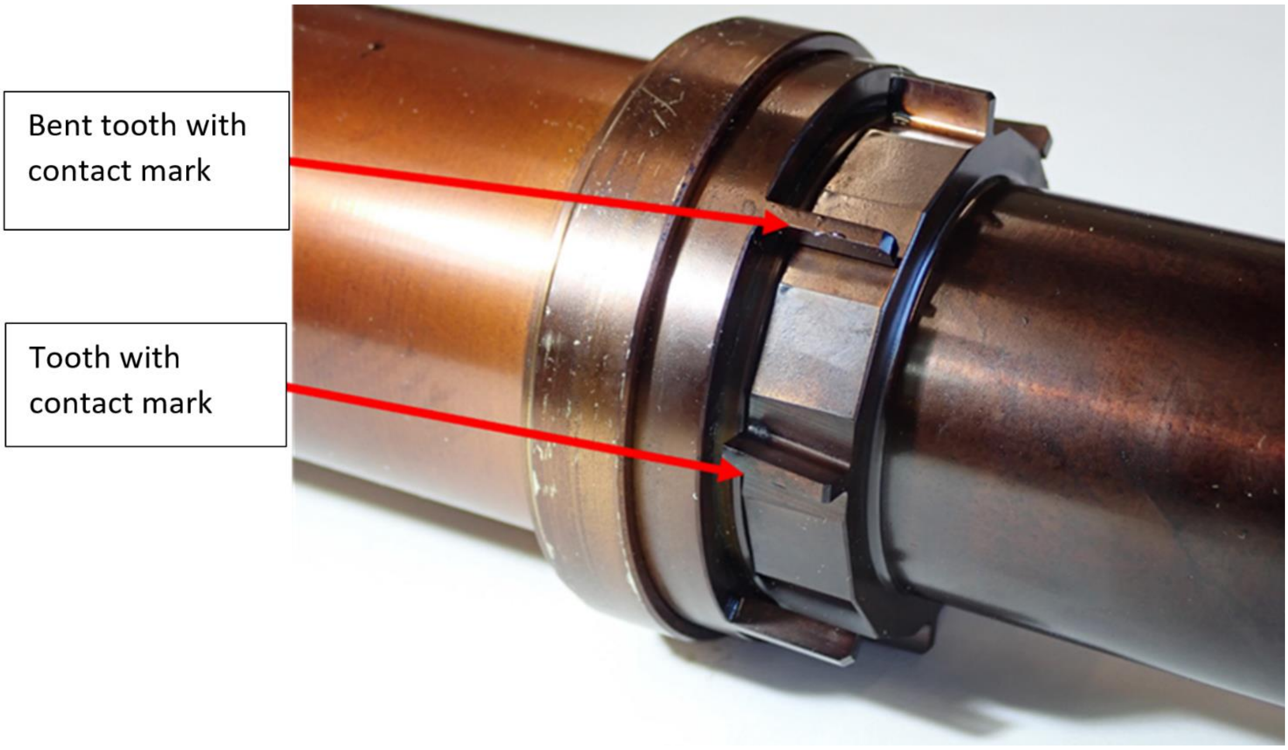

Figure 65: The engine's transmission shaft with contact mark and bent tooth. Photo: NSIA

1.16.6.5 The engine's power transmission

As part of the investigation, it was of interest to determine whether there had been any overloading of the drive train between the power turbine and the rotor system, for example as a result of the engine supplying power at the same time as the rotor blades were exposed to abrupt braking forces at the moment of impact with the ground. The engine's transmission shaft with freewheel clutch (Module M01) and gearbox (Module M05) was dismantled. The gearbox was in good condition, except where it was connected to the power turbine where parts of the gearbox housing had broken off in the impact.

The freewheel clutch was function-tested and inspected. It could be rotated manually, and the locking function appeared to work as intended. The clutch was then disassembled for interior inspection. Blue oxidation marks were found on the outer ring of the freewheel clutch. The clutch was then brought to AIM at Kjeller for measurement of dimensions, shaft deflection and surface roughness. No significant deviations were observed. It was established that the oxidation was due to contact with oil at high temperature (see Figure 66).

Two alignment marks on one shaft and nut in the gearbox (Modul M05) had not moved in relation to each other (see Figure 67). Movement of these marks in relation to each other would indicate that the engine has supplied power at the time of the accident. However, based on experience, it is quite possible for the engine to supply power during a crash without the marks becoming misaligned.

Figure 66: The freewheel clutch. From left to right: the outer ring with blue oxidation marks, the inner shaft with oxidation marks from the sprags and the ring with sprags on the bottom right. Photo: NSIA

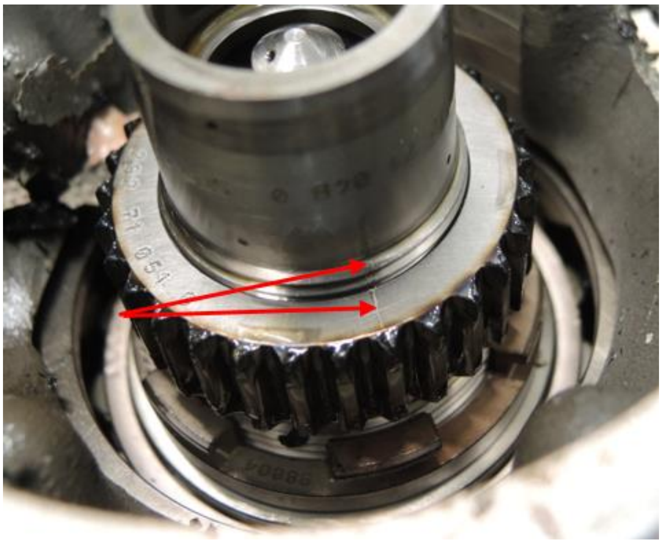

Figure 67: The alignment marks on LN-OFU. The blue discolouration of the nut was caused by the heat that developed after the crash. Photo: Safran Helicopter Engines/NSIA

1.16.7 FUEL SAMPLES

The helicopter was completely burnt out and no fuel was found at the accident site. It was thus impossible to take fuel samples from the wreckage. The day after the accident, the NSIA, accompanied by the helicopter operator, secured fuel samples from the tank at the operator's base in Alta Airport, where the helicopter's tank was topped up for the last time. There were no traces of water in the fuel samples, which were taken from the fuelling nozzle/hose and bottom of the tank, respectively.

1.17 Organisational and management information

1.17.1 HELITRANS AS

Helitrans AS is a Norwegian operator with its head office at Trondheim Airport Værnes. The operator started up in 1990 and was, the following year, granted an Air Operator Certificate (AOC) based on BSL JAR-OPS 3. Helitrans AS used to operate both aeroplanes and helicopters. It gradually wound up its aeroplane operations and has focused exclusively on helicopter operations since 2012. Its core business was to offer services to companies and private individuals, including personnel transport, sling load operations and mast installation.

At the time of the accident, Helitrans AS employed a total of approximately 100 staff. The operator had an approved technical department with 12 employees who performed inspections and maintenance on their own helicopters.

At the time of the accident, Helitrans AS had a total of 21 helicopters, 14 of which were of the type Airbus AS 350 B3. The base at Alta Airport was one of eight bases run by the operator. The operator also conducted inland operations from Værnes, Tromsø, Kjeller, Narvik, Mo i Rana, Sauda and Stavanger. The air operating certificate also applied to commercial sightseeing flights.

1.17.2 HELITRANS' PROCEDURES FOR SIGHTSEEING FLIGHTS

Excerpt from the helicopter operator's Operations Manual-Part E section 9.1 – Nature and complexity of the activity and section 9.5 – Normal procedures, are reproduced in Figure 68 and Figure 69.

Section 9.1 refers to commercial sightseeing flights as the most basic operation there is. There are no minimum flight hour requirements for this SOP.

According to section 9.5 on normal procedures, in addition to being entered on a list, passengers must be checked to ensure that they are fit to fly and given a safety briefing. The passengers on the first sightseeing flight have stated that they were not given any specific safety information before the flight. The NSIA has not been able to determine whether that was also true on the accident flight.

The loadmaster has informed Helitrans that he gave both groups of passengers a safety briefing before they boarded the helicopter.

The same section also defines maximum angles of roll (rotation around the longitudinal axis) and pitch (nose up/down) of 30° and 15°, respectively, at altitudes below 500 ft above ground level. Unless absolutely necessary, these limits shall also not be exceeded at altitudes of more than 500 ft above ground level. 'Stunt flying' is prohibited. The maximum limits for pitch and roll were introduced as a result of the NSIA's safety recommendations after the Dalamot accident (see section 1.6.8.3).

9.1 Nature and complexity of the activity:

For company pilots at an entry level this SOP allows them to start flying performing the most basic operation there is.

The purpose of sightseeing flights is to provide passengers a pleasant and memorable experience. Sightseeing flights are often held in conjunction with happenings of all kinds, but can also be facilitated in connection with birthdays, anniversaries, and other commemorations. The flight will be performed as smooth as possible so that it can not provoke any fear or discomfort among the passengers. Although a passenger may have "won" a helicopter ride, this passenger may never been aboard a helicopter before, and therefore may have a built-in scepticism towards helicopter. It is therefore important that the pilot has this in mind and performs a considerate flight. The pilot must under no circumstances be influenced to perform any kind of "stunt flying".

This SOP may not be performed in areas considered as congested hostile environment.

Helicopters to be used for activities involving takeoff and landing in urban and other densely populated areas shall be equipped with at least two engines, and the weight should be adjusted so that every phase of the flight can be conducted in a satisfactory manner with an engine inoperative.

Excluded from this provision are flying that can follow a route where the helicopter can land without hazard to persons or property on the ground.

Figure 68: Operations Manual-Part E section 9.1 – Nature and complexity

9.5 Normal procedures:

All passengers shall have a ticket which the company retains a copy of the passenger's name. This is the passenger manifest.

Passengers under visible influence of alcohol or other sedative / intoxicants (such as drugs) are not accepted.
It is not allowed to bring knives or firearms of any kind

Perform a standard passenger briefing IAW OM-A

The helicopter shall within the operating site and takeoff/landing path be maneuvered so as to cause minimum inconvenience to the public and any neighbors. Flying over houses and similar is forbidden.
Otherwise observe all noise abatement in the General information part to this manual

Maximum angle of pitch / bank shall not exceed 30 degrees bank and 15 degrees nose up / nose down when flying below 500 ft agl. This limitation should not be exceeded when flying over 500 ft agl unless it is strictly necessary. "stunt flying" is prohibited.

A flight shall not be conducted over water.

Figure 69: Operations Manual-Part E section 9.5 – Normal procedures

1.17.3 REGULATIONS ON MINIMUM ALTITUDE

The minimum altitude above the terrain that was permitted during the relevant sightseeing flights was 500 ft; see the Regulations of 14 December 2016 No 1578 on aviation rules and operational procedures (BSL F 1-1[23]).

[23] BSL F 1-1 describes Standardised European Rules of the Air (SERA) and includes special provisions for Norway.

1.18 Additional information

1.18.1 INFLUENCE FROM PASSENGERS

The NSIA has searched within research on road traffic and in findings from air accidents relating to whether and how a pilot's behaviour potentially can be influenced by having passengers on board. This is summarized in Appendix C.

1.18.2 AS 350 SIMULATOR AND SIMULATOR TRAINING

On 17 October 2019, Coptersafety opened a AS 350 full flight simulator (FFS) training facility at Vantaa in Finland. This is an EASA/FAA FFS level D (the highest level) simulator. According to the manager, it can also offer training in how to deal with servo transparency. The COVID-19 pandemic has freed up simulator capacity.

Requirements for use of simulator training are described in AMC1 ORO.FC.230(a)(4)(ii)(A) and AMC1 ORO.FC.230(e), as well as in the corresponding Easy Access Rules for Flight Crew Licensing (Part-FCL):

FCL Appendix 9 A (1):

> *The training, skill test or proficiency check for class or type ratings for SPA and helicopters shall be conducted in:*
>
> *(a) an available and accessible FFS, or*
>
> *(b) a combination of FSTD[24](s) and the aircraft if an FFS is not available or accessible; or*
>
> *(c) the aircraft if no FSTD is available or accessible.*

CAA-N considers that the simulator in Finland is available and has informed the NSIA of its intention to follow up on the use of FFS in the training for AS 350 helicopters.

Use of simulator training was also a topic in the investigation of the accident with LN-OXC at Dalamot. No safety recommendations were issued relating to use of simulator training. The experience of using an AS 350 simulator in connection with the Dalamot investigation was very positive. The experience of servo transparency in the simulator was described as very realistic. Appendix A contains excerpts of the memo from the simulator trials. It is considered in the memo that previous accidents could have been prevented through more use of simulator training.

On 19 June 2019, CAA-N adopted a decision amending the Regulations of 28 November 2015 No 1365 on certification of aircrew operating aeroplanes. The regulations implement Commission Implementing Regulation (EU) 2018/1974 of 14 December 2018 amending Regulation (EU) No 1178/2011 in Norwegian law (national implementation).

Requirements are defined for upset prevention and recovery training (UPRT) as part of the pilot education. 'Upset' refers to an unexpected aircraft situation or attitude. The proposed UPRT requirements are intended to make pilots better able to avoid and handle such unexpected situations.

The requirements for UPRT do not apply to rotorcraft.

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[24] *Flight simulation training device (FSTD). Less advanced than a full flight simulator (FFS). EASA certification specifications CS-FSTD(H), Decision 2012/011/R of 4 July 2012.*

1.18.3 THE ACCIDENT WITH LN-OML IN FINNMARK COUNTY IN NORWAY IN 2009

LN-OML, an AS 350 B3 helicopter, crashed at Brannsletta in Nesseby in Finnmark County[25] due to losing hydraulic pressure just above the ground. The helicopter ended up laying on its left-hand side. The pilot was only lightly injured and was able to get out of the cockpit without assistance. Fire developed very fast, however, as a result of the crash and the margin in which to escape was very narrow. The front window was broken, which made it easier to get out. Evacuation through the right-hand door, which was pointing skywards, would have taken longer. Had the pilot been seriously injured or lost consciousness, the situation could have been very critical. The pilot was secured by seatbelts and wore a helmet. This most probably contributed to limiting the pilot's injuries and enabled self-evacuation.

