Accident
Investigation Board
Norway

Issued June 2015

REPORT SL 2015/06

REPORT ON AIR ACCIDENT AT SOLLIHØGDA IN BUSKERUD, NORWAY 14 JANUARY 2014 WITH AIRBUS HELICOPTERS EC 135 P2+, LN-OOI OPERATED BY NORSK LUFTAMBULANSE AS

The Accident Investigation Board has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety shall be avoided.

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

Photos: AIBN and Trond Isaksen/OSL

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AIR ACCIDENT REPORT

Aircraft:	Airbus Helicopters Deutschland GmbH EC 135 P2+
Nationality and registration:	Norwegian, LN-OOI
Owner:	SG Finans AS, Lysaker, Norway
User:	Norsk Luftambulanse AS, Drøbak, Norway
Crew:	Three, of which two were fatally injured and one was seriously injured
Passengers:	None
Accident site:	Outside the eastern exit of the Sønsterud tunnel in Hole municipality in Buskerud County, Norway (59° 59'N 010° 18'E)
Date and time:	Tuesday, 14 January 2014, 10:49:21 hours

All hours stated in this report are local time (UTC + 1 hour) unless otherwise indicated.

ACCIDENT NOTIFICATION

The Accident Investigation Board's (AIBN) on-duty officer received notification from Northern Buskerud police district on Tuesday 14 January, at 1104 hours, that an air ambulance helicopter had crashed near Sollihøgda in Hole municipality. There were both fatalities and serious injuries. The Joint Rescue Coordination Centre for Southern Norway and Norsk Luftambulanse AS notified AIBN about the accident shortly thereafter.

Five accident investigators from the Accident Investigation Board responded and started investigation at the accident site the same afternoon. In accordance with ICAO Annex 13, ”Aircraft Accident and Incident Investigation”, the Accident Investigation Board notified the states of manufacture; Canada (Transport Safety Board – TSB) and Germany (German Federal Bureau of Aircraft Accident Investigation – BFU). BFU appointed an accredited representative who, together with advisors from Airbus Helicopters, assisted in the investigation.

SUMMARY

An HEMS helicopter from Norsk Luftambulanse AS (a Norwegian Air Ambulance operator) was flying from the base at Lørenskog to a traffic accident at Sollihøgda. During approach, the helicopter hit a power line which caused such extensive damage to the main rotor that the helicopter fell vertically from an altitude of approx. 25 m. The ground impact was so severe that two of the crew members were fatally injured and one was seriously injured. The helicopter was destroyed.

The power line was not physically marked and was unusually difficult to detect from the air. However, it was marked on a digital map (moving map display) and the crew was aware that there were power lines in the area before they arrived at the accident site. The crews in Norsk Luftambulanse AS had experienced that the obstacle database connected to the moving map had many deficiencies, and the company's procedures did not specifically state that the system should be

used as support to visual detection of obstacles during approach. Consequently, the functions in the system were only partially utilised.

Personnel on the ground were aware of the power line, but were unable to achieve radio contact with the flight crew. It has not been possible to determine the cause of this. The fact that the accident occurred in a transition zone between the analogue and digital public safety network, complicated communications.

Aviation obstacles constitute a substantial risk factor during operations at low altitude, and particularly when landing at an unknown location. The Accident Investigation Board (AIBN) has identified several potential measures to reduce this risk. For example, predefined landing sites should be used as much as possible, the existing obstacle database should be improved and utilised more effectively, and the work to identify and control the risk of such operations should be strengthened.

The Accident Investigation Board has issued three safety recommendations in connection with this investigation.

1. FACTUAL INFORMATION

1.1 History of flight

1.1.1 The ambulance helicopter[1] was in normal preparedness at the base at Lørenskog, when the emergency medical services communication centre for Oslo and Akershus counties (AMK O/A) received a report of a traffic accident at Sollihøgda at 1029 hours. A truck had overturned and one person was seriously injured. The helicopter was pulled out of the hangar and start-up proceeded as normal. The aircraft commander sat in the front right-hand seat and the HEMS crew member (HCM) in the left, while the physician was in the right-hand cabin seat. The helicopter departed at 1038 hours, and the HEMS crew member set an initial course towards the accident site, located approx. 21 NM west of the base. En-route, the physician received the accident site coordinates via the fleet management system LOCUS used by the emergency medical communication centre. The HEMS crew member set a course for position 595950N 0101810E in the helicopter's digital map system (EURONAV[2]) and the course to the traffic accident site was displayed on the cockpit multi-function display.

1.1.2 Communication between the ambulance helicopter and AMK O/A after 1038 hours focused on position and estimated time of arrival. In order to communicate directly with personnel at the accident site, the HEMS crew member contacted the emergency medical services communication centre for Vestre Viken (AMK Vestre Viken), and requested the analogue medical channel 33 to be ”opened“. This centre was responsible for the area where the accident took place. There was no contact between the ambulance helicopter and Vestre Viken after this. Somewhat later, the HEMS crew member attempted to call up the accident site on medical channel 33 without getting a response. Accordingly, the

[1] In accordance with Norwegian and international regulations, this was an HEMS flight (Helicopter Emergency Medical Services) and not an ambulance flight (patient transport). The HEMS flight regulations differ from ambulance flights, which are regarded as regular air transport. This applies throughout the report when the term air ambulance is used.
[2] EuroAvionics Navigation System, EURONAV IV

crew on board in LN-OOI was unaware that the patient had been transferred to an ambulance and was receiving treatment when the helicopter arrived at Sollihøgda.

1.1.3 The majority of the flight was flown at an altitude of 2 000 ft. (MSL), outside controlled airspace. It was cloudy and light snow, but there were no issues with visibility or cloud ceiling during the flight. The crew did not submit a flight plan to the air traffic services, and was not in contact with Oslo Air Traffic Control Centre (ATCC) during the flight. This was not required, nor common practice for such flights. In order to establish contact with any traffic in the uncontrolled airspace, the aircraft commander would call on relevant frequencies for the Kjeller and Oslo area as the helicopter progressed westward.

1.1.4 The crew was very familiar with the area, but the HEMS crew member followed the procedures regardless and zoomed in on the possible landing site on the moving map display. He then discovered a span above the site. According to the HEMS crew member, both he and the aircraft commander saw the span symbol. In order for all to be informed, the physician was also alerted to this.

1.1.5 After a ten-minute flight, the helicopter arrived at the scene of the traffic accident which had occurred between the exits of the Nes and Sønsterud tunnels (see Figure 1). The aircraft commander reduced the speed to 50 kt and flew approx. 200 m south of the site, in a south-western direction, at approx. 800 ft. altitude above the ground (1 461 ft. MSL) in order to find a suitable landing area (see Figure 12). According to the HEMS crew member, they flew relatively fast and high, and were not on particular lookout for any aviation obstacles.

1.1.6 The HEMS crew member has explained that he and the aircraft commander agreed to land on the road by the southern exit of the Nes tunnel. This decision was made from flight operational considerations. They did not notice anyone on the ground attempting to indicate a suitable landing site. They saw power lines and streetlights in the area. After passing the landing site, the helicopter continued on a south-western course, at the same time as it descended to 700 ft. (MSL) and made a wide right turn. It then slowly continued towards the landing site in a north-eastern direction.

1.1.7 A police patrol (P05) comprising an incident commander and a leading advisor arrived at the traffic accident in a police car four minutes prior to the helicopter. It became apparent that it would not be possible to land a helicopter right next to the truck. The leading police advisor therefore drove to the western exit of the Sønsterud tunnel to look for a possible landing site there. Since this site was not suited either, he drove the car to the southern exit of the Nes tunnel. At this time, the helicopter passed approx. 200 m south of the traffic accident site. The leading police advisor then parked the police car on the road at an emergency lay-by, with the front of the vehicle facing southward, approx. 40 metres from the tunnel exit. He then walked out of the car, and stood in front of the vehicle with his hands raised.

1.1.8 The leading police advisor wanted to communicate the presence of power lines in the area and the risk of whiteout in snow during landing. Before parking the car, he therefore called up the helicopter from the car radio on channel 5 (Rescue 1[3]) at 10:47:10 hours, with the words: *"Air ambulance, this is the police, over".* He did not receive a response and repeated the message at 10:48:15 and 10:48:39. The final call took place as the

[3] Analogue radio

helicopter passed over the area. After the leading police advisor had left the car, the site commander also called up the helicopter from his handheld radio with the words: *”You got someone waving at you up there, possible landing site”.* This call was monitored in the police car, and happened just 24 seconds prior to the helicopter hitting the power lines.