1.18.4 MEASURES IMPLEMENTED AFTER THE ACCIDENT WITH LN-OFU

1.18.4.1 Drive shaft and flexible couplings

Based on the condition of the drive shaft between the engine and main gearbox and related flexible couplings (see 1.16.5) and early witness statements (see 1.1.6.2) an Emergency Alert Safety Bulletin (EASB), AH AS 350 ASB 63.00.32, was issued on Airbus Helicopters' initiative on 11 September 2019. It was distributed to operators of relevant helicopter types as an EASA Emergency Airworthiness Directive (AD)[26] No.: 2019-0225-E on 11 September 2019.

The operators were ordered to immediately conduct a visual inspection of the flexible couplings and discs, bolts, nuts and locking pins at either end of the drive shaft. The order only applied to relatively new helicopters with less than 300 hours' flight time.

Helitrans conducted such an inspection without finding any nonconformities. Nor is the NSIA aware that other operators have detected nonconformities as described in the AD note.

1.18.4.2 Crash resistant fuel system

Shortly after the accident with LN-OFU, CRFS for AS 350 was also certified compliant with CS 27.952 with underbelly cargo swing installation. Airbus Helicopters has informed the NSIA that all new AS 350 helicopters delivered after 1 October 2019 will be equipped with CRFS. Airbus Helicopters[27] stated the following on its website:

> *The H125 is now equipped in baseline with a crash-resistant fuel system fully compliant to 27.952 with swing load operation.*

Airbus Helicopters sent a letter dated 10 October 2019 to all operators of AS 350, H125 and EC130, urging them to retrofit a crash resistant fuel system. The following is quoted from the letter:

> *Airbus Helicopters strongly recommends all its customers operating AS 350's, H125's and EC130's in all types of mission segments and geographical regions to equip their aircraft with the CRFS or CRFT solution of their choice.*

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[25] *https://www.nsia.no/Aviation/Published-reports/2013-18-eng*
[26] *An Airworthiness Directive imposes a mandatory aircraft inspection or modification.*
[27] *AS 350 B3 is marketed by Airbus Helicopters as H125.*

This was reiterated and further urged in EASA's revision of SIB, SIB No 2017-18R2 dated 14 January 2021, but such installation has not been ordered through an AD:

> *EASA has recently approved revisions of AH STC 10060852 and AH STC 10061056 to extend the CRFS to EC 130 B4 helicopters, and also approved Major Change 10072097 (MOD 07.20034), to introduce the CRFS on all AS 350 B3 helicopters as part of Type Certificate (TC), demonstrating compatibility with AH underbelly cargo hook installation. This SIB is revised to reflect these modifications.*
>
> *EASA considers that the installation of any of the modifications listed in Table 1 for AS 350/ EC 130 in service aircraft, will reduce the risk of post-crash fires and contribute to increase the occupant escape time after a survivable crash.*
>
> *At this time, the safety concern described in this SIB is not considered to be an unsafe condition that would warrant Airworthiness Directive (AD) action under Regulation (EU) 748/2012, Part 21.A.3B.*
>
> *EASA is, however, reviewing the accident data and further recommendation and/or regulatory action may follow.*

With effect from May 2020, the US Congress has decided that all new helicopters delivered in the USA shall have crash resistant fuel system installed. The decision was taken as a result of accidents that had occurred in the USA and reports issued by the NTSB (see section 1.6.11.2).

1.18.4.3 Warnings about servo transparency

Following the external consultation of the draft report concerning LN-OFU, Airbus Helicopters made the NSIA aware that they were about to implement a warning in the Aircraft Flight Manual regarding servo transparency. This amendment was approved by EASA in December 2021. The SIN 2187-S-67 has been updated in order to inform operators about this amendment and will be released Q1/2022

Further, in September 2021 Airbus Helicopters presented EASA with a roadmap regarding a technical solution intended to warn to the pilots prior to servo transparency.

1.19 Useful and efficient investigation methods

1.19.1 USE OF SEISMOLOGY AND INFRASOUND

NORSAR was approached to see if it was possible to determine exactly when the crash occurred and the rotor rpm or helicopter speed before impact with the terrain. NORSAR works with seismology and infrasound in the Far North and Arctic. In connection with the investigation of the accident with a Russian helicopter near Barentsburg in Svalbard on 26 October 2017, it was possible to give a good indication of location and correctly indicate the time of impact with the sea. It was also possible to estimate the helicopter's speed changes recorded by the infrasound microphones in the vicinity of Heerodden. The accident with LN-OFU occurred in an area where this type of information is not recorded by NORSAR, which meant that the query did not yield any results of relevance to the present investigation.

2. Analysis

2. Analysis

2.1 Introduction

2.1.1 ANALYSIS METHODS AND STRUCTURE

Analysis of the data collected, and investigations conducted was based on a simplified fault tree describing alternative scenarios that could lead to loss of control, see Figure 70. The scenarios were allocated to the following branches: external factors outside the helicopter, operational and human factors, and technical factors, including different types of technical failure and structural loss.

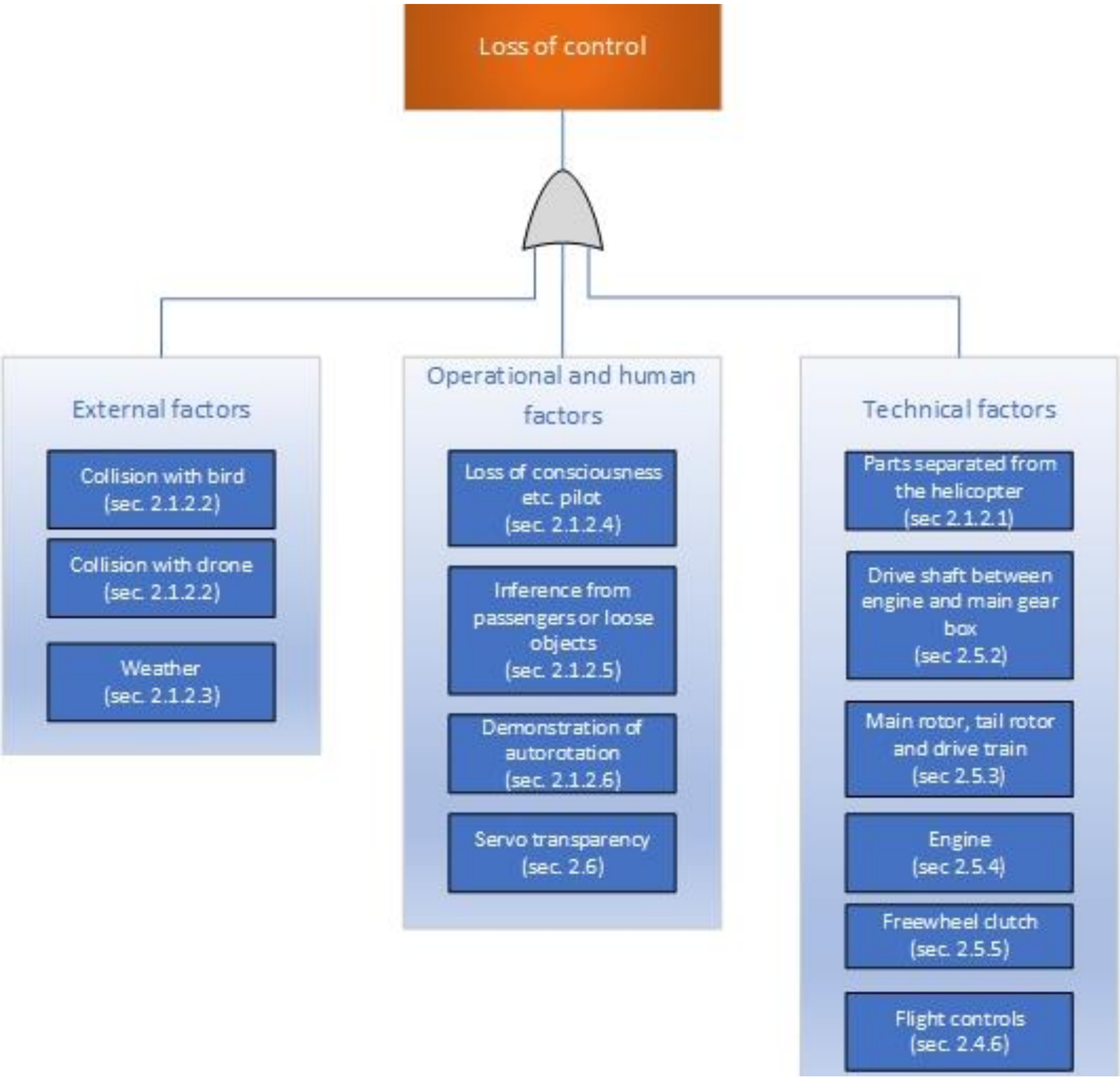

Figure 70: Simplified fault tree model – scenarios that could lead to loss of control, followed by impact with the ground and fire. Reference to section in the analysis. Illustration: NSIA

In section 2.2, the analysis discusses the sightseeing flight and the pilot's manoeuvring of the helicopter that led to loss of control. The analysis is based on downloaded data, photo documentation and information about flight path, altitude above ground level and ground speed. Then, the findings at the accident site and wreckage information is discussed. The consequences of the loss of control with survival aspects, including accident forces, fire and safety equipment, is analysed in section 2.4.

Section 2.5 discusses the probability of a technical failure having occurred in the helicopter, including in the drive shaft between the engine and main gearbox, the engine and power transmissions, the freewheel (sprag) clutch, main rotor, tail rotor and its drive train, and the flight controls.

A substantial part of the analysis relates to the servo transparency phenomenon. Section 2.6 discusses the probability that servo transparency occurred. Measures to prevent the phenomena from occurring and risks associated with servo transparency are discussed in 2.7.

Section 2.8 discusses human factors, including the pilot's experience, education and training, and any passenger influence related to the sightseeing flight.

Finally, the analysis addresses storage and securing of data and access to data after the accident.

2.1.2 DELIMITATION OF THE ANALYSIS – FACTORS DEEMED TO BE OF LOW PROBABILITY

The NSIA has considered the following factors and found the probability that they contributed to the accident as low:

2.1.2.1 Parts separated from the helicopter

The fault tree analysis includes a branch for 'Parts separated from the helicopter'. Parts that fall off a helicopter during flight can hit or damage rotor blades or other critical components. The wreckage and accident site has not given any information about possible parts that have fallen of the helicopter. The NSIA has therefore conducted a thorough search of the terrain below the presumed flight path to detect any parts that may have fallen off the helicopter, without finding anything. It is thus unlikely that anything of significance fell off and damaged the helicopter during flight. The NSIA considers that the helicopter was intact before the impact with the ground.

2.1.2.2 Collision with a bird or drone

A collision with a bird or drone can damage critical components and cause the pilot to lose control. The bird or drone can also break the front windows and slam into the cockpit with great force. Inland low-level helicopter flights are particularly prone to collide with objects, the most common of which are birds, particularly in late summer.

The NSIA has concluded that there is little probability that the accident was caused by a collision with a bird or drone. No bird or remains of a bird were found in the terrain or at the accident site after the accident. Nor were any foreign objects found at the accident site or during the metal detector search of the terrain below the presumed flight path. There were also no reports of a missing drone after the accident. Furthermore, a harmful collision with a large bird or drone would probably have been visible on the last Snapchat video that was recorded from the aft seat in the helicopter. The recipient of the video has not described anything which could be related to undesirable objects in the cockpit.

2.1.2.3 The weather

It was good weather for flying and no icing or turbulence had been forecast. A photo taken from the Komsatoppen peak just after the accident showing vertically rising smoke indicates almost no wind and good visibility. The NSIA does not consider the weather to have been a contributing factor to the accident.

2.1.2.4 Loss of consciousness or sudden illness on the part of the pilot

The pilot had a valid Class 1 medical certificate without restrictions. There is no information to indicate that the pilot suffered from insufficient sleep or fatigue, lack of nutrition, or was under the influence of alcohol or drugs. The NSIA has also been informed that the pilot made sure he got some extra rest in the morning on the day of the accident. Hence the NSIA has concluded that the pilot had a good starting point for flying the helicopter on the day of the accident. Furthermore, the findings in the investigation seem to indicate that the pilot was close to regaining control when the accident occurred, which leads the NSIA to conclude that the pilot was fully conscious and operated the helicopter when the accident occurred.

2.1.2.5 Interference from passengers or loose objects

The NSIA has studied photos/images, video recordings and flight paths and, on that basis, sees any intentional interference by passengers as unlikely. Furthermore, none of the passengers had brought any loose objects on board that could hook onto or interfere with the flight controls.

2.1.2.6 Demonstration of autorotation

The NSIA have considered if an attempt to demonstrate autorotation might have been the cause of the accident but does not find this likely.

2.2 The sightseeing flight and the pilot's manoeuvring of the helicopter

Position data, calculated ground speeds and altitudes from Flightradar24 and the CelloTrack unit have been very useful in the investigation. The NSIA has compared the data sets and found them to be relatively consistent. On that basis, the NSIA has been able to describe both the ferry flight from Alta Airport to the festival area and the two sightseeing flights up until the accident occurred. Storage frequencies varied, however, and some areas were without coverage.

The NSIA lacks data for the first and final periods of both sightseeing flights. This means that data is lacking about the final manoeuvres prior to impact with the ground on the accident flight. Based on an overall review of all available information, the NSIA has been able to substantiate a probable sequence of events.

The NSIA has compared the two sightseeing flights with the ferry flight to the festival area from the base at Alta Airport. On the ferry flight, there were no passengers on board. During this flight there were no notable variations in ground speed or vertical speed, and the altitude above ground level was significantly higher than on the subsequent sightseeing flights.

Flight data show that, on both the first and the second sightseeing flight, there were periods of more widely varying speeds and flight altitudes. These variations occurred over virtually the same area during both flights. This was particularly the case during the final period of the flights, when the altitude above ground level varied between being just above and just below the minimum altitude of 500 ft.

Should an unexpected event occur, a higher flight altitude leaves more time in which to understand the situation and take corrective action. Such unexpected situation could be a technical fault requiring autorotation searching for an appropriate landing site or entering servo transparency.

The passengers on the first sightseeing flight have described that they, despite the relatively low flight altitude, felt safe.

The photo taken during the descent over Hjemmeluftbukta bay on the accident flight (see Figure 3) shows that the limit values for pitch given in the operator's procedures for sightseeing flights were exceeded. Among other things, this limit is intended to provide a margin to avoid servo transparency, without this being mentioned specifically in the procedure.

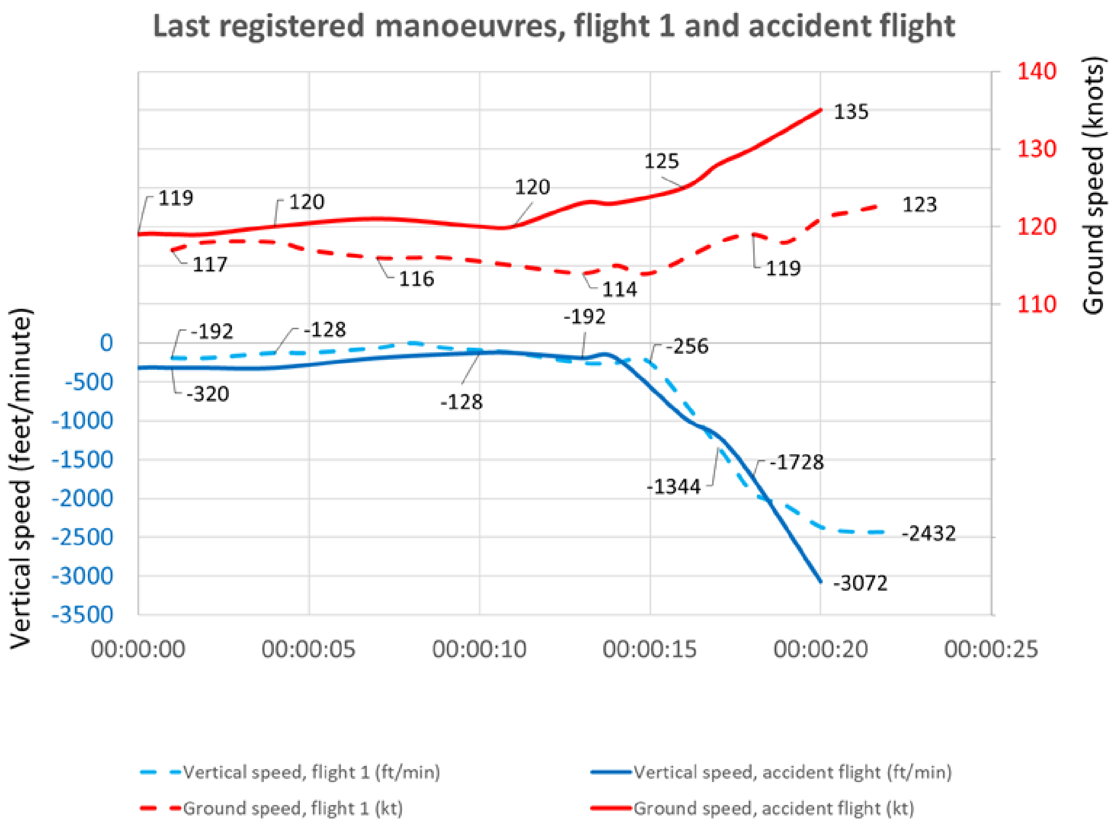

Figure 71: Last helicopter movements registered by FlightRadar24. Comparison between the last recorded manoeuvre (approx. 20 seconds) on the first sightseeing flight and the accident flight. Source: NSIA

Figure 71 shows the similarities between the manoeuvres during the last registered seconds of the first sightseeing flight and the accident flight, both of which were terminated by a slight right-hand turn. On the accident flight, the concurrent increase in sink rate and ground speed was greater than on the first sightseeing flight. During the final seconds, the first sightseeing flight kept an altitude of around 500 ft above ground level, while the altitude was somewhat lower on the accident flight.

The final data from the accident flight were registered by Flightradar24 at 17:05:05. At that point in time, the helicopter had a ground speed of 135 kt, a course of 251 degrees and a sink rate of 3,072 ft/min. These data indicate a significant change in sink rate and increasing ground speed. In the NSIA's assessment, the helicopter may have entered servo transparency at that point in time. Given the high mass and speed the margins to servo transparency would be relatively small. The probability of servo transparency having occurred is discussed further in section 2.6.

The helicopter was heavier during the first sightseeing flight, but its speed was somewhat lower. On the first flight, the helicopter levelled out sooner, which meant that there was not enough time for the speed to reach a critical level. Hence, the NSIA considers that only small margins prevented the helicopter from entering servo transparency during the last recorded seconds of the first sightseeing flight.

JRCC for Northern Norway registered ELT-signals with position and identification from the helicopter at 17:06. There might be a slight delay between the signals are sent and are recorded.

The NSIA therefore believes that the accident happened between the last recorded Flightradar24 at 17:05:05 and the recorded ELT-signals at 17:06

2.3 The accident site and wreckage information

Based on findings at the accident site, the examinations of the helicopter wreckage and the forensic reports, the NSIA has formed the clear impression that the helicopter crashed relatively flat into the ground with its nose pointing slightly down and with a slight roll to the left. It can be excluded that this was a high energy accident. This is described in more detail below.

The wreckage lay in a concentrated area. Minor parts of the windshield were outside the area of the fire, immediately in front of the main wreckage. Furthermore, no parts were thrown away from the main wreckage. The fact that the wreckage was concentrated in a small area is another indication that high horizontal speed[28] on impact with the ground can be excluded.

The ELT was triggered automatically and sent signals. This indicates that the energy of the impact was sufficient to activate the ELT, but insufficient to destroy the transmitter, antenna, or antenna wire. The NSIA often experiences that ELTs are destroyed in accidents.

The engine and main gear box were displaced in relation to each other. This is evident from the damages to the flex coupling between the engine and main gearbox and the fact that the rear engine mount was bent downwards in the front.

The step on the right side was only slightly compacted at its forward edge from the impact with the terrain. This might also be related to the fact that the left side of the helicopter seems to have impacted the ground before the right side. The step broke off and was therefore not consumed by the fire. The cross-rods between the skids had not been significantly deformed or stretched. The forces were powerful enough to cause fractures in the transverse tubes in the heat-affected zones near welds. These indications tend to exclude high horizontal and vertical speeds.

There was only minor deformation of the shock absorbers for the front seats. The seats were bent leftwards and the deformation in the suspension system was greatest on the left-hand side. This can possibly be explained by the rising terrain on the left-hand side or the rising terrain combined with the helicopter banking to the left as it hit the ground. The tubular frame for the aft seats was not deformed. The autopsy reports indicate relatively small injuries in spine and pelvis. Overall, this indicates that the vertical speed was relatively low. The survival aspect is discussed further in section 2.4.

Several findings indicate that the tail rotor was rotating at the time of impact with the ground. Damage to the tail boom suggests that it was separated from the fuselage in connection with the crash. Scratch marks from the shaft indicate that this happened while the shaft for the tail rotor was rotating. When the tail boom was separated from the fuselage, the tail rotor lost its drive system and it stopped. This can explain why the tail rotor and the horizontal fin sustained relatively limited damage when the tail boom subsequently hit the ground.

Damage to the main rotor, impact marks on the ground and cut marks in the shrubbery show that the main rotor was rotating at the time of impact with the ground. Only three, not very prominent, impact marks from the rotor blades were found on the ground. That the alignment marks on the engine's gearbox (Module M05, see Figure 67) were not misaligned, does not clearly mean that

[28] Horizontal and vertical forces are described with reference to the helicopter, i.e. horizontal means along the helicopter's longitudinal axis while vertical means along the helicopter's vertical axis.

the engine has not had a high-power output. The NSIA is of the opinion that is difficult to determine rotational speeds and force based on these findings.

Based on all the findings, the NSIA is of the opinion that the descriptions above are compatible with a scenario where the pilot might have been about to regain control of the helicopter after a possible servo transparency.

2.4 Survival aspects

2.4.1 THE ACCIDENT FORCES AND FIRE

The helicopter collided with the terrain at a far lower speed than indicated by the last flight data registered immediately before the crash, and the damage sustained was relatively moderate until it caught fire. The NSIA considers that the forces involved in the accident probably did not inflict fatal injuries on those on board. The forces were sufficient, however, to rip open the fuel tank, separate the tail boom from the fuselage and misalign the engine and main gearbox.

It is assumed that LN-OFU was consumed by fire shortly after impact with the ground. This is supported by witness observations. One witness heard a series of small bangs shortly after the accident and the NSIA connects this to the pressure bottles onboard exploding due to the heat from the fire. This is further confirmed by similar accidents involving AS 350 helicopters in the USA and Portugal, and the accident in Norway involving LN-OML (see section 1.18.3). Fires escalate very quickly and the time available for evacuation is very short. The pilot of the Heli-Team helicopter, which arrived at the accident side 10 minutes after the accident, has described that the helicopter at that time was almost completely burnt out.

In general, the terrain around the helicopter wreck can be described as steep and rocky, and not suited for landing. The area where the helicopter impacted the ground seemed like a small shelf. The terrain under the wreckage was relatively flat and without any larger rocks. The cargo swing which was installed on LN-OFU is placed directly under the fuel tank. If the cargo swing contributed to the fuel tank rupturing is unknown.

If the horizontal speed is high, it can be assumed that a fan-shaped spray of fuel will be thrown forward in the direction of movement. This was not the case. The findings suggest that the fuel tank was ruptured or punctured in the crash, with limited fuel spread. Hence, the burning fuel had only ignited the heather and other vegetation around the wreckage to a limited extent.

The NSIA has not concluded with what ignited the fuel. It can have been electrical spark; the battery is for example installed next to the fuel tank. It might also be initiated by heat from the gas generator that continued to run for a short time after the impact or heat generated when the power turbine blades separated.

The passenger who had managed to get out of the helicopter had sustained severe burns and had injuries like those found in the other passengers in the post-mortem examination. The passenger probably sustained external head injuries from falling in the steep and rocky slope, but these were also not fatal. This further supports that this was a survivable accident.

2.4.2 CRASH RESISTANT FUEL SYSTEM

The NSIA believes that this accident could have been survivable had a fire not immediately broken out. Since this can be excluded as a high-energy accident, a crash resistant fuel system could have reduced the possibility of a life-threatening fire. The passengers could therefore have had time to evacuate the helicopter and subsequently survive the accident.

The Norwegian inland helicopter operators use the AS 350 for several types of operation. Some of these require cargo swing and some are pure passenger transport. It is not unusual for the same helicopter to be used for different kinds of operation on the same day. This means that it is impractical to install and remove the cargo swing multiple times in a day.

LN-OFU was ordered in June 2019. At that time, it was possible to order the helicopter with a crash resistant fuel system. One of these was certified in accordance with CS 27.952 for use with cargo swing. Airbus Helicopters offered a crash resistant fuel system but specified that the offered system was not certified for use with cargo swing. The customer decided to not order the crash resistant fuel system. At that time, there was also no other AS 350s in Norway with a crash resistant fuel system installed. Even though both EASA and Airbus Helicopters had promoted installation of crash resistant fuel system this was not required by EASA.

Even if the type certificate for the AS 350 was issued before 1994, so that a crash resistant fuel system is not a requirement for certification, Airbus Helicopters has decided that all new AS 350 helicopters manufactured after 1 October 2019 shall be equipped with a crash resistant fuel system. The NSIA supports this decision. At the same time, many helicopters of the AS 350 type and others fly without a crash resistant fuel system. As of November 2014, only 15% of a total of 5,600 new-build helicopters built in the USA after 1994 had a crash resistant fuel system installed. On that basis, the NTSB issued a safety recommendation to FAA that all new helicopters be equipped with a crash resistant fuel system in accordance with FAR 27.952 or FAR 29.952, regardless of their type certification date. As a result, the US Congress decided that all new helicopters delivered to the USA after May 2020 must be equipped with crash resistant fuel system.

EASA's latest revision of SIB no 2017-18R2 dated 14 January 2021 promotes the retrofit of crash resistant fuel system. At the same time, EASA considers that flying without a crash resistant fuel system is not an unsafe condition which would warrant an airworthiness directive. They state that based on further review of accident data, this may change.

Crash resistant fuel system will not prevent any accidents, but this accident shows that the consequences due to an accident are great when a crash resistant fuel system is not installed. The NSIA is of the opinion that it is less likely that helicopter operators voluntarily choose to retrofit a crash resistant fuel system. Based on the NSIAs role as an observer in the different national helicopter safety forums it seems difficult to compete in the market with increased safety as an argument. Economically, it can therefore be challenging to voluntarily retrofit crash resistant fuel system.

Based on the present investigation, the NSIA addresses a recommendation to EASA that all helicopters, new and used, delivered or imported to Europe be equipped with crash resistant fuel systems in accordance with CS 27.952 or CS 29.952, regardless of their type certification date.

Furthermore, the NSIA considers passengers to be exposed to unnecessarily high-risk during transport by helicopters without crash resistant fuel system. Passengers are generally not able to determine whether a helicopter has such a safety system or to understand the heightened risk the absence of such a system entails in the event of an accident.

The NSIA therefore recommends EASA to not permit commercial passenger flights with helicopters that are not equipped with a crash resistant fuel system in accordance with CS 27.952 or CS 29.952, regardless of their type certification date.