1.1.9 The HEMS crew member has explained that he checked the engine instruments and that no warning lights were on. He then gave the aircraft commander the all clear. After landing check was performed, he switched to flight instrument mode on the multifunction display. Accordingly, the moving map was no longer displayed. He then monitored the radio altimeter. At this time, none of the crew members communicated with external units by radio. The HEMS crew member did not hear any calls. All three focused on looking for aviation obstacles. The helicopter flew horizontally with a speed of 8 – 10 kt while the aircraft commander turned the nose of the helicopter somewhat to the left so that it started to fly sideways.

1.1.10 As they approached poles with a line between them, the HEMS crew member opened the door on his side and looked down to ensure that there was good clearance between the obstacle and the helicopter. As he closed the door and looked forward again, he heard a bang and the helicopter started to shake severely. As they started to drop, he gripped the door handle with one hand and the lock on the seat belt with the other. In case of a fire, he wanted to get out quickly. However, the impact with the ground was so hard that he lost consciousness.

1.1.11 LN-OOI had hit the power line marked on the moving map. It consisted of three live lines and a grounded line that crossed directly above the line between the street lamp posts (see Figure 2). The latter lines were not indicated on the map.

1.1.12 The last part of the approach and the accident are well documented with video recordings. The Accident Investigation Board has been granted access to a video that shows the accident directly from behind, two videos that show the accident from the right side of the helicopter and two videos that show the approach and accident seen towards the front of the helicopter. The videos confirm the statements from the HEMS crew member and the police.

1.1.13 The videos show that the helicopter flew slowly and horizontally towards the power line. Just before the initial contact with the lines, with a distance of approx. one to two metres, the nose of the helicopter lifted and it started to bank to the left. The lowest wire (see Item 1.12.1.2 and Figure 2) got caught in the helicopter's wire cutter (see Chapter 1.6.4). However, the wire was merely pulled away without being cut. Then the main rotor blades came in contact with the live wires and several powerful flashes occurred. All lines were cut and the helicopter started to fall straight down.

1.1.14 One rotor blade broke as the main rotor hit the wires. On the way down, white smoke came out of the helicopter's right engine, and several smaller parts fell off. The main rotor started to shake heavily in relation to the helicopter fuselage, and prior to the helicopter hitting the ground, one could clearly see that the main gear box and main rotor were about to come apart from the fuselage.

1.1.15 The videos show that the helicopter banked approx. 50° to the left prior to it hitting the ground. At the same time, the nose of the helicopter started pointing downward during the fall, so that the helicopter hit the ground with the forward left section first. The fall lasted approx. 2.7 seconds. A white steam cloud appeared from the crash site for the first 20 seconds after the helicopter had crashed. The helicopter did not whirl up snow prior to hitting the lines.

1.1.16 Medical personnel and personnel from the fires and rescue service were present in connection with the traffic accident. They responded quickly and immediately started lifesaving first aid.

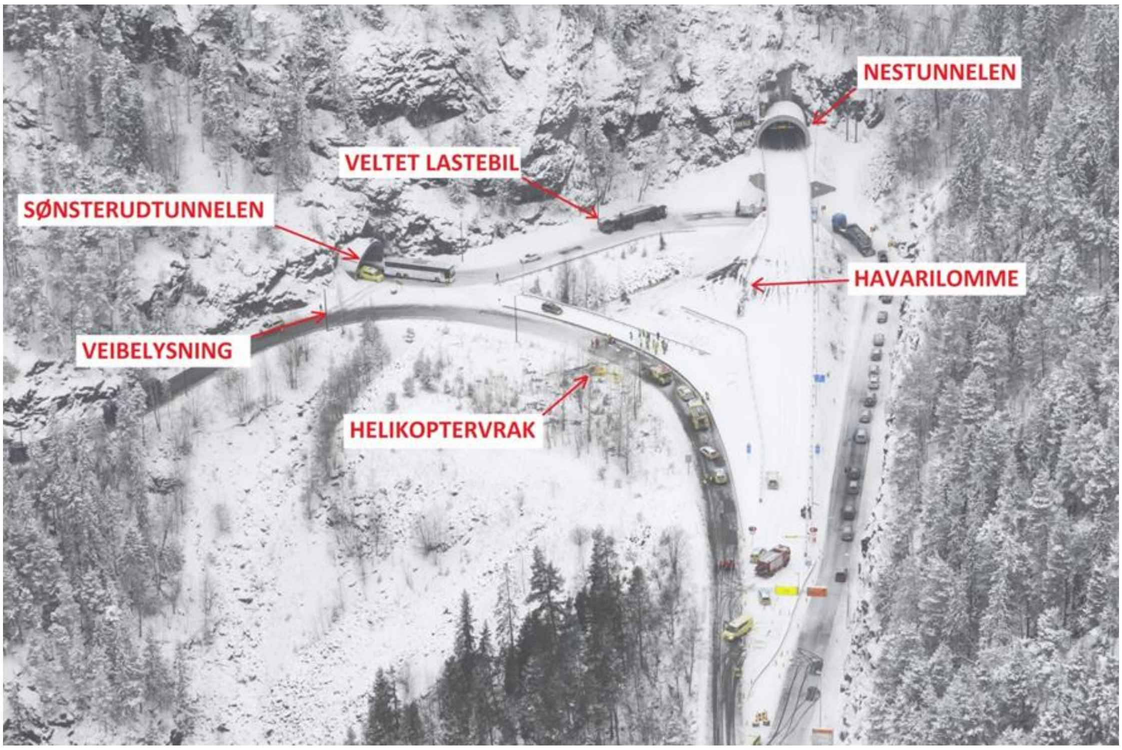

Figure 1: Photo of the crash site seen towards north shortly after the accident had occurred. Photo: the Police

Figure 2: The helicopter has hit the lower line with the wire cutter and pulled it in the direction of flight. The main rotor rotate under the live lines. The line between the street lights along the E16 entry ramp is visible in the bottom of the photo. Photo: Still image from a private video recording

Figure 3: Immediately after the main rotor has cut one of the live lines. One of the ends of the line is moving out of the image towards the right. Another section of the line is about to be slung by the rotor. Photo: Still image from a private video recording

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Others
Fatalities	2		
Serious	1		
Light/none			

1.3 Damage to aircraft

The aircraft was a total loss, see 1.12.2 for detailed description.

1.4 Other damage

All the four leads on a 22 kV power line were torn down. This caused a power outage until approx. 1600 hours for some customers. A car was hit by one of the lines and sustained minor damage.

1.5 Personnel information

1.5.1 Aircraft commander

1.5.1.1 The aircraft commander, 52 years, had military helicopter training from 1982. He served as a helicopter pilot in the Royal Norwegian Air Force until 1991, when he was hired as a helicopter pilot in Norsk Luftambulanse AS. The aircraft commander started to fly from the Lørenskog base in 2001. During the period 1997 – 2001, he was the senior pilot, and from 2001 to 2010 he was the company's flight operations manager. In addition to being a pilot, he also served as an instructor and test pilot in the company.

1.5.1.2 Colleagues describe the aircraft commander as knowledgeable, thorough and safety-minded. With his long experience in the company, both as pilot and flight operations manager, he had good insight into the operational conditions in connection with landing at unfamiliar sites.

1.5.1.3 The aircraft commander held an Airline Transport Pilot Licence for Helicopters (ATPL(H)) with Instrument Rating (IR), Type Rating Instructor (TRI) and Type Rating Examiner (TRE). In addition, he was appointed by the company to function as an instructor during night vision flight training (Night Vision Goggles - NVG). The rights to fly EC 135 were renewed with proficiency check (OPC/PC) on 20 May 2013, and the rights to fly EC 145 were renewed with proficiency check (OPC/PC) on 18 October 2013.

1.5.1.4 In March 2013, the aircraft commander underwent a routine flight medical check. This included a vision test. It became clear that he had slightly reduced distance vision. His vision was just above the minimum requirement for civil medical certificate class 1 granted in BSL JAR-FCL 3.220(a)[4]. Based on the check, the aircraft commander was given medical certificate class 1, valid until 3 March 2014. The medical certificate had the following limitation: VNL *Shall have available corrective spectacles for near vision and carry a spare set of spectacles."*

[4] Requirements related to distance vision, with or without correction: Visus 0.7 (6/9) or better on each eye and 1.0 (6/6) or better with both eyes. Equivalent military requirements are Visus 1.0 (6/6) or better on each eye.