These safety recommendations concur with the safety recommendation issued by the Portuguese investigation authority after the accident in Sobrado on 5 September 2019.

2.4.3 HELMET

The LN-OFU pilot did not wear a helmet and sustained significant head injuries in the crash. Hence, he would probably not have been capable of assisting the passengers to evacuate the helicopter, had that been an option. In this case where an intense fire developed very quickly it would have made no difference if the pilot had used a helmet. All Helitrans pilots have their own personal helmet, which they use during all flights other than commercial sightseeing flights. The company's Standard Operation Procedure (SOP) contains no requirement for use of helmets during sightseeing flights.

The NSIA is aware of arguments that wearing a helmet over time causes discomfort but regards it as a bigger problem in connection with lifting operations where the pilot constantly needs to look out and downwards. It is mandatory to use helmet in these operations. The requirement (ORO.GEN.200 sub para (a)(3) in (EU) No 965/2012) that a risk assessment must be conducted for all assignments is intended to ensure that measures, such as the use of helmets, are introduced for assignments associated with too high a risk. Commercial sightseeing flights are deemed to be low risk, however, and it is therefore unlikely that a risk assessment will result in the use of helmets as a safety measure. In the NSIA's view, the potential consequences of an accident with passengers on board are not given sufficient weight. Since helmets are already used by helicopter companies on other types of assignments, introducing use of helmets on sightseeing flights will not lead to extra costs.

The NSIA is currently investigating two accidents (LN-OAX and LN-OFQ) involving AS 350 helicopters engaged in load operations, in which helmets have proven to prevent pilots from sustaining head injuries. In the earlier accident involving LN-OML (see section 1.18.3), the pilot survived because he was secured by seat belts and wore a helmet. This most probably contributed to limiting the pilot's injuries and enabled rapid self-evacuation when the helicopter caught fire immediately after impact.

The NSIA is of the opinion that, in addition to saving the pilot's life, use of a helmet during sightseeing flights can also enable the pilot to assist passengers in the event of an accident. Use of a helmet will also reduce the probability of the pilot sustaining injuries in the event of a collision with a drone or bird. The NSIA has considered issuing a safety recommendation to EASA on the use of helmets. EASA has informed the NSIA that they have discussed this and concluded that this issue is best solved through the operator's regulation mandated risk assessments, ref. ORO.GEN.200 of Commission Regulation (EU) No 965/2012.

The NSIA submits a safety recommendation to CAA Norway on the use of helmets for crew during flights with paying passengers to ensure that this safety issue is addressed at the national level.

2.5 Probability of technical failure

2.5.1 INTRODUCTION

Meticulous examinations of the wreckage have revealed no indication of technical failure having caused or had a bearing on the outcome of the accident. This is supported by the fact that no faults were detected in any of the rotating components in the audio frequency analyses that were carried out of the Snapchat videos. No messages, photos or videos sent by the passengers indicates any technical failure of the helicopter. There was also not received an emergency message from the helicopter. The NSIA will nonetheless describe some of the technical examinations and conclusions.

2.5.2 DRIVE SHAFT BETWEEN ENGINE AND MAIN GEARBOX

As none of the six bolts which holds the transmission train together or parts of the flex coupling was found near their original position, this received a great deal of attention early in the investigation. A hypothesis was that there could have been an issue during assembly causing the bolts to come loose. Therefore, EASA in collaboration with Airbus Helicopters issued an AD to inspect the connection on newer helicopters. The NSIA is not aware of any findings from these inspections.

After a while the NSIA found a total of 11 halves of the six bolts in the connection and all six castle nuts. Consequently, it was possible to conclude that the nuts had been in place. They could therefore not have come loose and caused separation between the engine and the main gear box. Several of the bolts had marks after being damaged while rotating.

Thus, the NSIA had at least one fracture surface of each bolt. All 11 fracture surfaces were subjected to fracture analysis. None of the fracture surfaces had signs of fatigue. Chemical composition and tensile strength were found to be within specifications. All the fractures were due to overload in shear and tension. The NSIA finds it unlikely that this has occurred while airborne.

Almost all the fragments from the flex coupling were found. Fracture analysis of all the segments showed that the fractures were mainly due to ductile overload. None of the fracture surfaces had signs of fatigue. Most fragments were small and contained only one hole, while four fragments had a total of five holes. Additionally, there were cuts and impact damages on the edges of several of the segments. To have loose segments with more than one hole, the bolts must quickly have come loose. An animation in where different misalignment angles between the engine and the gear box was simulated, showed that there must be a significant misalignment angle to create the cut and impact damages as found. Such a misalignment can occur if the engine or the gear box shifts position. If the gear box had shifted position while the helicopter was airborne, this would among other factors have led to damages in the tail rotor shaft. No such damages were found. The gimbal ring, which encapsulates the drive shaft, and the flex coupling connected to the main gear box, had rotational damages that indicates that the drive shaft had rotated after the engine and main gear box had become misaligned. The NSIA consider these damages to be compatible with damages that occurred after the impact with the ground where the engine and main gear box became misaligned while the driveshaft was rotating.

2.5.3 MAIN ROTOR, TAIL ROTOR AND PERTAINING DRIVE TRAIN

The main rotor with relating drive train and main gearbox were severely damaged by fire, but no mechanical faults were found in the gearbox that could have led to the accident.

The tail rotor with related gearbox and drive shaft were intact, and the NSIA concluded that it had been in good working order up until the time of impact with the ground. No fault or damage that could have arisen before the accident was found in other drive shaft components.

2.5.4 ENGINE

The engine has several protection systems.

The power turbine was recovered without turbine blades. All the turbine blades had been shed, as they are designed to be at an N2 of 150%. To investigate if there had been a fault in one or more of the turbine blades, all 37 blade root fracture surfaces were examined. If one blade fractures, there is a high probability of a cascade effect where all the blades separate and appear as seen here. Due to displacement of the engine while the turbine was still rotating, many of the fracture surfaces were damaged, but it was still possible to examine some areas. There were not found any signs of fatigue or faults in the material structure which can explain fracture of one or more turbine blades. Based on this there is reason to believe that the engine reached an rpm of 150% which led to turbine blade shedding.

The engine is also equipped with an electrical stop valve which should stop the fuel flow when the engine reaches 120% rpm. If this is in operation, the engine should not be able to reach an rpm of 150% with associated blade shedding. All three sensors must register an rpm of 120% before the stop valve closes. This design choice is made to ensure that the engine does not stop in flight due to sensor faults. X-ray examination of the stop valve unit indicated that the vale was in open position after the accident. The system makes it difficult for the valve to have closed and then returned to the open position. The NSIA therefore assumes that the valve did not close. An examination of all the sensors have not revealed any faults with these. A fault was on the other hand found on the connector to one of the sensors, the torque sensor. This damage can be related to damages that occurred during the crash. This leads to the NSIA conclusion that the system was in operation before impact with the ground. It was the impact with the ground that rendered the system inoperable. This enabled the rpm of the engine to reach 150% and blade shedding. The NSIA therefore concludes that the blades separated on the ground after impact

Only smaller fragments of the separated turbine blades were found when the engine was dismantled and examined at the NSIA. No blades or blade fragments were found at the accident site. This can be explained with the fact that the blades can be shredded so much that they are difficult to recognize. At the accident site everything was burnt, and the ground was covered with burnt material from the helicopter and burnt vegetation. To recognize fragments of turbine blades is deemed less likely. Furthermore, the engine was airlifted out from the accident site hanging under a helicopter. The engine was not wrapped, and fragments may have fallen out of the engine at this time. The fact that blades are not found could indicate that the blades separated while the helicopter was in flight. However, a review of all the available data and based on the analysis above it is the NSIA's conclusion that the blades separated on the ground.

2.5.5 FREEWHEEL (SPRAG) CLUTCH

A sprag clutch that slips and suddenly re-engages during flight can make it difficult to control the rotor rpm, and thus contribute to loss of control of the helicopter. The sprag clutch bore no signs of mechanical damage or marks, and thus the accident was not caused by any defect in the clutch.

2.5.6 FLIGHT CONTROLS

The flight controls were so severely damaged that it was impossible to verify the condition of all details. It was, however, possible to identify and examine a large number of bolts, arms and rod ends as well as the cyclic. Parts of the hydraulic servo actuators and the hydraulic system were also examined, but the condition of the system could not be verified. Yellow colouration on the pulley of the hydraulic pump indicates that the belt was present at impact.

The NSIA has not found faults or damage to the flight controls that could have caused the accident.

2.6 Probability of servo transparency

2.6.1 INTRODUCTION

In the following chapter, the NSIA will discuss the likelihood that servo transparency occurred. To the pilot, servo transparency can occur unexpectedly. The phenomenon is considered by Airbus Helicopters to be self-correcting. The NSIA does not necessarily disagree with this, but it will require that flights are conducted with sufficient margins to the terrain and obstacles, both below and to the sides, and that the pilots are sufficiently aware of and trained in how to handle the situation.

2.6.2 HELICOPTER MASS

Due to unnecessary amounts of fuel, the helicopter was heavy during the two sightseeing flights, which increased the load on the main rotor. The sightseeing flights were planned to take place in the immediate vicinity of the operator's fuel base, and the intention was to fill up all the five passenger seats on both flights. The helicopter's fuel tank was nonetheless filled to 90% of full capacity. The NSIA have not found any warning relating to helicopter mass in Helitrans's standard procedure for sightseeing flights. According to the pilot's weight and balance calculations, and the NSIA's calculations, the helicopter's mass was very close to the maximum take-off mass for the helicopter type. The pilot had used 378 litres fuel in his mass- and balance calculations for the first sightseeing flight. The loadmaster has informed that they filled the fuel tank up to roughly 90% which corresponds to 486 litres. Of these, 404 litres were filled right before taking off at Alta Airport. This means that pilot believed that the helicopter was 76 kg lighter than it actual was, if one assumes that 10 kg of fuel were burnt on the ferry flight.

2.6.3 FLYING TECHNIQUE

The photo taken over Hjemmeluftbukta bay on the accident flight (see Figure 3) shows an indicated helicopter speed of approximately 90 kt, a leftward roll (rotation around the longitudinal axis) of approximately 10° and a downward nose angle of approximately 30°. This exceeded the limit for pitch defined by Helitrans. This limit was defined based on a safety recommendation after the helicopter accident with LN-OXC at Dalamot. The limit defined by Helitrans in the procedure is 15° nose down.

On 31 August 2019 the QNH was 1007 hPa. Alta Airport is at an elevation of 10 ft. The altitude indicator in the helicopter was found with a QNH setting of 1002 hPa, which would give an indicated altitude 150 ft lower than the real pressure altitude. This does not seem to have influenced the pilot's choice of altitude, as he flew by visual cues only.

The photo also shows an FLI[29] value of between 77 and 79%. Data from Flightradar24 show that the ground speed increased from 70 to 110 kt and that the highest sink rate was 2,420 ft per minute during the descent, which was of approximately 12 seconds' duration. A sink rate where altitude is traded for speed due to a lowering of the collective would result in a lower FLI-value than the picture shows. The NSIA therefore believes that this manoeuvre above Hjemmeluftbukta was

[29] *First limitation indicator; see footnote **Feil! Bokmerke er ikke definert.**.*

largely carried out by moving the cyclic forward and not by lowering the collective pitch control. The manoeuvre increased the load on the rotor, both through increasing the speed and through increasing the G load during pull-out from the high sink rate. Lowering the collective would have given the passengers a similar experience without dropping the helicopter nose, and this would have maintained a greater margin for avoiding servo transparency.

This manoeuvre was carried out after a climb, and therefore at a low initial speed. After the manoeuvre the helicopter levelled out at 1,250 ft above the open sea after having lost approximately 275 ft with a relatively low ground speed (110 kt) at the same time. The manoeuvre was in addition carried out at a relatively good altitude above the sea. Even though the helicopter was heavy, and the G load increased when it levelled out, the low speed meant that the margins for avoiding servo transparency were adequate. If servo transparency had occurred at this time, the altitude would be sufficient to recover the situation.

Flight data show that the pilot had also carried out three similar manoeuvres on the first sightseeing flight. The first manoeuvre was carried out on passing the first mountain peak and flying over Hjemmeluftbukta, the second at a relatively high altitude above the terrain and the third during the descent south-east of where the accident subsequently occurred (see Figure 5). The three abovementioned manoeuvres were similar in that there was a certain loss of altitude at the same time as the speed increased.

The NSIA sees these manoeuvres as forming a pattern along the same lines as on the accident flight, both in the case of the manoeuvre above Hjemmeluftbukta and in the case of a manoeuvre in connection with the descent after turning back towards the festival area. During the accident flight the flight was conducted at a slightly lower altitude and slightly higher speed compared with the first sightseeing flight. While the speed ranged from 80 to 110 kt on the first sightseeing flight, it ranged from 100 to 120 kt on the accident flight. The margins where therefore lower on the second flight than the first flight.

2.6.4 MANOEUVRING DURING THE FINAL PHASE BEFORE IMPACT WITH THE GROUND

During the final descent on the first sightseeing flight, the speed increased to 123 kt at the end of the manoeuvre. Flight data indicate that the pilot may have carried out a similar manoeuvre shortly before the helicopter crashed. The last recorded speed on the accident flight was 135 kt, while the helicopter was still in descent. The rate of descent was also greater: 3,072 ft/min. as opposed to 2,432 ft/min. on the previous flight, at the same time as the altitude above the terrain was lower. The NSIA believe that the margins to servo transparency was very small due to the high mass and speed.

The NSIA has calculated the total mass of the helicopter to be roughly ca. 2,230 kg at this time in the flight. The last recorded ground speed was 135 kts and increasing. The NSIA cannot exclude that the helicopter had entered servo transparency at this time. If not, only small corrections to the flight controls would probably have been enough to enter servo transparency. The helicopter was in a slight right turn, which increases the probability of entering servo transparency. The accident in Canada with C-FBLW on 16 March 2016 has many similarities with this accident. This helicopter was also heavily loaded and had a high speed. A slight correction with the cyclic made the helicopter enter servo transparency.

One of the passengers sent a Snapchat video right before the accident. The video is recorded from the backseat and looks through the front cockpit windows. The recipient of the Snapchat Video has explained that the video showed vegetation and no sign of sky. Based on this and the registered flight track the NSIA has reason to believe that the helicopter had already entered servo transparency.

The helicopter flew low above the terrain just before the accident occurred. The last recorded data show that it was below 300 ft. When servo transparency occurs at a low altitude, the pilot has a limited possibility of exiting the critical situation. To exit servo transparency the load on the rotor disc must be reduced. This is done by lowering the collective pitch control. Lowering the collective would give an increased sink rate and a reduction in altitude. This would have brought the helicopter even closer to the ground. A reduction of collective in this situation would probably give a significant increase in speed, both for the main and tail rotor. This might give a noise that indicates an increase of rpm and probably high-frequency noise from the tail rotor. Witness statement corroborates this.

If servo transparency occurs with the nose pointing downwards while the helicopter is descending, the built-in characteristic whereby the nose is raised can cause the high load on the rotor to persist. The self-correcting effect (see Figure 19) can thus exacerbate or postpone the situation. Experience of simulator trials with a corresponding nose attitude in connection with the Dalamot investigation was described as follows (see Appendix A): '*Next, we put ourselves in a situation like the one that LN-OXC had with a 300 ft agl right-hand turn, nose down, and then pulled out of the turn. We were of course aware of what would happen, but if you're not, you have to be very lucky to avoid crashing into the ground!'*

2.6.5 SUMMARY

An assessment of the damage to the helicopter indicates that it did not crash into the terrain at high speed. The uneven terrain at the accident site also indicates that the pilot would not have chosen a controlled emergency landing there. There were several more appropriate landing sites in the immediate vicinity, and the site does not appear to have been selected on purpose.

An overall assessment of the wreckage and the accident site gives the NSIA reason to believe that the helicopter crashed while under partial control. The helicopter crashed north of the last documented flight path, after having changed course by almost 180°. This is consistent with the previously described servo transparency phenomenon introducing an uncommanded right and aft cyclic load, which is associated with a collective down action.

The NSIA has no data about the flight path for the last minute of the accident flight. It is therefore not possible to unambiguously determine the helicopters manoeuvres. The NSIA believes that it is probable that the pilot may have been in the process of regaining control at low altitude with course towards rising terrain when the helicopter crashed.

Assuming the helicopter was on course towards rising terrain in the last phase of the flight and had a large sink rate due to large roll to the right because of servo transparency, a pilot would instinctively try to straighten the helicopter and decrease the sink rate by increasing the collective. Trying to avoid a collision it is possible to increase collective sufficiently to overload the rotor disc, this would cause a drop in rotor rpm. This means that the helicopter is manoeuvred in such a way that during a period more lift than the rotor disc can provide and more power than the engine can provide is demanded.

The loss of lift could lead the pilot to lower the collective to try and increase the rotor disc rpm, but to avoid impact with the ground the helicopter must have sufficient altitude.

A witness has described that the helicopter was almost still with its nose pointing slightly down immediately before it crashed and caught fire. These details of the witness's statement did not emerge until two years after the accident. The original interview did not go into as much detail. The NSIA cannot therefore give any weight to this statement except that it does not contradict with other observations made by the NSIA.

Several witnesses have reported hearing an unusual sound pattern from the helicopter. With one exception these witnesses were relatively far away from the site of the accident, and these noise observations relates to the flight before the accident. Frequency and image analysis of the Snapchat-videos give no indication of any faults with the helicopter. The NSIA is further of the opinion that if there had been any faults with the helicopter at this time the pilot would have landed. The NSIA believes that the witness observations are likely to be the result from altitude and speed variations and is in no way related to technical faults. In addition, when the helicopter hit the ground and the connection between the engine and the main gearbox was lost, the power turbine rpm increased until blade shedding occurred. The closest witness describes the sound as if the helicopter was about to land or hovering with increasing rpm. The sound of increasing rpm had a duration of about five seconds. It is difficult to relate the witness observations to blade shedding.

Based on an overall assessment of all alternative scenarios, the NSIA considers it most likely that the pilot, inadvertently ended up in a servo transparency situation.

2.7 Measures to prevent servo transparency

2.7.1 INTRODUCTION

The present accident is the latest in a series of accidents in which servo transparency was suspected as a contributing factor. Several reports on accidents involving AS 350 helicopters, refer to the investigation of the accident with LN-OXC at Dalamot in 2011 and the subsequent safety recommendations. The safety recommendations concerned manoeuvring limitations at low altitudes when carrying passengers, warnings about risks associated with servo transparency and the need for flight recorders.

In addition, aspects such as knowledge of servo transparency, the need for more training including simulator training, placards in the cockpit and pre-warning indicators for servo transparency were analysed and assessed by the investigation. Based on discussions with the parties involved, no safety recommendations were submitted in these areas. Similar accidents are still occurring ten years later, and it seems to the NSIA that the helicopter type is more sensitive to servo transparency than pilots commonly believe to be the case.

The NSIA is of the opinion that EASA, Airbus Helicopters, helicopter operators and helicopter pilots themselves, can do more to prevent potential accident as a result of servo transparency, and welcomes Airbus Helicopters’ proposed changes.

2.7.2 PERMANENT WARNING IN THE FLIGHT MANUAL

The investigation authority submitted the following safety recommendation as a consequence of the accident with LN-OXC at Dalamot: ‘*If servo transparency is encountered in a right turn, the associated uncommanded right roll and possible pitch-up have the potential to cause a significant deviation from the intended flight path, which, if encountered in close proximity to terrain or obstacles, could be hazardous. The Accident Investigation Board Norway (AIBN) recommends that EASA requires the type certificate holder Eurocopter to issue a warning of the particular hazard when encountering servo transparency in a right turn, preferably as a permanent note in the Flight Manual of the helicopter models in question.*’

The NSIA look forward to the safety actions which Airbus Helicopters are in the process of implementing. Airbus Helicopters decided to introduce a permanent warning in the aircraft flight manual which was certified by EASA in December 2021. The SIN 2187-S-67 has been updated in order to inform customer about this modification and will be released Q1/2022.

2.7.3 TECHNICAL SOLUTION AND PLACKARDS IN THE COCKPIT

The challenges that servo transparency entail appear to be under-communicated among AS 350 pilots in Norway. There is no single table in the flight manual where specific real values can be checked against limit values to determine when servo transparency can be expected. The NSIA acknowledges that there are many factors to be taken into account and that this can easily become a complex exercise.

The helicopter is not equipped with technical aids that gives advance warning, or prevent reaching, of the maximum load on the main rotor. The following is quoted from the Dalamot report: '*If retrofitting warning lights is not possible, the AIBN believes that the manufacturer should ideally find another technical solution that prevent or give advance warning of servo transparency. What solutions could be practicable has not been considered by the AIBN.'*

The NSIA is aware that Airbus Helicopters initiated a prefeasibility study in 2018 and that solutions and roadmap were presented to EASA in September 2021. So far, no solution has been implemented. The NSIA look forward to the safety actions which Airbus Helicopters are in the process of implementing. As no solution yet is implemented the NSIA issue a safety recommendation about a technical alerting system:

> The NSIA recommends that EASA, in consultation with Airbus Helicopters, establish a technical solution for helicopters that are prone to servo transparency, with a view to preventing or giving advance warning of the phenomenon.

2.7.4 TRAINING IN GENERAL AND SIMULATOR TRAINING IN PARTICULAR

It is important that helicopter pilots, who fly helicopters equipped with simple hydraulic systems, know about the helicopter's limitations. They must also be aware that, under certain circumstances, the safety margins may shrink faster than expected. Despite the fact that the training and checkout procedure for the helicopter type include familiarisation with the servo transparency phenomenon, it cannot be ruled out that, in addition to practical simulator training, more knowledge and understanding is required in this area. This statement is based on the fact that the pilot had been trained by Airbus Helicopters 15 months prior to the accident. He was thus among the operator's pilots with the most updated knowledge of servo transparency. Nonetheless, in this case he practised a technique of exchanging altitude for speed, and the fuel tank was filled up so that the helicopter mass was close to the authorised maximum. He also chose to fly at an altitude above the terrain that reduced or eliminated the safety margins should anything unexpected occur.

The NSIA is not sure that the elements of risk that act together were made sufficiently clear in the training offered by either Airbus Helicopters or the operator. The training may have been based on the same principle as the current flight manual, namely that the situation is self-correcting, and thus less critical. In the NSIA's opinion, it is misleading to state that the phenomenon is self-correcting without, at the same time, stressing the adverse effect on manoeuvring capabilities, and that it also demands sufficient room for manoeuvring. This means that the altitude and distance to the side terrain must be sufficient to be able to recover from a servo transparency situation.

Full flight simulator (FFS) is available in both Europe and the USA. The simulator in Finland meets the EASA/FAA FFS level D requirements, which is the highest level. The simulator can offer realistic training in how to deal with servo transparency. This would also be the case for other FFS where the flight controls and control dynamics are simulated realistically and in the same manner as the helicopter under the same flight conditions.

The regulations demand that a full flight simulator shall be used if one is available. CAA-N considers that the simulator in Helsinki in Finland is available and accessible for Norwegian AS 350 pilots and has informed the NSIA that they consider that there is thus a basis for enforcing the requirement for the use of simulators. When the accident occurred, the simulator was new and not yet in use by Norwegian helicopter operators and pilots.

When the accident with LN-OXC at Dalamot was investigated, there was no easily available simulator for Norwegian pilots, which is why the NSIA did not issue any safety recommendation relating to the use of simulators at that time. The experience of using an AS 350 simulator in the USA in connection with the Dalamot investigation was very positive, however. The experience of servo transparency in the simulator was described as very realistic. Appendix A contains excerpts of the memo from the simulator trials in the USA. It is considered in the memo that previous incidents could have been prevented through more use of simulator training.

The NSIA considers that simulator training could be useful with regards to servo transparency, and therefore issues the following safety recommendation:

> The NSIA recommends that both CAA-N and EASA review requirements for instruction and continuous training on the AS 350. This is to ensure that the training includes attention training that enables early recognition and recovery from a servo transparency situation.

2.7.5 THE HELICOPTER OPERATOR'S PROCEDURES

The operator's procedures contained no specific warning against high helicopter mass during sightseeing flights, and the operator had a standard procedure in which the minimum altitude could be understood to mean the normal flight altitude. The procedure specifies maximum angle of bank/pitch and nose angle for flying below 500 ft. The procedure goes on to state that these limitations should also not be exceeded when flying over 500 ft, unless it is strictly necessary. The wording '*when flying over 500 ft'* in the procedure is unfortunate, as it can contribute to normalising low-level flying with reduced safety margins. Furthermore, the operator has no guidelines for reducing the maximum flight speed during sightseeing flights.

As a result of the investigation the NSIA issues two safety recommendations:

> The NSIA submits a safety recommendation to Helitrans AS that it revise its standard procedure for commercial helicopter flights in general, and for AS 350 flights in particular, so as to better reflect challenges relating to flight altitude, mass and speed.
>
> The NSIA also recommends that CAA-N should use its leadership of various safety forums for inland helicopters to raise awareness of the challenges related to flight altitude, mass and speed in general, and to the AS 350 helicopter type in particular.

2.8 The pilot's training, experience and sightseeing flights with passengers

2.8.1 THE PILOT'S TRAINING AND EXPERIENCE

The pilot had a total of 256 hours of flight time and only 17 hours on AS 350. The NSIA therefore considers him as inexperienced. He had completed both the helicopter manufacturer's and operator's training schemes as required under rules and regulations. The training did not involve the use of a simulator to enable early recognition and recovery from a servo transparency situation.

It is not uncommon in the industry to employ pilots on short or longer-term seasonal contracts. The pilot was half-way through an eight-month contract for 2019 when the accident occurred, and he had been employed on similar contracts before. In the NSIA's opinion, such contracts can make it difficult to gather experience, which is particularly important immediately after having completed the proficiency check. They can also make it difficult to say no to assignments the pilot feels uncomfortable with and stand in the way of peer support and the exchange of experience.

All in all, the sequence of events suggests that the pilot's training and level of experience may have had a bearing on the accident. Research indicates that experience and expertise have an impact on situational awareness[30]. Based on this the NSIA considers that a more experienced pilot on the type could have been better equipped to maintain safe margins to avoid servo transparency and to respond correctly.

Reference is made to the accident with LN-OXC at Dalamot in 2011, where the pilot had a total of 700 hours of flight time on the helicopter type and more than 60 hours during the month preceding the accident. Long experience alone is thus not a factor that prevents accidents relating to servo transparency, but none of the pilots had undergone simulator training to enable early recognition and recovery from a servo transparency situation.

2.8.2 PASSENGER INFLUENCE

Among Norwegian helicopter operators, commercial sightseeing flights are seen as the simplest form of helicopter flights. Inexperienced pilots are therefore allowed to conduct sightseeing flights to accumulate hours of flight time to be able to undertake more demanding assignments. The NSIA agrees that there are more complex and technically demanding operations, for example sling-load operations, but that does not necessarily mean that sightseeing flights entail a low level of risk.

Helitrans does not have any minimum requirements to flight hours but requires pilots to have a separate proficiency check before they are allowed to carry passengers on sightseeing flights. The pilot had completed that proficiency check on 20 April 2019. After this he had flown a total of 50 hours with passengers before the accident flight. After the accident the helicopter operator has informed the NSIA that they have implemented minimum flight hour requirements of 250 hours before a pilot can fly sightseeing flights. The NSIA sees this as a positive contribution to flight safety.

LN-OFU is a small helicopter in which the passenger cabin is not physically partitioned off from the cockpit. The company's vision for such flights was to give the passengers a positive and memorable experience. Such flights are also to be conducted so as not to provoke any fear or

[30] Situational awareness (SA) is defined as follows: Situational awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and a projection of their status in the near future (Endsley 1995, p. 36).

discomfort among the passengers. Striking a balance between meeting expectations and avoiding fear during the flight requires constant attention and adaptation on the part of the pilot.