Table 2: Flying hours commander

Flying hours	All types	Relevant type
Last 24 hours	1:27	1:27
Last 3 days	1:27	1:27
Last 30 days	1:27	1:27
Last 90 days	21:18	4:57
Total	6 016:18	1 382:51

1.5.2 HEMS crew member

1.5.2.1 The HEMS crew member (HCM), 51 years of age, was hired at the helicopter base in Lørenskog in 1991. At the time of the accident, he was in charge of the HEMS crew members at the helicopter base in Lørenskog.

1.5.2.2 As a HEMS crew member in the Norsk Luftambulanse AS, he had passed the theory exam for a Private Pilot Licence (PPL(H)) for helicopter. Furthermore, he had completed the annual proficiency check[5] in a simulator in accordance with the company's requirements. In order for the HEMS crew members and pilots to be able to train together, he actually completed two simulator training sessions over the past year.

1.5.2.3 The HEMS crew member was particularly involved in questions relating to radio communications. He is considered one of the company's foremost experts in this area.

Table 3: Flying hours HEMS crew member

Flying hours	All types	Relevant type
Last 24 hours	2:09	2:09
Last 3 days	2:09	2:09
Last 30 days	11:10	4:29
Last 90 days	31:13	14:07
Total	3 314:58	1 719:56

1.5.3 Physician

The physician, 38 years of age, started on ordinary shifts as a physician at the helicopter base in Lørenskog in 2008. In 2013, he was appointed the leading local medical advisor at the base. The physician had undergone training as a medical crew member in accordance with the company's procedures and had a valid rating in relation to this. He also worked shifts for the Royal Norwegian Air Forces' search and rescue helicopter stationed at Rygge, and was an experienced glider pilot.

Table 4: Flying hours physician

Flying hours	All types	Relevant type[6]
Last 24 hours	2:09	
Last 3 days	2:27	
Last 30 days	11:05	
Last 90 days	16:49	
Total	526:36	

[5]Described as HPC in the company
[6] Flying hours are not differentiated by helicopter types for physicians.

1.5.4 Activity prior to the mission

The crew flew one mission together on 13 January. The flight, which was between Elverum and Oslo, was completed at 1604 hours. The HEMS crew member and physician then carried out a mission with an ambulance that was completed at 1949 hours. The entire crew stayed together at the air ambulance base in Lørenskog. The HEMS crew member has explained that he felt rested and fit in the morning after a good night's rest. He ate breakfast before the flight to Sollihøgda. Regarding the commander and physician, he explained that they both appeared rested and fit in the morning. He did not specifically remember when they ate breakfast, but assumed that everyone had eaten as usual.

1.6 Aircraft information

1.6.1 Introduction

1.6.1.1 The EC 135 is a light twin engine helicopter with four main rotor blades and a Fenestron tail rotor[7]. This helicopter type was developed as the successor to Messerschmitt-Bölkow-Blohm (MBB) Bo 105, a popular helicopter type that was also previously operated by Norsk Luftambulanse AS. MBB Bo 108, a further development of Bo 105, flew for the first time in 1988. MBB was later incorporated in the newly established Eurocopter, and Bo 108 received Fenestron, among other things. The helicopter type name was changed to Eurocopter EC 135. The EC 135 flew for the first time in 1994, and received a type certificate in 1996. Airbus Helicopters Deutschland GmbH took over as the type certificate holder from January 2014. Specifications for EC 135 P2+ are listed in the EASA Type Certificate Data Sheet (TCDS) No R.009.

1.6.1.2 Considerable parts of the helicopter are constructed out of composite materials and a large part of the fuselage has a honeycomb structure. The cabin has two doors on each side and a cargo door in the back. The helicopter can be flown from both sides in the cockpit. The flight controls are hydraulic, and both the hydraulic system and power supply are duplicated.

1.6.1.3 The LN-OOI was specially fitted as an ambulance helicopter. It had two seats in the cockpit and two seats as well as a stretcher in the cabin. The ambulance helicopters are equipped with intensive medical equipment for treating and monitoring patients. Analogue and digital radio equipment were installed on board in order to be able to communicate with the two types of emergency communication networks that currently exist in Norway. The LN-OOI was new when it entered use by Norsk Luftambulanse AS in 2007.

1.6.2 Helicopter data

Manufacturer:	Airbus Helicopters Deutschland GmbH
Type designation:	EC 135 P2+

[7] Fenestron is a built-in tail rotor that reduces noise and increases the safety for personnel moving around the aircraft on the ground. The "fan housing" also protects the rotor against foreign objects during landing and take-off in narrow locations.

Serial number:	0586
Construction year:	2007
Airworthiness certificate:	Issued 30 July 2008
Airworthiness Review Certificate:	Valid until 15 July 2014
Flight time, total:	4 370:30 hours
Engines:	2 Pratt & Whitney PW 206 B2
Serial number left engine (No. 1):	BJ0199
Serial number right engine (No. 2):	BJ1166
Motor rating per engine, max continuous:	612 hp
Motor rating per engine, OEI[8] 30 seconds:	816 hp
Diameter main rotor:	10.2 m
Main rotor direction:	Counter-clockwise, top view
Maximum mass:	2 910 kg
Mass empty (NLA configuration):	2 022.5 kg
Fuel:	Jet A1

The last Periodical Inspection was carried out on 3 June 2013, at a total flight time of 3 965 hours. A 100-hour inspection was carried out on 10 January 2014, at a total flight time of 4 361:23 hours. When the accident happened, the helicopter's technical log contained no remaining remarks (Deferred Defect List).

1.6.3 Relevant mass and centre of gravity (CG)

	Arm (mm)	Mass (kg)	Torque
The helicopter's empty	4 453	2 022.5	9 006 258
Pilot and HCM	2 428	170	412 760
Physician	4 192	85	356 320
Equipment	4 116	138	567 957
Fuel main tank	3 928	260[9]	1 021 280
Fuel supply tank	5 026	89.3	448 822
CG and total mass at the time of the accident	**4 273**	**2 765**	

[8] OEI: One Engine Inoperative

[9] Based on the main tank having a standard refilling to 310 kg before take-off, a consumption of 200 kg an hour and a 13-minute flight time from Lørenskog to the Sønsterud tunnel.

The helicopter was therefore operated within the limits as regards both weight and location of the centre of gravity.

1.6.4 Protection against power lines and transport cables

LN-OOI was equipped with wire cutter, devices that will deflect and cut power lines and transport cables if the helicopter collides with these. There is an upper and lower knife that will cut wires. The precondition is that the target is within the area for the upper and lower knives. If a wire passes above the upper knife, it could hit the main rotor. If a wire passes below the lower knife, it will also pass under the skids. According to Airbus Helicopters, the system is designed so that it is efficient at speeds between 13 and 52 kt.

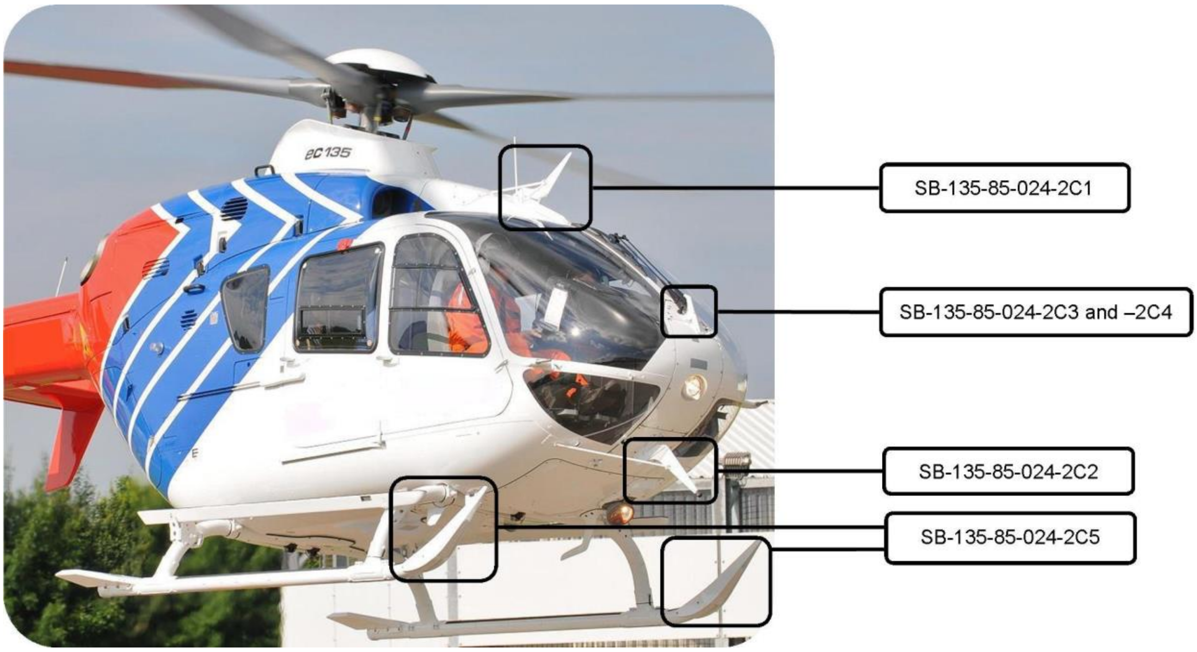

Figure 4: The system for protection against wires is shown on an equivalent helicopter. Photo: Airbus Helicopters

Figure 5: One of the lines from the power line stuck in the wire cutter on the cockpit roof on LN-OOI. Photo: AIBN

1.7 Meteorological information

1.7.1 METAR for Oslo Airport Gardermoen (ENGM)

The following weather report (METAR) was in effect for Gardermoen at 1050 hours:

ENGM 140950Z 02008KT 9000 -SN OVC022 M08/M10 Q1015 TEMPO 4000

1.7.2 Weather observations

Pictures and videos taken in connection with the accident shows that it was overcast with a few scattered clouds down towards the terrain (scattered in 1 500 – 2 000 ft). Below the clouds, visibility was more than 10 km. When the accident occurred, there were indications of light snowfall, negligible wind and an estimated temperature of -3 °C.

1.8 Aids to navigation

1.8.1 Introduction

The helicopter type was equipped for instrument flying (IFR). However, Norsk Luftambulanse AS flights are normally executed according to visual flight rules (VFR) when flying outside clouds and with the ground in sight. The helicopter was not equipped for flying in icing conditions.

1.8.2 Digital map systems

1.8.2.1 Collisions with aviation obstacles have led to multiple helicopter accidents, including ambulance helicopters. One measure to reduce this risk is that all helicopter in service for the Luftambulansetjenesten ANS (see Chapter 1.17.3) are equipped with digital map systems. This means that paper maps serve only as a back-up. The LN-OOI was equipped with a digital map system, of the EuroAvionics Navigation System, EURONAV IV type[10].

1.8.2.2 EURONAV contains a database with digital maps[11] that provide more detailed information as you scale up the map. This is combined with GPS positioning data from the GARMIN GNS 430A unit in the helicopter and shows the helicopter's position as a symbol on the map (moving map display). Aviation obstacles are presented on the maps in the form of symbols and lines[12]. LN-OOI was equipped with EURONAV software version 4+.

1.8.2.3 The digital map system is based on map data from Statens kartverk (the Norwegian Mapping Authority). The database in Norsk Luftambulanse AS shall be updated every 90 days. The database in LN-OOI was most recently updated on 29 September 2013. This means that the database should have been updated on 29 December 2013. The database update that should have taken place did not contain any changes to relevant information for the crash site.

1.8.3 Statens kartverk (The Norwegian Mapping Authority)

1.8.3.1 The Norwegian Mapping Authority is required to keep a register of aviation obstacles, as stipulated by regulations (see Item 1.8.3.2). This task is managed through the National register of aviation obstacles (Nasjonalt register over luftfartshindre – NRL), which is a digital register of reportable aviation obstacles that have been reported to the Norwegian Mapping Authority.

1.8.3.2 The information in the NRL mainly comes from reports which obstacle owners are required to provide through the regulations relating to aviation obstacles. ”*Reporting and registration of aviation obstacles”* in the Civil Aviation Regulations (BSL) E 2-1 were in effect at the time of the accident (see also Chapter 1.17.5.1).

1.8.3.3 The Norwegian Mapping Authority also carries out several tasks to quality control the database content:

- Photogrammetric inspection of obstacles (normally aerial photo)
- Visual verification from the ground
- Analysis of other data sets to identify obstacles (particularly power lines)

1.8.3.4 The Norwegian Mapping Authority has an online form that must be used when reporting measures or structures that could obstruct or be a danger to aviation. The NRL contains information about both position and altitude. The data is exported in the format SOSI 4.5

[10] EURONAV IV with software 4+ is called EURONAV V (or EURONAV 5) by the manufacturer EuroAvionics Navigation System
[11] Vector map.
[12] Lines on the map are symbols for power lines, ski lifts, cableways and transport cables.

and via change log-API. This format was developed in Norway, and must be converted in order for international map suppliers to use it. NRL delivers to a number of national data users, including Avinor, the Norwegian Armed Forces, the Police and Norsk Luftambulanse AS. The Norwegian Mapping Authority delivers updated information from NRL to Norsk Luftambulanse AS every 90 days.

1.8.3.5 The Norwegian Mapping Authority also has several map databases adapted to different purposes. These include:

- A joint map database (FKB) containing the most detailed map data. A power line grid can be included in this map database, regardless of altitude above ground.
- N50 map data. Suitable for trekking maps, topographical maps, etc. Adapted to maps in scale 1:25 000 – 1:100 000.
- N250 map data. Suitable as background maps, for geographical analyses, online map solutions, etc. Adapted to maps in scale 1:100 000 – 1:300 000.

1.8.3.6 The power line at the accident site had a maximum height of 35 metres above the terrain[13]. It was thus subject to reporting requirements, but not subject to marking requirements in accordance with the applicable regulation (see Item 1.17.5.1). The low power lines between the lamp posts were not subject to reporting or marking requirements.

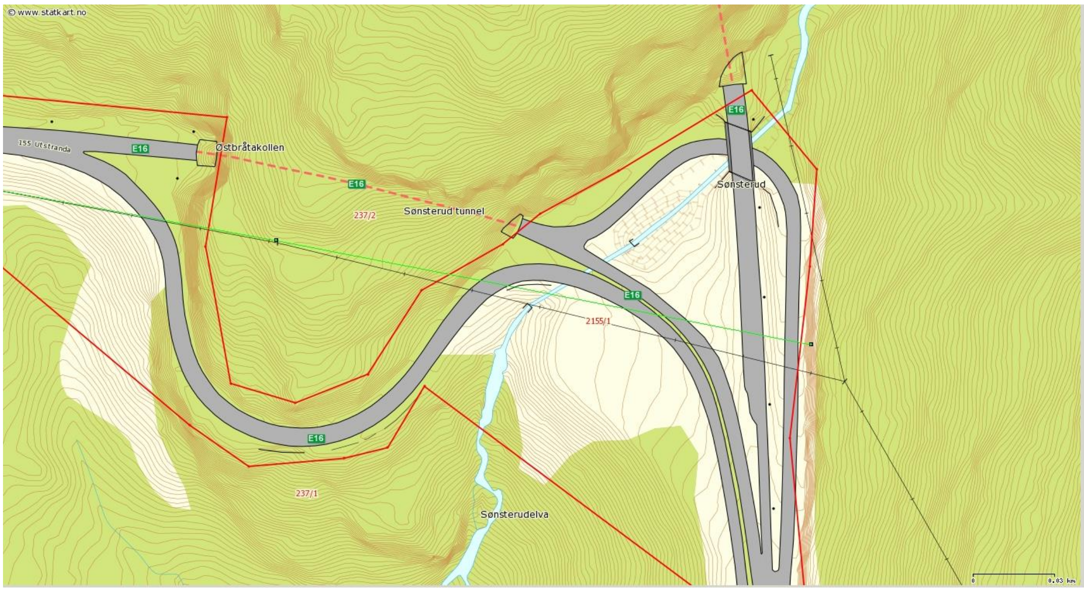

Figure 6: Segment from the Norwegian Mapping Authority's map of the accident site with obstacles from FKB. The green line represents the power line in question, drawn in with data from the NRL. The power line is registered in the NRL because it is higher than 15 m. The black line is the same line drawn in with data from FKB. See Figure 10 for more information.

1.8.3.7 The Norwegian Mapping Authority has told the Accident Investigation Board that important stakeholders cooperate on joint establishment/public administration, operations, maintenance and use of geographical information. This cooperation is called Geovekst. In order to improve the practice of updating power line data, a new product specification was prepared for a map database called FKB-Ledning. It outlines a new

[13] According to information from the Norwegian Mapping Authority.

update procedure, where the individual power line owner is responsible for updating their power line data, and regularly exchanging this data with the Norwegian Mapping Authority. Over time, the work will provide more comprehensive and up-to-date data sets. The project could also provide important information about power lines and towers to the NRL.