The investigation has shown that the helicopter was manoeuvred in excess of the limitations described in the operator's procedures for sightseeing flights. Based on the information provided by the passengers on the first flight the safety information they received prior to flight does not appear to be in accordance with the helicopter operators' procedures sightseeing flight. The loadmaster checked, fastened and provided headsets to the passengers. The NSIA has no reason to claim that eventual lack of safety information contributed to the accident nor the outcome. The NSIA is of the opinion that there must be a correlation between the operators' SOPs and actual practice. On the first flight, the pilot had also said that he would fly close to the ground for parts of the flight to give the passengers a sense of speed. The NSIA has no information as to what was done on the accident flight, but altitude data indicates that the same was the case here.

The NSIA believes that inexperienced pilots, who are in the process of building self-confidence while gathering experience, can be more easily influenced than experienced pilots and feel greater strain when carrying passengers. Based on the findings in this investigation, the NSIA considers that, by their very presence, the passengers may have influenced the flight, even though they were not aware of it.

2.8.3 SUMMARY

The NSIA believes that the inland helicopter sector in general has not given sufficient attention to the safety challenges, complexity and consequences associated with sightseeing flights with passengers. The company approval for commercial flight with passengers appears to be a formality that does not include practical flying with passengers on board in the presence of an experienced pilot. The sector seems to have underestimated the effect of an inexperienced pilot, in this case also relatively young, flying with young passengers on board. Potential consequences in the event of an accident also appear to have been overlooked. CAA Norway has no special approval of the helicopter operators' procedures (SOP) for commercial air transport operations involving light helicopters but can influence industry standards. One safety recommendation is proposed in this context.

> The NSIA submits a safety recommendation that the CAA Norway should establish and publish an industry standard for commercial flights with passengers with single engine helicopters. This should pay particular attention to sightseeing flights. The standard should contain guidance for both development of the underlying risk assessment and description of the operation in the Standard Operating Procedures with accompanying skill requirements and training program. The standard should be developed in collaboration with the two forums for inland helicopter operations and should be promoted through these.

2.9 Available data

2.9.1 LIGHTWEIGHT RECORDERS

EASA initiated in 2017 a rulemaking process to introduce a requirement for flight recorders in more types of aircraft. The new regulations include a requirement for turbine-engined helicopters with a maximum mass of 2,250 kg or more to carry lightweight flight recorders, with effect from 5 September 2022. The AS 350 has both turbine engines and a maximum mass of 2,250 kg and is covered by the new regulations. Helicopters such as the Robinson R44, which is also used for commercial air transport, fall outside the scope of the new rules in terms of both weight and engine type. The NSIA believes that the requirement regarding which aircraft must have a lightweight flight recorder also must be tied to commercial air transport.

For several years, Airbus Helicopters has, on its own initiative, equipped its AS 350 helicopters with Appareo Vision 1000 recorders. LN-OFU thus had recorder equipment installed. The fire destroyed the memory unit. The NSIA did therefore not have access to information that would have been very important during the investigation. If LN-OFU had been equipped with a lightweight flight recorder fulfilling the new requirements, data might have been available after the accident.

The NSIA has reviewed the consultation submissions on NPA 2017-03, and the outcome appears to be a compromise in response to divergent views. It appears that lightweight flight recorders are only regarded as an expense and tool used in accident investigation. Active use of flight data monitoring (FDM) has not been a topic. EASA points out to the NSIA that it would be a large burden for smaller operators to introduce a regime like FDM. The NSIA understands this view, but still holds the opinion that operators of Helitrans' size would increase flight safety implementing FDM. The NSIA finds it difficult to issue a safety recommendation to a single operator on this topic. Helitrans, however, have informed the NSIA that they on their own initiative have begun testing of a technical solution with the ambition to implement FDM.

In the NSIA's opinion, the compromise has turned out to be a solution with easier requirements to what information should be recorded, than Airbus Helicopters already has made available with the Appareo Vision 1000 recorder. The requirements in the new regulation does also not ensure the intention to provide safety investigation authorities with sufficient information to understand the accident regarding aircraft with a MTOW of less than 2,250 kg.

The new regulation only requires sufficient information to be stored to determine the flight path and speed. The regulation does not require additional data or audio and video recordings to be made and stored. Especially in helicopter accidents, such data is not sufficient in order to unambiguously be able to conclude how and why the accident occurred. The NSIA has investigated several accidents involving AS 350 where sound and picture stored on the Appareo Vision 1000 recorder have been vital to conclude and therefore improve aviation safety.

EASA's adjustments and intentions are good, but the NSIA believes that the regulations have weaknesses. The regulations should also apply to all light helicopters with and without a turbine that are used for commercial air transport operations, regardless of their certificate of airworthiness date. It should also be more requirements as to what should be stored.

On that basis, the NSIA addresses three safety recommendation to EASA in order to revise the Regulation (EU) 2019/1387 amending (EU) 965/2019 for lightweight flight recorders by:

a) Including requirements for audio and video recordings to be made and stored
b) Extending the scope to all types of light helicopters used for commercial air transport of persons
c) Extending the scope to all helicopters used for commercial air transport of persons, regardless of their certificate of airworthiness date

2.9.2 ACCESS TO SNAPCHAT VIDEO

The NSIA has not been given access to the Snapchat video sent from one of the passengers immediately before the accident occurred. The video was of no more than a few seconds' duration and was clearly recorded during the final phase of the flight. If the NSIA had been granted access to the video, its content could have been very helpful in the investigation. This illustrates that national authorities lack sufficient legal authority in this area.

3. Conclusion

3. Conclusion

3.1 Main conclusion

The investigation has not revealed technical faults or irregularities relating to the helicopter that could have impacted the sequence of events. At the last recorded position the helicopter was in descent and in a slight right turn. The helicopter was heavily loaded. The NSIA believes the flight control hydraulic system may have reached its limit during the manoeuvring, and thereby triggered servo transparency. Based on the last recorded altitude data, the helicopter had insufficient altitude above the terrain for the pilot to regain control in time.

The helicopter was almost new but was not fitted with a crash resistant fuel system (CRFT or CRFS). Since this can be excluded as a high-energy accident, the NSIA believes that such a protection system could have reduced the possibility of a fire where all the passengers died.

The NSIA look forward to the safety actions which EASA and Airbus Helicopters are in the process of implementing. Additionally, the helicopter operators and pilots need to keep focus on avoiding servo transparency and the challenges associated with sightseeing flights with passengers.

3.2 Investigation results

3.2.1 THE SEQUENCE OF EVENTS

A. The helicopter was heavy, with unnecessary amounts of fuel during the two sightseeing flights, which gave a high the load on the main rotor.

B. Flight data show periods of widely varying speeds and flight altitudes in virtually the same geographical area on both flights. Particularly during the final period, the flight altitude appears close to the terrain and below the minimum flight altitude of 500 ft.

C. One passenger has told the NSIA that the pilot said he would fly closer to the ground to give them a better sense of speed.

D. During the accident flight, the helicopter exceeded the limit value for pitch (nose down) given in the operator's procedures for sightseeing flights.

E. The last recorded data from the accident flight indicate a significant change in sink rate and increasing ground speed.

F. The helicopter was probably in descent in a slight right turn at a low altitude above the terrain immediately before the accident occurred. The last recorded data show that it was below 300 ft.

G. If servo transparency occurred at a low altitude above the terrain, the pilot had limited possibility of exiting the critical situation, as he would have had to lower the collective pitch control to reduce the load on the main rotor. This would bring the helicopter even closer to the ground.

H. The helicopter crashed while on course towards upward sloping terrain, north of the last documented flight path, after having changed course by almost 180°.

I. The crash occurred between 17:05 and 17:06

J. The tail rotor and main rotor were rotating when the helicopter hit the ground.

K. An overall assessment of the wreckage and the accident site suggests that the pilot manoeuvred the helicopter, was conscious and close to regaining control when the accident occurred.

3.2.2 SURVIVAL ASPECTS

A. The helicopter did not impact the ground with high energy, considering that the helicopter was not destroyed before it caught fire. It impacted the ground with low ground speed and low vertical speed.

B. The forces involved in the accident are unlikely to have caused fatal injuries to the passengers. It is assumed that the fire started just after impact with the ground.

C. The cause of death of the passengers is assumed to be extensive burn injuries.

D. The pilot did not wear a helmet and is assumed to have died from a combination of burn and head injuries.

E. The forces were sufficient to rip open the fuel tank, separate the tail boom from the fuselage and misalign the engine and main gearbox.

F. Under EU legislation, helicopters whose type certificates were issued before 1994 are not required to have crash resistant fuel system, and therefore few helicopters delivered after 1994 have such a system installed.

G. Given that it was not a high energy accident, a crash resistant fuel system could have minimized the risk and the propagation of fire.

3.2.3 FACTORS THAT CAN BE RULED OUT

A. It is unlikely that parts fell off and damaged the helicopter during flight.

B. No findings have been made to indicate that the crash was the result of a collision with a bird or drone.

C. The weather was not a factor in the accident.

D. There were no indications that the pilot suffered from insufficient sleep or fatigue or was under the influence of alcohol or drugs.

E. Intentional interference from the passengers is found unlikely. Nor were there any loose items in the cockpit that could influence the flight controls.

F. The accident site was unsuitable for emergency landings and amidst several suitable landing sites in the area. Engine power was delivered at the time of the accident.

G. The investigation has not found any technical faults or irregularities relating to the helicopter that could have had any influence on the sequence of events.

3.2.4 THE SERVO TRANSPARENCY PHENOMENON AND MEASURES

A. The total load on the main rotor, and hence the probability of servo transparency, increases with the following factors: high speed, high collective pitch, high mass, high G load, and high-density altitude, i.e. increasing flight altitude, temperature and/or humidity.

B. It appears to the NSIA that the helicopter type is more sensitive to servo transparency than many pilots believe to be the case.

C. The helicopter's self-correcting behaviour may lead to deviations from the flight profile that can be both sudden and unexpected for the pilot.

D. The helicopter flight manual has no warning describing the risk involved when servo transparency occurs in a right turn.

E. The helicopter was not equipped with a technical solution that gives advance warning of maximum load on the main rotor, and thereby servo transparency.

F. Simulator training can be useful for attention training that enables early recognition and recovery from a servo transparency.

G. Helitrans' procedures contained no specific warnings relating to high mass and no guidelines on reducing the maximum speed during sightseeing flights.

3.2.5 HUMAN FACTORS

A. The pilot had limited experience in general (a total of 256 hours of flight time) and on the helicopter type in particular (17 hours of flight time on the AS 350).

B. The pilot's type rating at Airbus Helicopters included familiarisation (ground course based on FLM content and additional explanation of the phenomenon), and demonstration of servo transparency on board the helicopter (several manoeuvres performed by the pilot/instructor in accordance with the "EASA Operational Suitability Data (OSD) – Flight Crew Data (FCD)", paragraph "Training Areas of Special Emphasis (TASE)") and without the use of simulator.

C. By their very presence, the passengers may have influenced the flight, even though they were not aware of it.

D. Sightseeing flights are regarded by the inland helicopter sector as the simplest form of operations and are therefore used as a means for inexperienced pilots to gain experience.

E. The operator proficiency check appears to be a formality that does not include practical flying with passengers on board in the presence of an experienced pilot.

F. Inexperienced pilots can be more easily influenced and feel greater strain when carrying passengers than experienced pilots.

G. Some of the passengers had been drinking alcohol but were not considered as unfit to participate in the flight.

3.2.6 AVAILABLE DATA

A. Except for the tail boom, the helicopter wreckage was completely burnt out. It was impossible to retrieve recorded flight data or information from other electronic components in the wreckage.

B. Several witnesses made observations relating to the flight, but no witnesses had seen the helicopter crash.

C. Information about the helicopter's position, altitude and speed has been obtained from Flightradar24 and the helicopter company's CelloTrack 3Y tracking device. There are no ADS-B data available about the helicopter's final manoeuvres before impact with the ground due to lack of coverage.

D. Even though it is not required for the purpose of certification, Airbus Helicopters had equipped the AS 350 with a Appareo Vision 1000 recorder, but the memory unit did not resist the fire.

E. The NSIA has not been given access from Snap Inc. to a Snapchat video sent by one passenger immediately before the accident.

4. Safety recommendations

4. Safety recommendations

The Norwegian Safety Investigation Authority proposes the following safety recommendations [31]:

Safety Recommendation Aviation No. 2022/01T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, cannot be described as a high-energy accident. The passengers could probably have survived had an intense fire not broken out immediately. The helicopter was almost new but had not been fitted with a crash resistant fuel system. Under EU legislation, helicopters whose type certificates were issued before 1994 are not required to have crash resistant fuel system. In the USA, all new helicopters delivered after May 2020 should be equipped with crash resistant fuel system.

The Norwegian Safety Investigation Authority recommends that EASA requires that all helicopters, new and used, delivered or imported to Europe be equipped with crash resistant fuel systems in accordance with CS 27.952 or CS 29.952, regardless of their type certification date.

Safety Recommendation Aviation No. 2022/02T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, cannot be described as a high-energy accident. The passengers could probably have survived had an intense fire not broken out immediately. The helicopter was almost new but had not been fitted with a crash resistant fuel system. Passengers are exposed to unnecessarily great risk during transport by helicopters without crash resistant fuel system.

The Norwegian Safety Investigation Authority recommends EASA to not permit commercial passenger flights with helicopters not equipped with crash resistant fuel systems in accordance with CS 27.952 or CS 29.952, regardless of their type certification date.

[31] The Ministry of Transport forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation § 8.

Safety Recommendation Aviation No. 2022/03T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, cannot be described as a high-energy accident. The passengers could probably have survived had an intense fire not broken out immediately. The pilot did not wear a helmet during the flight. In general, in addition to saving the pilot's life, use of a helmet can enable the pilot to assist passengers in the event of an accident.