1.8.3.8 The Norwegian Mapping Authority currently registers all reports on a continuous basis, thus fulfilling the current aviation obstacle regulations. They claim that the regulations must be amended if the NRL shall be expanded to also include obstacles that are lower than 15 m (30 m in some areas). Furthermore, they believe such an expansion of the number of reportable objects must be discussed extensively by the involved parties in order to determine whether this is the most expedient way to safeguard flight safety. Generally, the Norwegian Mapping Authority is of the opinion that a complete database of all objects that could pose a danger to aviation is unrealistic with the available budgets.

1.8.4 Presentation of aviation obstacles in EURONAV

1.8.4.1 The HEMS crew member can choose which information are shown on his/her Multi Function Display (MFD). The primary alternatives are:

- The map is shown on the entire display (see Figure 7)
- Flight instruments are shown on the entire display
- A combination where the display is split so that both the map and parts of the flight instruments are shown (see Figure 8)

1.8.4.2 The presentations in the EURONAV system only indicate the height over the terrain of obstacles that exceed the height subject to marking requirements in accordance with the regulations (60 m).

Figure 7: Cockpit in one of the Air Ambulance's EC 135s. The large display on the left is operated by the HEMS crew member. He can choose to view the moving map on the entire display, as shown in the picture, or to split the display, as shown for the pilot on the right. A third possibility is that the display on the left shows flight instruments on the top half and the moving map on the lower half of the display (see Figure 8). Photo: AIBN

Figure 8: Example of combined display on the HEMS crew member's display with flight instruments on the top and the moving map on the bottom. Photo: AIBN

1.8.4.3 In Figure 9 below there is a picture of the accident site with the power line as presented on EURONAV with normal display of 1:25 000 vectorised map (see also Item 1.8.6.1). Figure 10 shows the same area with a maximum zoom on 1:25 000 vectorised map. Power lines lower than 60 m have no height indication and are represented as a blue line. The presentation seemingly indicates two lines. This is because the presentation is reiterating two obstacle databases. One of the databases is from 2007 and is currently managed by Norsk Luftambulanse AS. The database contains several aviation obstacles that are lower than 30 m above ground level. Norsk Luftambulanse AS tries to update and add as many relevant obstacles as possible to this database. The other database is managed by NRL, and only contains reported aviation obstacles that are higher than 15 m above ground level outside densely built-up areas and 30 metres in densely built-up areas. Inaccuracies in these two databases result in the two lines that are not identical.

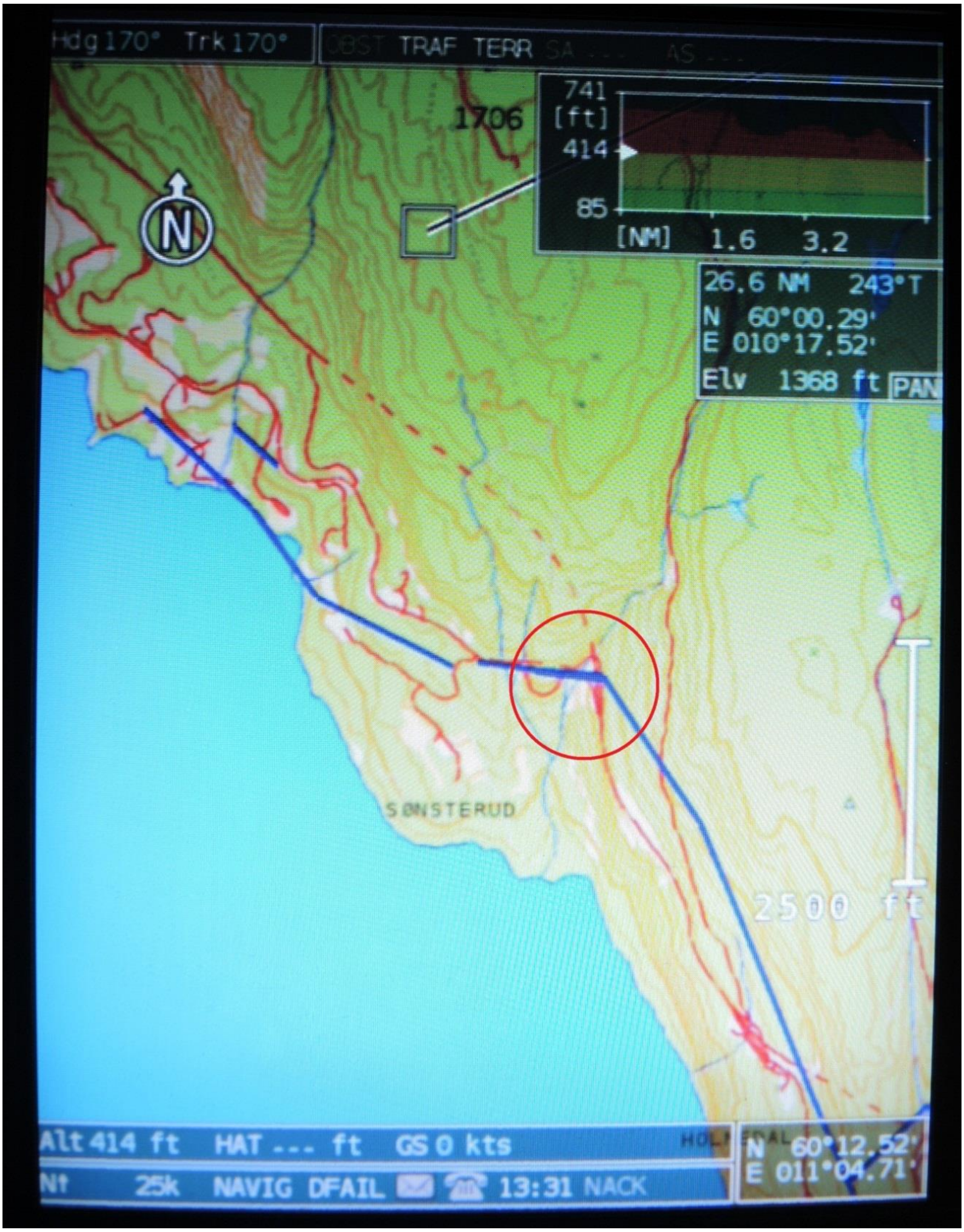

Figure 9: The accident site and overhead line with a normal display of 1:25 000 vectorised map from EURONAV. The red ring around the crash site was added by the AIBN. Photo: AIBN

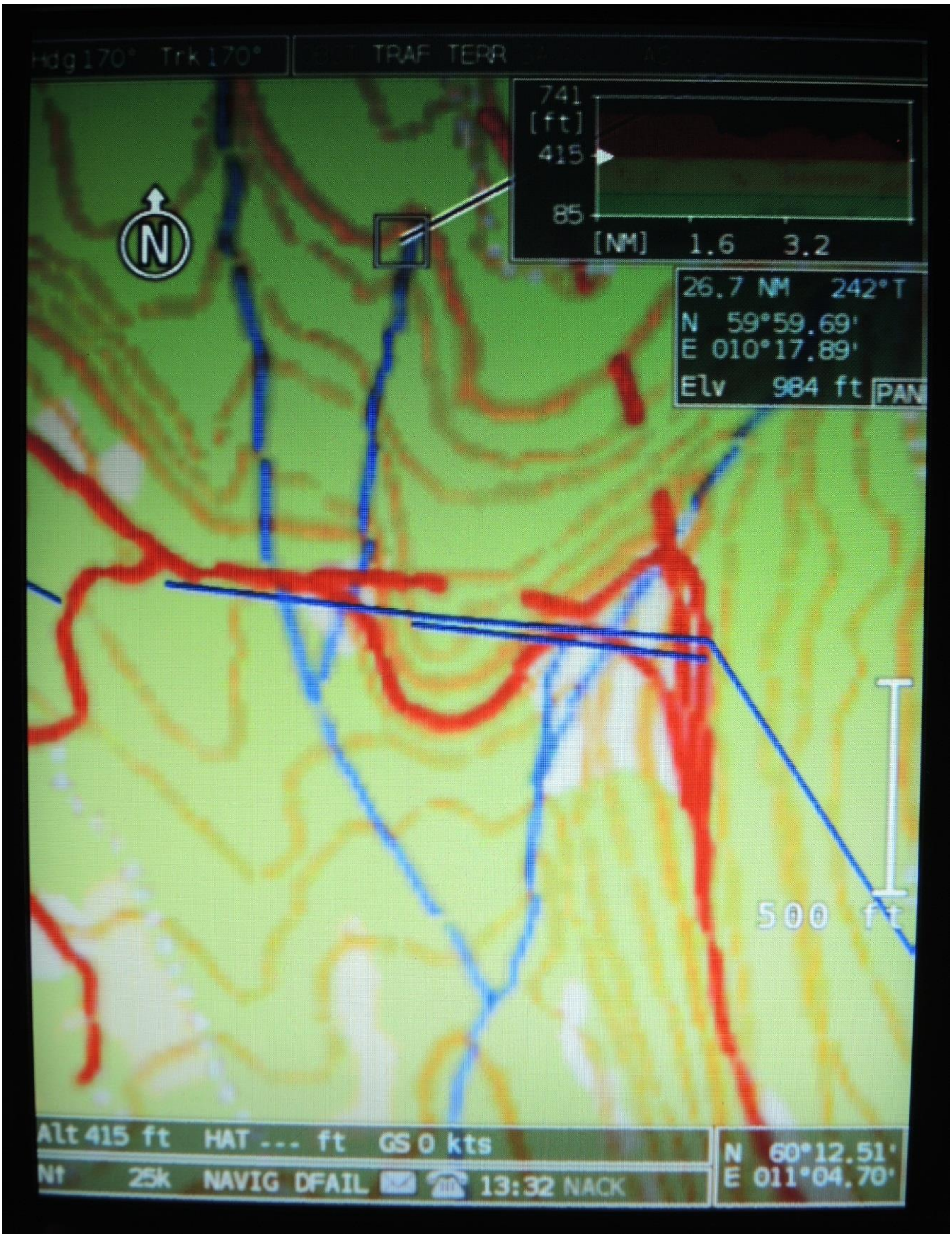

Figure 10: Segment from the same map as Figure 9 with maximum zoom. The presentation seemingly indicates two overhead lines. There is really only one power line, but with data collected from two different databases that both contain inaccuracies. Photo: AIBN

1.8.4.4 EURONAV got a number of additional warning functions in connection with the company's upgrade to software version 4+ in 2007. Part of this was a terrain warning system. When this system is activated, the terrain can be shown in different colours, depending on terrain high in relation to actual altitude. Terrain that is higher than actual altitude is shown in red on the map. The colour scale is shown on the top right corner of the map in Figure 8. In the same display, 499 ft. is shown as actual altitude (see also the line on the bottom left in the display).

1.8.4.5 This system also included the possibility of aviation obstacle warnings. The company chose to add a warning if the helicopter was less than 200 ft. or 20 seconds away from colliding with an aviation obstacle. The warning is a flashing red marker in the upper right corner of the display, flashing red text OBSTACLE in the upper left corner and two blinking red lines in parallel with the obstacle. The system does not have audible warnings. The height of power lines was entered as two points corresponding to the height of the terminal towers. This meant that long power lines with significant height differences would trigger a warning even if the helicopter passed over the line with an altitude that is significantly higher than the warning distance of 200 ft.

1.8.5 Improvements after the accident

1.8.5.1 Already before the accident, Norsk luftambulanse AS made sure to transfer information from the two map databases N50 and N250 from the Norwegian Mapping Authority to EuroAvionics in Germany. These two databases contain information about more aviation obstacles than the NRL database. The purpose of this action was to improve the data in EURONAV, particularly with regard to aviation obstacles below 15 m and 30 m, respectively. EuroAvionic converted the data from the Norwegian Mapping Authority so that it was ready to be entered in the company's helicopters in January 2015.

1.8.5.2 New helicopters that Norsk Luftambulanse AS uses will receive a digital EURONAV 7 map system. This system has the option for audible aviation obstacle warnings, in addition to the visual warning.

1.8.6 The company's procedures for use of digital maps

1.8.6.1 Procedures for using the digital map system are generally gathered in the company's OM-A (Operations Manual Part A). See also Chapter 1.17.2 where other procedures are discussed.

Item 8.3.2(a):

> *Due to all the variables in HEMS missions a rigid SOP for VFR navigation is not practical. In the following we have described guidelines that will secure a standardized way of utilizing all available means for safe navigation.*
>
> *Moving Map with digital obstacle database implemented is the normal aid to VFR navigation.*

Item 8.3.2 (a) (2):

> *During VFR navigation Moving map shall always be shown in full or half screen whenever terrain or obstacles may become a factor for the safety of flight. For normal VFR navigation it is recommended to show moving map in full screen. HCM/PNF informs continuously about relevant obstacles. Obstacles less than 1 NM from planned track and/or with less than 500 feet vertical clearance are always considered relevant. It is recommended to announce other obstacles that may be a factor later in the mission, for example large powerspans across fjords or obstacles in the planned departure path when this is different than the*

approach path.
Correct use of zoom levels is paramount when using moving map for navigation! Obstacle data (NRL) is only shown at lower zoom levels. This requires active use of zoom levels by the HCM/PNF in order to be able to maintain navigational overview and being able to detect all potential obstacles. All NRL data appears at the same zoom level.

The HCM/PNF is normally operating the moving map. It is his duty to continuously maintain navigational situational awareness, and detect obstacles.

HCM/PNF gives navigational instructions according to OM-A 13.9 standard calls.

Item 8.3.2 (a) (3):

The approach and landing should be discussed during wpt verification, and this should be repeated prior to arrival. It is important to zoom all the way in until 1:25000 scale charts are shown in order to get all available information. Use arrow keys to move the picture around the destination if this is necessary to see all obstacles.
When approaching a waypoint for landing the HCM/PNF should zoom in so that the destination stays in the upper half of the screen until the landing site is visually detected, and 1:25000 charts are shown.
Moving map should always be displayed when landing at an unknown site, this in case of a go-around. Consider using "track up center" here.

1.8.6.2 Operations manuals are relatively extensive manuals that are not intended for use during flight. Checklists that are specific for the helicopter type are instead used here. The procedures for reviewing aviation obstacles and planning the approach to non-prepared landing sites are not available in another format than what is available in OM-A.

1.8.6.3 A supplement[14] to the helicopter's "Flight Manual EC 135 P2+", published by the helicopter manufacturer, contains a brief description of EURONAV. Supplementary procedures for using the system were not available in the company's manuals. A EURONAV 5 User Guide was available on the company's intranet. However, this document was very extensive (177 pages) and not particularly adapted to flight crews. To help understanding and managing the system, the company made a presentation that is used in compulsory training.

1.9 Communications

1.9.1 Communications equipment

1.9.1.1 LN-OOI was equipped with the following communications units:

1. Equipment for internal communication between crew members (intercom – ICS).
2. VHF 1, radio for communication with air traffic services and other aircraft.
3. VHF 2, radio for communication with air traffic services and other aircraft.

[14] FMS 9.2-80

4. TETRA 1[15], digital radio for communication with emergency agencies.
5. TETRA 2, digital radio for communication with emergency agencies.
6. VHF FM, analogue radio for communication with emergency agencies (NAT-radio[16]). Can handle two channels individually.
7. GSM telephone radio.

1.9.1.2 All communication was managed via the intercom panels. The helmets had earphones and microphones. The three people on board each had their own intercom panel where they could select which unit they wanted to listen to, or transmit from. It was possible to listen to multiple units, but each crew member could only select one unit at a time for transmission. Intercom. was active the entire time. The main volume and intercom volume could be adjusted individually on the respective intercom panels. Channels, mobile phone numbers, frequencies and unit volume had to be selected on the respective communications units. The individual crew members were thus unable to adjust the volume on the individual communications units on their intercom panel.

1.9.1.3 Below is a simplified principle drawing with the relevant settings when LN-OOI crashed, as found by AIBN when the helicopter was investigated. The red line represents the unit selected for transmission (and listening) and the yellow line indicates the unit that could only be listened to.