The Norwegian Safety Investigation Authority recommends that the Civil Aviation Authority Norway, when approving procedures (SOP) for commercial air transport operations, ensures that the helicopter operator's risk assessment involves aspects related to the use of helmets for pilots.

Safety Recommendation Aviation No. 2022/04T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, probably occurred after the helicopter encountered servo transparency while in descent and in a slight right-hand turn. The helicopter was heavily loaded, and its speed was increasing. The accident involving LN-OXC at Dalamot on 4 July 2011 occurred under similar circumstances. The helicopter is not equipped with technical aids that gives advance warning, or prevent reaching, of the maximum load on the main rotor, and thereby servo transparency. The NSIA is aware that Airbus Helicopters initiated a prefeasibility study in 2018 and that solutions and roadmap were presented to EASA in September 2021. So far, no solution has been implemented.

The Norwegian Safety Investigation Authority recommends that EASA requires the type certificate holder Airbus Helicopters to establish a technical solution preventing or giving advance warning of servo transparency, for helicopters that are sensitive to this phenomenon.

Safety Recommendation Aviation No. 2022/05T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, probably occurred after the helicopter encountered servo transparency while in descent and in a slight right-hand turn, at a low altitude above terrain and while its speed was increasing. Simulator training for the AS 350 should take place in an approved full flight simulator, or similar simulators that can recreate servo transparency. This is to ensure that pilots can recognise when the helicopter is about to enter a servo transparency condition, and practise manoeuvres to bring the helicopter out of such a situation.

The Norwegian Safety Investigation Authority recommends that EASA review instruction and continuous training on the AS 350. This is to ensure that the training includes attention training that enables early recognition and recovery from a servo transparency situation based on the UPRT principles.

Safety Recommendation Aviation No. 2022/06T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, probably occurred after the helicopter encountered servo transparency while in descent and in a slight right-hand turn, at a low altitude above terrain and while its speed was increasing. Simulator training for the AS 350 should take place in an approved full flight simulator, or similar simulators that can recreate servo transparency. This is to ensure that pilots can recognise when the helicopter is about to enter a servo transparency condition, and practise manoeuvres to bring the helicopter out of such a situation.

The Norwegian Safety Investigation Authority recommends that Civil Aviation Authority Norway review instruction and continuous training on the AS 350. This is to ensure that the training includes attention training that enables early recognition and recovery from a servo transparency situation based on the UPRT principles.

Safety Recommendation Aviation No. 2022/07T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, probably occurred after the helicopter encountered servo transparency while in descent and in a slight right-hand turn, at a low altitude above terrain and while its speed was increasing. The helicopter fuel tank was filled to 90% of full capacity. Helitrans AS had a standard procedure in which the minimum altitude could be understood to mean the normal flight altitude. It defined maximum nose angles, but contained no information or warnings in the SOP relating to mass or speed limitations for sightseeing flights.

The Norwegian Safety Investigation Authority recommends that Helitrans AS revise its standard procedure for sightseeing flights in general, and for AS 350 flights in particular, to better reflect the challenges related to flight altitude, mass and speed.

Safety Recommendation Aviation No. 2022/08T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, probably occurred after the helicopter encountered servo transparency while in descent and in a slight right-hand turn, at a low altitude above terrain and while its speed was increasing. The helicopter fuel tank was filled to 90% of full capacity. Helitrans AS had a standard procedure in which the minimum altitude could be understood to mean the normal flight altitude. It defined maximum nose angles but contained no information or warnings in the SOP relating to mass or speed limitations for sightseeing flights.

The Norwegian Safety Investigation Authority recommends that Civil Aviation Authority Norway, through its leadership of various safety forums for inland helicopters, raise awareness of the challenges related to flight altitude, mass and speed in general, and to the AS 350 helicopter type in particular.

Safety Recommendation Aviation No. 2022/09T

The air accident on 31 August 2019 in Alta involving an Airbus Helicopters AS 350 B3, LN-OFU, occurred on a sightseeing flight with passengers. Sightseeing flights are regarded by the inland helicopter sector as the simplest form of operations and are therefore used as a means for inexperienced pilots to gain experience. The sector appears to have underestimated that inexperienced pilots can be more easily influenced and feel greater strain when carrying passengers than experienced pilots. The operator proficiency check appears to be a formality that does not include practical flying with passengers on board in the presence of an experienced pilot. Consequences in the event of an accident also appear to have been overlooked.

The Norwegian Safety Investigation Authority recommends that the Civil Aviation Authority Norway develop and publish a standard for commercial air transport operations with single engine helicopters. This should pay special attention to sightseeing flights. The standard should include guidance to develop the underlying risk assessment and a description of the operation for SOPs with accompanying requirements for qualification and training program. The standard should be developed in collaboration with the two forums for inland helicopter operations and be promoted to the operators through these.

Safety Recommendation Aviation No. 2022/10T

A vicious fire broke out when an Airbus Helicopters AS 350 B3, LN-OFU, crashed in Alta on 31 August 2019. The helicopter was equipped with a lightweight flight recorder of the type Appareo Vision 1000, which stored several technical parameters in addition to audio and video records. The memory unit did not resist the fire and it was impossible to retrieve any data. The new requirements concerning lightweight flight recorders (Commission Implementing Regulation (EU) 2019/1387 SPO.IDE.H.146) do not entail audio and video recordings to be made and stored. Furthermore, it is only a requirement that sufficient information is stored to determine the flight path and speed. Especially in helicopter accidents, such a data basis is not sufficient.

The Norwegian Safety Investigation Authority recommends that EASA revise Regulation (EU) 965/2012 for lightweight flight recorders, by including requirements for further registration of data, as well as for audio and video recordings to be made and stored.

Safety Recommendation Aviation No. 2022/11T

A vicious fire broke out when an Airbus Helicopters AS 350 B3, LN-OFU, crashed in Alta on 31 August 2019. The helicopter was equipped with a lightweight flight recorder of the type Appareo Vision 1000, which stored several technical parameters in addition to audio and video records. The memory unit did not resist the fire and it was impossible to retrieve any data. The new requirements concerning lightweight flight recorders (Commission Implementing Regulation (EU) 2019/1387 SPO.IDE.H.146) (EU 965/2012) do not entail all types of light aircraft used for commercial operations, for example the Robinson R44. It does not ensure the regulations' intention to provide safety investigation authorities with sufficient information to understand accidents.

The Norwegian Safety Investigation Authority recommends that EASA revise Regulation (EU) 965/2012 for lightweight flight recorders, by extending the scope to all types of light helicopters used for commercial air transport of persons.

Safety Recommendation Aviation No. 2022/12T

A vicious fire broke out when an Airbus Helicopters AS 350 B3, LN-OFU, crashed in Alta on 31 August 2019. The helicopter was equipped with a lightweight flight recorder of the type Appareo Vision 1000, which stored several technical parameters in addition to audio and video records. The memory unit did not resist the fire and it was impossible to retrieve any data. The new requirements concerning lightweight flight recorders (Commission Implementing Regulation (EU) 2019/1387 SPO.IDE.H.146) (EU 965/2012) do not entail aircraft with airworthiness certificate issued before 5 September 2022. It does not ensure the regulations' intention to provide safety investigation authorities with sufficient information to understand accidents.

The Norwegian Safety Investigation Authority recommends that EASA revise Regulation (EU) 965/2012 for lightweight flight recorders, by extending the scope to all helicopters used for commercial air transport of persons, regardless of their certificate of airworthiness date.

Norwegian Safety Investigation Authority
Lillestrøm, 18 March 2022

Appendices

Appendix A Experience of AS 350 simulator after the accident with LN-OXC at Dalamot

Excerpt from memo after AS 350 simulator flight at American Eurocopter on 14 February 2012.

…

The first impression was very good.

The simulator was brand new (February 2011) with only approximately 550 hours' [flight time].

…

The simulator had an identical AS 350 cabin and exterior body installed from the aft seat going forward. A ramp was wheeled out on either side of the cockpit, for entering the cockpit through ordinary AS 350 doors. This made it incredibly realistic. The cockpit felt very familiar except for the pedestal. It had a toggle switch installed instead of the push button we are used to. The instrumentation and position of other controls were otherwise the same as in our helicopters.

…

It is necessary to get a sense of/experience the simulator before a stable hover can be achieved. This is because the view ahead is two-dimensional, which means that you must seek to keep your head as steady as possible so as not to disturb your senses. Once this trick was learnt, the experience was incredibly good. Because of the graphics and width of the image (240 degrees horizontally and 80 degrees vertically), the experience was very close to the real thing. The large width and height of the graphics gave a full view in all directions from the pilot seat.

…

The translational lift was incredibly realistic. Vibrations in the fuselage, control feedback and control input were also absolutely correct. When the first landing round had been completed, we tried dealing with some emergencies.

First out was tail rotor control failure … … Felt that the simulator pre-set the tail rotor pitch absolutely correctly. The final part of the flight and touchdown felt very right.

Next out was hydraulic failure. … This also felt right.

We then set the helicopter to max. weight to provoke hydraulic transparency. Our instructor had never done this in the simulator so he was also curious as to how the manoeuvre would be simulated. We established a level flight at 120 kt. We initiated a right-hand turn and then pulled back the cyclic. FRIGHTENINGLY realistic! We entered an uncontrolled roll, banking further to the right. The controls 'froze' at the same time as the collective wanted to come down. Those who had not experienced this manoeuvre in real life were very surprised. The manoeuvre was then repeated in a left-hand turn. This was much less violent, as is also the case in a real flight; it largely righted itself.

Next on the programme was to establish a situation like the one LN OXC was in: 300 ft agl, right turn, nose down and then pull us out of the turn. We were of course aware of what would happen, but if you're not, you have to be very lucky to avoid crashing into the ground!

The manoeuvre was also completed by lowering the collective before initiating the right-hand turn. It produced only a slight feedback in the controls, which is also the case in a real-life situation.

Based on the test flight, I would say that simulator training would be incredibly beneficial for our pilots. The emergency training would be much more advanced at the same time as other hazards such as whiteouts and hydraulic transparency could be realistically demonstrated with the frightening effects they can have. We would be able to practise inadvertent IMC, proficiency check on ship operation, and mission training (e.g. marking polar bears or sling-load operations) could be simulated by installing a monitor in the floor window.

I want to conclude by saying that my view of the value of training and use of simulators is unequivocally positive. It would raise our pilots' level of knowledge, which would, in turn, improve the safety of our operations. The training would motivate the pilots to increase their skills, because the training becomes more advanced. You can just look at the accident statistics for offshore flights from before and after simulator training started. I will not claim that the latest accidents we have experienced on inland flights in recent years could have been avoided given simulator training, but the probability of this being the case is very high.

Perhaps it's time to advance another step when it comes to training?

Yours sincerely,

xxx

Training Captain

Appendix B Altitude data

The NSIA has collected, analyzed, and compared altitude data from different sources. These sources include CelloTrack 3Y, Flightradar24 and The Norwegian Mapping Authority, and the local barometric pressure (QNH) at Alta Airport around the time of the accident.

QNH

QNH on 31 August 2019 was 1007 hPa, and the airport elevation is 10 ft. The altimeter in the helicopter seems to have been set to a QNH of 1002, and this will result in an indicated altitude that is 150 ft lower than the actual pressure altitude. The deviation will only affect the visual indication on the altimeter on the instrument panel.

CelloTrack 3Y

This system sends data to the operator, including altitude data, and the altitude data is GNSS-based. The system transmits with a relatively low frequency, and the period between relevant data points was 15–20 seconds.

GPS altitude information is with reference to WGS84, which differs from the NN2000 reference used by The Norwegian Mapping Authority. The difference will cause the altitude indicated by a GPS to be 84 ft higher in the area around Alta than the terrain elevation stated by The Norwegian Mapping Authority.

Comparison of the data registered by CelloTrack seems to indicate that the GPS altitude is corrected to map elevation. According to The Norwegian Mapping Authority, the elevation of the landing site at the festival is 234 ft, and the elevation of the accident site is 945 ft. CelloTrack has registered 235 ft and 238 ft for the festival site, and 906 ft for the accident site.

ADS-B and Flightradar24

Altitude data from the ADS-B (Automatic Dependent Surveillance-Broadcast) in the helicopter is transmitted by the transponder, registered by Flightradar24, and rounded to the nearest 25 ft. ADS-B is a system that broadcasts information about the aircraft, such as position and altitude.

There are different types of ADS-Bs that are connected to and receive information from various flight data systems in the aircraft. Altitude data from the type of transponders installed in LN-OFU will typically be based on barometric altitude with reference to the standard atmosphere, i.e., an altitude calculated from air pressure. A transponder can also transmit altitude estimated from GPS or other satellite systems, but there is no information that indicate that the transponder in LN-OFU was satellite based.

The standard atmosphere is defined with an air pressure of 1013.25 hPa at mean sea level. A pressure difference of 1 hPa at sea level represents 27 ft altitude, and this is increased to 37 ft at an altitude of 10 000 ft. The altitude deviation per hPa at the relevant altitudes for the helicopter flights in this case is then approximately 30 ft. Thus, the barometric altitude with reference to the standard atmosphere (QNE) will differ 180 ft compared to a QNH of 1007, where data based on QNE will indicate 180 ft higher than actual barometric altitude.

Comparison of data

Altitude data from Flightradar24 has a high frequency and has been used to determine the flight altitude curves. The curves are also verified by comparing with the accumulation of altitude from vertical speed information. This shows that changes in altitude correspond but does not verify the reference of the altitude data.

Data points from CelloTrack that coincide with data points from Flightradar24 have been used to estimate the difference in altitude data from the ADS-B due to local air pressure. This has also been compared to information from relevant pictures and videos.

There are three coinciding points in time during the first flight. These have a deviation of 171 to 205 ft, with an average of 183 ft. All the data points from CelloTrack indicate a lower actual flight altitude than the data from Flightradar24. The deviation corresponds with the difference between QNE and the relevant QNH, and CelloTrack has registered an elevation of the festival area that for all practical purposes is identical to that from The Norwegian Mapping Authority.