[15] TETRA is an abbreviation for TErrestrial Trunked RAdio and is a standard for digital radio systems for closed, group-oriented radio communication that is specially developed for public emergency and preparedness services
[16] NAT is an abbreviation for Northern Airborne Technology LTD, the manufacturer of the radio

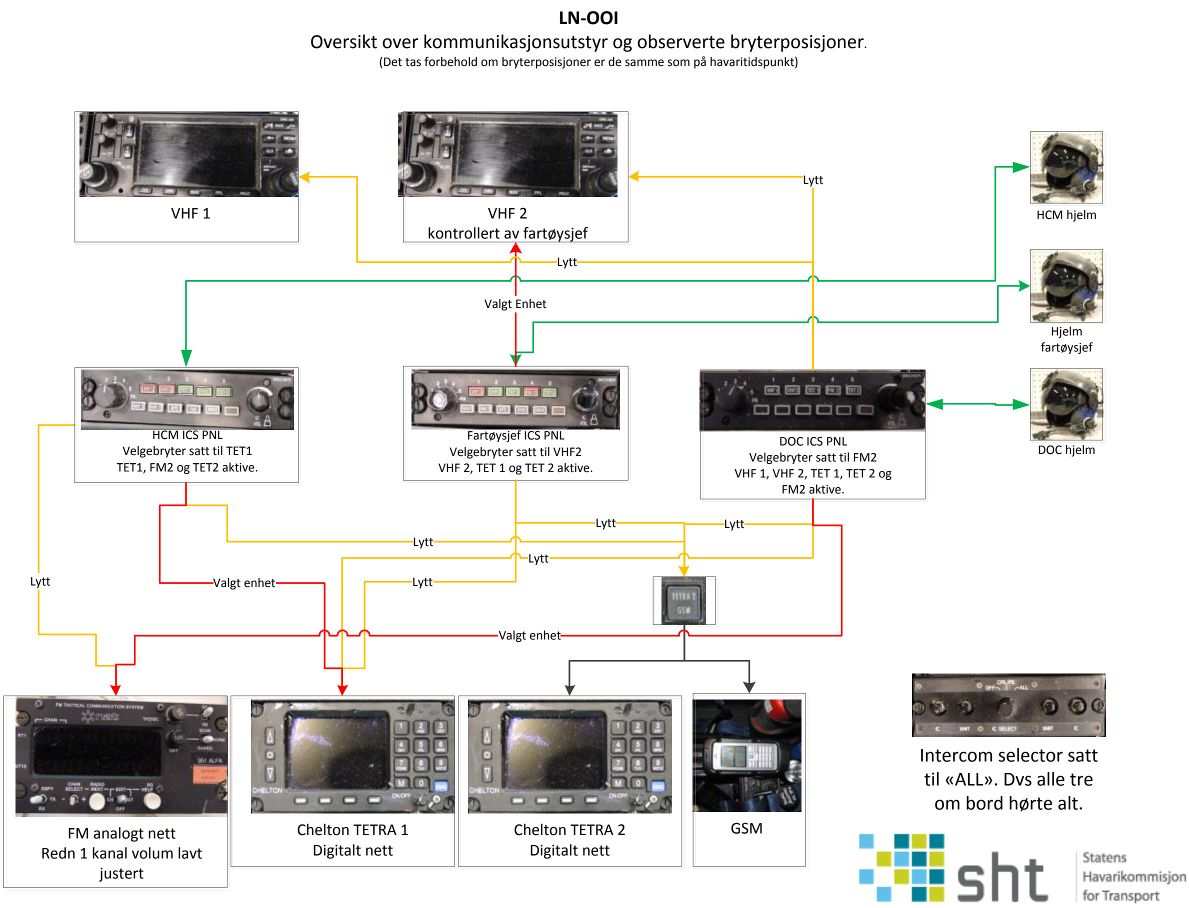

Figure 11: Diagram of communications equipment in LN-OOI. Source: AIBN

1.9.1.4 The same switches and volume control positions are listed in table form below.

	VHF1	VHF2	GSM	TETRA 1	TETRA 2	VHF FM
Aircraft commander	Not selected on ICS panel.	Selected for transmission Set-up for communication with air traffic services.		Listening	Listening	Not selected on ICS panel.
HCM	Not selected on ICS panel.	Not selected on ICS panel.	Not used according to log from network operator.	Selected for transmission. Set-up for communication on TETRA, Communication group LA SØRØST 2	Listening	Have been able to listen to channel 33 "Medical Radio" and channel 5 "Rescue 1" on guard[17] .
Physician	Listening	Listening		Listening	Listening	Selected for transmission. Have been able to listen to channel 33 "Medical Radio" and channel 5 "Rescue 1" on guard.

[17]*Guard* is a listening function on channel 5 on the VHF FM radio.

1.9.1.5 As mentioned earlier, the police tried to call LN-OOI via analogue radio channel 5 “Rescue 1”. This was not detected by the HEMS crew member. AIBN therefore conducted an in-depth investigation of the helicopter's VHF FM radio.

1.9.2 Investigation of VHF FM radio type NAT TH250C-003

1.9.2.1 The Accident Investigation Board wanted to test the function of the analogue VHF FM radio on LN-OOI. The radio was therefore installed in a corresponding helicopter belonging to Norsk Luftambulanse AS. The investigation showed that the radio did not work.

1.9.2.2 The radio's control panel was then opened and it became clear that an electric multi-pin plug had come loose. The plug was connected to a collection of wires with a ferrite core. The ferrite core, which was relatively heavy and attached with Velcro, had come loose. After the plug was put back into place, the radio worked. This indicates that the weight of the ferrite core was a contributing factor in loosening the plug during the crash.

1.9.2.3 The FM radio has two individual radio units with individual volume control. In the relevant scenario, channel 33 ”Medical Radio” was set on one of the radios. The other radio was permanently set on channel 5, ”Rescue 1” (guard). Normally, the volume on one channel can be turned all the way down. Guard can only be adjusted down to a preset volume. This minimum value can only be adjusted via a potentiometer when the control unit is removed from the helicopter.

1.9.2.4 The radio function test, after the multi-pin plug was back in place, showed that the volume on the guard was erroneously influenced by the volume on channel 33. The test was carried out with the switches in the same position as photographed right after the accident. It then became clear that guard receiver had an acceptable volume, even though the volume control on guard was turned all the way down. The position on the potentiometer also did not affect the receiver volume on guard, as long as the volume for channel 33 was as documented in pictures.

1.9.2.5 On the basis of these discoveries, Norsk Luftambulanse AS tested all of the company's VHF FM radios produced by NAT. The review revealed that another one of these radios had a similar fault.

1.9.3 Communication between involved units

1.9.3.1 AIBN has gained access to audio logs from relevant communication. Approx. at 1024 hours, AMK Vestre Viken was contacted regarding a truck accident in the Sønsterud tunnel. Ambulance car 05-09 was in the area, and AMK Vestre Viken redirected the ambulance to the traffic accident. When the ambulance arrived at the accident site, it emerged that the analogue emergency communication network did not have coverage in the area. A decision was also made to requisition an air ambulance. All further communication between the ambulance car and AMK Vestre Viken took place via mobile phone. This information was not forwarded to the ambulance helicopter.

1.9.3.2 AMK Vestre Viken notified the police and fire/rescue departments, and contacted the Oslo and Akershus emergency medical communication centres (AMK O/A), requesting air ambulance assistance. AMK O/A called the helicopter base in Lørenskog and requested response to a traffic accident on E16 at Sollihøgda.

1.9.3.3 After departure at 1038 hours, the HEMS crew member sent a departure message to AMK O/A via the digital emergency network (TETRA) at 1039 hours. He also indicated the expected time of arrival (ETA) at approx. 1050 hours. The information was given to AMK O/A because the unit is responsible for flight following for air ambulances based at Lørenskog.

1.9.3.4 The Northern Buskerud district had not developed TETRA communication. Since the traffic accident occurred in Northern Buskerud, local emergency response units were not equipped with TETRA communication. In order to communicate via the old analogue emergency communication network, the HEMS crew member on LN-OOI asked AMK Vestre Viken to “open” analogue medical channel 33 for direct communication between units. The HEMS crew member has stated that he later called up the accident site on medical channel 33 and received no response. According to audio logs, there is no registered communication between LN-OOI and personnel at the accident site on medical channel 33.

1.9.3.5 At 1039 hours, the physician on board the helicopter received the coordinates to the accident site via the emergency medical communication centre's fleet management system, LOCUS. The HEMS crew member entered position 595950N 0101810E in the helicopter's moving map system[18]. The helicopter used this position for the remainder of the flight. Later, AMK Vestre Viken and AMK O/A communicated several times between themselves regarding updated coordinates for the site of the traffic accident, but this was not relayed to the helicopter.

1.9.3.6 At 1047 hours, the HEMS crew member reported that the helicopter would land in 50 seconds. The message was given via TETRA communication to AMK O/A.

1.9.3.7 At 10:47:10 hours, the leading police advisor attempted to contact the air ambulance, stating the following: *”Air ambulance, this is the police, over”.* The call took place on channel 5 (Rescue 1) on the analogue emergency communication network from the response vehicle's built-in radio[19]. When he did not receive a response, he repeated the message at 10:48:15 and 10:48:39. The final call took place as the helicopter passed over the area. After the leading police advisor had left the car, the site commander also called up the helicopter from his handheld radio with the words: *”You got someone waving at you up there, possible landing site*”. This last call took place just 24 seconds before the helicopter collided with the lines.