There are 12 coinciding points in time during the accident flight. These deviate with 5 to 337 ft, and all the data points from CelloTrack indicate a lower altitude. The average difference is 128 ft, which is about 50 ft less than the barometric altitude difference between QNE and the relevant QNH. CelloTrack indicates the elevation of the festival area to 238 ft, and the elevation at the accident site to 906 ft. These differ from The Norwegian Mapping Authority's elevations by 3 ft and 39 ft.

All the altitude data from CelloTrack indicates a lower altitude above the terrain than the data from Flightradar24. There is, however, a limited number of data points, and both barometric altitude and GPS altitude will be somewhat uncertain. NSIA has thus decided to illustrate the flight path curve based on data from Flightradar24, and the altitude of the path by adjustments based on altitude data from CelloTrack. The adjustments are 183 ft for the first flight, and 128 ft for the accident flight. Terrain elevation is data from The Norwegian Mapping Authority.

Appendix C Influence from passengers

Findings from investigations and research relating to road traffic

A survey from Spain showed that drivers are significantly less likely to cause a collision between two or more vehicles that results in injury or death when they carry passengers. This effect was found to be consistent, regardless of driver or passenger types (Trinidad Rueda-Domingo et al., 2004). The preventive effect of being accompanied by passengers was greatest among the youngest drivers (<24 years) and drivers of 45 years plus, and where male drivers carried female passengers.

A similar survey was carried out in Germany (Vollrath, Meilinger & Krüger, 2001), in which having passengers in the car was also found to have a preventive effect. The positive impact was less pronounced, however, in young drivers, when driving in the dark, in traffic queues and at intersections, particularly in situations involving disregard for right-of-way and overtakings. The findings were interpreted as demonstrating a general positive effect of carrying passengers, in that it, in many situations, led to more careful and safer driving behaviour. However, the findings also indicated that passengers can sometimes distract the driver, thereby reducing the positive impact of having company when driving.

The preventive effect of having passengers in the car has also been confirmed in more recent studies (Rosenbloom & Perlman, 2016; Lee & Abdel-Aty, 2008; Engström et al., 2008).

A study conducted in Italy (Orsi et al., 2013) presented a somewhat different picture. For drivers under 25 years of age, the risk of accidents increased when they carried one or more passengers. The same was not found to be the case in drivers who were 25 years or older. In accidents involving only one vehicle, it was found that the presence of passengers increased the risk of accidents among young drivers, while it had a positive impact on more mature drivers.

A review from 2001[32] of studies of passenger influences on drivers also showed that specific driver-passenger combinations increase the risk of collision, while other combinations are without any impact or reduce the risk. Review findings:

- Young drivers have a higher risk of collision than older drivers, and this risk is further increased when the driver is accompanied by passengers of the same age, but reduced when accompanied by an adult or a child passenger, when compared with carrying no passengers.
- Young male drivers were at greater risk of colliding in the presence of passengers than young female drivers.
- When carrying male passengers, drivers, whether male or female, were at greater risk of colliding than when carrying female passengers.
- For young drivers, the risk of a collision having a fatal outcome was reported to increase with two or more passengers in the car, provided that the passengers were of the same age as the driver.
- The risk of collision for young drivers, whether male or female, increased with each additional male passenger.

[32] Regan, MA & Mitsopoulos, E (2001): Understanding Passenger Influences on Driver Behaviour: Implications for Road Safety and Recommendations for Countermeasure Development. Monash University Accident Research Centre – Report #180 – 2001

- Having two or more female passengers was observed to have a favourable impact on young drivers, but only where the driver was a woman.

Similar observations regarding young drivers' risk of accidents and passengers in the same age group are described in the Norwegian Centre for Transport Research's Handbook of Road Safety Measures. Ulleberg and Must (2005) have also established that, for young drivers, the risk of accidents increases with the number of young passengers in the car. The increased risk of accidents may be related to young drivers becoming more distracted when carrying passengers. The risk of accidents is particularly high, for example, when both the driver and passengers are young men (Ulleberg and Must, 2005[33]).

A survey conducted in Australia of young drivers aged 16–25 years[34] showed that the risk of a collision causing injuries increased in step with the number of passengers. Compared with driving alone, it was more risky to carry one passenger, even more risky to carry two passengers, and carrying three or more passengers entailed the highest risk.

Horrey et al.[35] wanted to compare drivers' performance when distracted on a test track with their own assessment of the degree to which their driving was affected by the distraction. Compared with driving without distraction, drivers in all age groups performed worse when distracted. There was no strong correlation, however, between poor driving performance and the drivers' assessment of their own performance.

In general, young men (18–34 years old) had the poorest insight into the impact of distraction on their driving behaviour. Furthermore, it was found that the young men who scored lowest on driving behaviour also thought their driving was the least influenced by distractions. Older men (55–82 years old), on the other hand, had fairly good insight into the impact of distraction on their driving behaviour.

Experimental studies have shown that driving with a risk-accepting rather than a passive passenger in the same age group can double a young driver's risk of violating the traffic rules (Simons-Morton, Bingham et al., 2014[36]) and increase the driving speed (Shepherd, Lane, Tapscott & Gentile, 2011[37]).

[33] Ulleberg P and Must T (2005): Unga passagerare som skyddsänglar. Vad hindrar eller främjer deras roll som påverkare? Norwegian Centre for Transport Research, Report No 776/2005, Oslo.
[34] Lam, LT (2003): Factors associated with young drivers' car crash injury: comparisons among learner, provisional, and full licensees. Accident Analysis and Prevention 35 (2003), 913–920.
[35] Horrey, WJ, Lesch, MF and Garabet, A (2008): Assessing the awareness of performance decrements in distracted drivers. Accident Analysis and Prevention 40 (2008), 675–682.
[36] Simons-Morton, BG; Bingham, CR; Falk, EB; Li, K; Pradhan, AK; Ouimet, MC; … Shope, JT (2014): Experimental effects of injunctive norms on simulated risky driving among teenage males. Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association, 33(7), 616–27.
[37] Shepherd, JL; Lane, DJ; Tapscott, RL & Gentile, DA (2011): Susceptible to Social Influence: Risky 'Driving' in Response to Peer Pressure. Journal of Applied Psychology, 41(4), 773–797.

Findings from aviation accidents

There are few examples of aviation accidents in which the presence and influence of passengers may have had a safety-critical impact on the pilot's behaviour. The following accidents are mentioned in this context:

- One accident that took place in the USA[38] in connection with guided tours in a Eurocopter AS 350 B2 helicopter gives some insight into the interaction between passengers and pilot prior to the accident. One of the passengers survived and was able to describe how the tour was flown, which was also confirmed by audio and video records from a camera installed in the helicopter cabin. According to the passengers on the tour preceding the accident flight, the pilot talked a lot about the sights below the aircraft. On the accident flight, after having flown for about 20 minutes, the pilot turned to face the passengers and spoke to them while flying towards a mountainous area, apparently to provoke a reaction. A little further on, just before the accident occurred, the pilot flew low over the crater edge at high speed, and then tipped the helicopter nose towards the bottom of the ravine. This was meant to simulate driving off a cliff in a car. According to the NTSB, the accident occurred as a result of the pilot's decision to manoeuvre the helicopter in a way that significantly reduced the helicopter's performance limits. The outcome was a very high sink rate that could not be stopped. Contributing factors to the accident were the high density altitude and the pilot's decision to fly close to steep terrain, which made it difficult to take corrective action to avoid impact with the ground.
- The Norwegian investigation authority investigated the accident at Torghatten near Brønnøysund on 6 May 1988, in which a DHC-7-102 aircraft from Widerøe crashed into the Torghatten mountain while approaching Brønnøysund.[39] One important factor in causing the accident was that a conversation between a passenger and the captain in a critical phase of the flight drew attention away from important flight safety tasks.

Summary

In summary research into road traffic behaviour seems to suggest that carrying passengers often has a preventive effect, as the accident risk is generally reduced when there are passengers in the car. But there are also examples of heightened accident risk among young drivers (under 25 years) in the presence of peer passengers. Direct comparisons between ordinary driving and experience-based helicopter sightseeing flights are not possible, however, as the two activities differ in many respects. General findings related to road traffic behaviour should not be assigned too much weight alone, but should be seen in light of few findings from air accidents, and of how parts of the sightseeing flight under investigation was conducted in the area over the Skoddevarre mountains. There has been no information that the pilot in the present case performed anything close to the extreme manoeuvres leading up to the Arizona accident.

[38] *NTSB (2004): Eurocopter AS350-B2, N169PA, Arizona, August 10, 2001*.
[39] *Aviation Accident Committee (1989): Rapport om luftfartsulykke ved Torghatten nær Brønnøysund den 6. mai 1988 med Dash 7 LN-WFN*

Appendix D Documentation Line Check

HELITRANS OPERATIONS MANUAL – PART D Rev. 4 – 01.04.2017

Appendix D-3: Line Check

Name:	[redacted]	A/C type/reg:	AS 350/EC120
Licence no:		Place:	KVÆNANGEN / ÆRTA
Date (dd-mm-yy):	20.04.19	Flight time:	1:10

Flight preparation	Pass	Fail
Weather analysis	☒	☐
Flight planning	☒	☐
NOTAM	☒	☐
Pre-flight inspection	☒	☐
Pax briefing	☒	☐
Performance	☒	☐
Aircraft prep. (Including check for Cargo hook/longline/load equipment)	☒	☐
Fuel procedures	☒	☐
Cockpit preparation	☒	☐
Minimum safe altitude	☒	☐
Emergency procedures		
Ready knowledge	☒	☐
Emergency equipment	☒	☐

Approach and landing	1	2	3	4	5
Planning/wind direction	☐	☐	☐	☐	☐
Pax briefing	☐	☐	☐	☐	☐
Speed control	☐	☐	☐	☐	☐
Aircraft handling	☐	☐	☐	☐	☐
Altitude awareness	☐	☐	☐	☐	☐
Landing performance	☐	☐	☐	☐	☐

Flight crew	1	2	3	4	5
Flight management	☐	☐	☐	☐	☐
Compliance with legal regulations	☐	☐	☐	☐	☐
Air Traffic Control	☐	☐	☐	☐	☐
Airmanship	☐	☐	☐	☐	☐
Cockpit resource management	☐	☐	☐	☐	☐
Compliance with aircraft limitations	☐	☐	☐	☐	☐
Attitude towards customer	☐	☐	☐	☐	☐
Use of A/C documentation	☐	☐	☐	☐	☐
After last flight check	☐	☐	☐	☐	☐
Adherence to SOP's (Including relevant instruction to customer on site)	☐	☐	☐	☐	☐
Recent landing experience (day/night last 90)	☐ YES		☐ NO		
HESLO recurrent every 2 year Min. 20 hrs relevant HESLO within the past 12 months	☐ YES		☐ NO		

Departure	1	2	3	4	5
Radio communication	☐	☐	☐	☐	☐
Ground handling	☐	☐	☐	☐	☐
Starting procedure	☐	☐	☐	☐	☐
Lift off procedures	☐	☐	☐	☐	☐
Adherence to clearances	☐	☐	☐	☐	☐
Climb	☐	☐	☐	☐	☐

Mission Performance	1	2	3	4	5
Hovering	☐	☐	☐	☐	☐
Lifting	☐	☐	☐	☐	☐
Accuracy	☐	☐	☐	☐	☐
Release of load	☐	☐	☐	☐	☐
Communication	☐	☐	☐	☐	☐
Situational awareness	☐	☐	☐	☐	☐

Assessment rating	
Not qualified	1
Training required	2
Middle	3
Good	4
Very good	5

Remarks: PILOT CLEARED FOR RFL ACC SOP 09 OME. ALSO 4X TRAILE LDG ENAT / CONFINED LDG MOUNTAIN. (Continue on back side)

Result of the line check: ☒ Proficient ☐ Not proficient

Corrective training ☐ Required ☐ Recommended On the subjects: .... ☐ N/A

Signature pilot: [redacted]

Instructor Na[redacted]

Signature: [redacted]

Appendix E Documentation Operator Proficiency Check (OPC)

HELITRANS

Appendix D-2: Operator Proficiency Check (OPC)

Pilot, location and date

Name:		AC type/reg:	H-125. LN-OFU
License no:		Place:	ENAT
R.H. seat:	0:50	L.H. seat:	
Date:	19.08.2019	Flight time:	0:50
Instructor name:		Next check:	29.02.2020

Flight planning

Weather analysis	Pass
Fuel calc.	Pass
NOTAM	Pass
Pre-flight inspection	Pass
Payload	Pass
Operational Flight Plan	Pass
Personel licence	Pass
Fuel procedures	Pass
Documents	Pass

Field operation

Slope landing	3
Field landing	3
Winter operation	3
Quick stop	3

Prestart

External / Internal checks	Pass

Emergency

Hover auto	3
Autorotation(Straight in/180/360)	3
Hyd. failure and landing	4
Stuck pedals (high/low)	2
Fuel control failure	
Pilot induced oscillation (oral)	4
Servo transparency(oral)	4

Starting

Use of checklists	3
Cockpit proc. and checks	3
Radio com / Trans. code	3

Taxing / Hovering

Fore/backward/sideways	3
Spot turns	3

T/O and landings

Normal take off	4
Normal app	4
Steep app	3
Spot landing	4

In flight manoeuvers

Power checks	4
Level/climb/decent	4
Normal turns	4
Steep turns (30 bank)	3
Rapid speed changes	4

Recovery from unusual att	3
Navigation/EFB	4

Supplementary assessment

A/C maneuvering	Normal
Compliance with procedures	Good
Airmanship	Good

Condition

VMC	Day
Wind	Gusty

Assessment rating

Not qualified	1
Training required	2
Middle	3
Good	4
Very good	5

Remarks

Result

Result of the OPC	Approved

Signature

The pilo