1.9.4 Statements from employees in Norsk Luftambulanse AS

1.9.4.1 In conversations with AIBN, personnel from Norsk Luftambulanse AS have expressed that introduction of the digital emergency communication network in 2010 caused considerable challenges. The network was developed in stages and the helicopters that would operate in areas with the digital emergency communication network needed to have TETRA radios installed. This required extensive modification of the helicopter's communications system, without resulting in a satisfactory technical solution. Many were of the opinion that the Directorate for Emergency Communication introduced the digital emergency communication network without considering the needs of the air ambulance

[18] This position was located 0.5 kilometres northeast of the site of the traffic accident. However, this error had no real significance.
[19] The police car was recording video with audio during the entire operation. AIBN has gained access to these recordings.

service. There was initially little or no training, and the transition led to considerable frustration. Some have expressed that the digital emergency communication network was a nightmare in the beginning.

1.9.4.2 Previously, ambulance helicopters had routinely called up personnel on the ground via analogue communications (NAT radio) prior to landing. This became more difficult after introduction of the digital emergency communication network. This was particularly challenging in the transition between areas that were developed, and areas that still had an analogue emergency communication network. Finding the right communication group[20] was a challenge, and the digital emergency communication network would occasionally stop working when the helicopter descended to a low altitude before landing. This led to an increasing practice of not contacting personnel on the ground before landing, and instead placing more emphasis on their own assessments and observations.

1.9.4.3 They noticed several improvements in the time after the accident. Automatic switching between different base stations was improved, so communications no longer failed in the same way when descending to a lower altitude. Furthermore, they received a communication group that can be used throughout the mission. As development has moved forward, there have also been fewer transition zones between the new digital and old analogue emergency communication networks. Operation of the communications systems will also improve when acquiring new helicopters.

1.9.4.4 It was also noted that the overall communications situation had improved substantially in the time following the accident. This was because AMK O/A appointed a dedicated air ambulance coordinator. The coordinator had a greater understanding of the air ambulance's needs and could stay ahead of the game with regard to gathering information, planning and coordination. This function lifted a considerable weight off the crew, particularly in phases with high workloads. They therefore looked forward to all of the South-Eastern Norway Regional Health Authority, and eventually other parts of the country, to implement this function.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

1.11.1 Flight recorders were not mandatory and not installed in this type of aircraft.

1.11.2 The helicopter's EURONAV was connected to the satellite navigation system Garmin GNS 430 A. The system recorded data from the flights. After the accident, Norsk Luftambulanse AS downloaded data from EURONAV. The last part of the approach to the crash site is shown below.

[20] Groups of personnel that can communicate via the same channel

Figure 12: Approach repeated with Time, Heading, Speed, AGL and MSL Map source: NLA/Google Earth

1.12 Wreckage and impact information

1.12.1 The crash site

1.12.1.1 The helicopter fell down in a rock fill embankment on the southern shoulder of the entrance ramp to E16 near the eastern tunnel entrance at the Sønsterud tunnel. The helicopter wreckage was located approx. two metres from the asphalted road in the transition between the road shoulder and a rock fill embankment below the road. The main rotor of the helicopter cut a few small shrubs that were in the immediate vicinity of the crash site. The crash site was 200 metres above sea level. There was about 10 - 15 cm of snow on the ground.

1.12.1.2 The power line which the helicopter collided with was 215 m long, and consisted of three live wires and a groundwire. All of the wires were aluminium, with a diameter of 10.5 mm, and had a steel core with a diameter of 5 mm. The power line voltage was 22 000 V. The three live lines were installed horizontally with a distance of 1.5 m between them. The groundwire was located 2 m below the southern live wire.

1.12.1.3 The western pole was 10 m high and was partially hidden between trees on an approx. 30 m high knoll. The eastern pole was 11 m high and was located between trees on an approx. 20 m high nearly vertical rock out. The highest point on the power line was 35 m above ground. It was not necessary to clear a path in the forest for the involved power lines. The path in the forest for the power line that extended southward from the eastern pole was narrow and difficult to spot. Correspondingly, there was no path in the forest west of the western pole. The power line was not physically marked to prevent aircraft collisions.

1.12.1.4 The helicopter hit the power line at an altitude of 25 m above the terrain, approx. 62 m from the eastern pole. In the available video recordings, there are no signs of frost or snow on the lines, or that frost or snow fell off in connection with the crash.

1.12.1.5 A picnic area along E16, 520 m south of the crash site, was used as a landing site for several helicopters in the time following the accident.

Figure 13: Photo from the area showing the crash site (red arrow) and power line towers (blue arrow). The lamp posts and lines between these are not shown in the photo. E16 runs north-south in the photo. The work on the emergency lay-by south of the tunnel had not started when the photo was taken. Source: National Roads Database (cars on the roads have been removed using Photoshop)

Figure 14: The same photo as in Figure 1, but without text boxes. Photo: The Police

Figure 15: Photo taken facing east on the same day as the accident. The power line poles are marked with red arrows. The helicopter wreckage is located behind the trees marked with a green arrow. Photo: The Police

1.12.2 <u>The helicopter wreckage</u>

1.12.2.1 The helicopter wreckage remained in mostly one piece next to the road (see Figure 16). Only a few small parts, mainly composite materials, fell off. The helicopter was partially leaning to the left. The entire top of the cabin structure was pushed sideways to the left. The left skid was split into three parts, and had broken off at the attachment.

1.12.2.2 The cockpit structure was generally intact, but somewhat askew. Both the instrument panel and middle console were crooked and pushed to the left, but there was only minor visible damage to instruments and control panels.

1.12.2.3 The bottom of the cabin was crushed, particularly on the left side. An installation with two external cargo hooks, was pushed up against on the underside of the helicopter. The fuel tanks, which are made of rubber and are located below the cabin floor, were punctured, so most of the fuel had leaked onto the ground. Only a few remaining litres leaked out of the helicopter in connection with salvage and transportation of the wreckage.

1.12.2.4 The entire main gearbox, including parts of the cabin ceiling structure and main rotor, had come loose, was pushed to the left and was lying partially on the ground. The driveshaft from the left engine was pulled out of the engine. The driveshaft from the right engine was split in two in a manner indicating that it was transferring torque when it failed. The only thing keeping the main gearbox attached to the helicopter was hoses and wires.

1.12.2.5 Both engines were attached to their respective engine supports in the fuselage. The left engine was mainly undamaged externally, and rotated freely. The air intake chamber and the air intake screen were polluted by a number of small fragments, mainly composite materials from covers and the fuselage structure. The right engine was seemingly undamaged externally, but the power turbine (free turbine) had lost all turbine blades and the turbine stator had come loose. The air intake chamber and the air intake screen in the right engine were not polluted in the same way as in the left engine.

1.12.2.6 The four main rotor blades were attached to the rotor head, but the ”red” blade had snapped 90 cm from the blade root. Large parts of the ”green” blade had delaminated and the embedded bounding had burned away at a length of 304 cm. Two other blades also bore clear signs of contact with the high voltage lines and traces of arc faults. All four pitch links had been cut, and part of a high voltage line was coiled around the main rotor mast (see Figure 17).

Figure 16: The helicopter wreckage lying next to the road. Photo: AIBN

Figure 17: Rotor head, rotor mast, pitch mechanism and parts of the power line. Cut pitch links are marked with red arrows. Photo: AIBN

1.12.2.7 The tail rotor (Fenestron) came loose from the tailboom in connection with the crash. The actual fan rotor was virtually undamaged. The top of both vertical fins were cut off by the main rotor blades. Parts of Fenestron and the rear part of the tailboom were also damaged from being hit by the main rotor blades.

1.12.2.8 Most of the medical equipment on board were still attached in their respective mountings and brackets.

1.13 Medical and pathological information

1.13.1 A post-mortem was carried out on both fatalities at the Norwegian Institute of Public Health, Department of Forensic Pathology and Clinical Forensic Medicine in Oslo. Both had extensive injuries, including compression fracture of the back, extensive chest injuries, right atrium rupture and femur fracture. They predominantly had more and more extensive injuries on the left side. The injuries were so severe that it would not have been possible to save their lives.

1.13.2 The commander had discolouration and scrapes on his neck, which could have been caused by contact with the shoulder harness. The physician did not have these injuries.

1.13.3 The two fatalities showed no signs of consumption of alcohol, narcotic substances or medication.

1.13.4 A neck strap for eyeglasses was found around the commander's neck.

1.13.5 The HEMS crew member, who survived, also suffered extensive and severe injuries, including compression fracture of the back. However, he avoided any heart injuries.

1.14 Fire

A fire did not occur in connection with the crash. Shortly after the crew was removed from the wreckage, the helicopter was covered in foam by crews from the Asker and Bærum Fire Department.

1.15 Survival aspects

1.15.1 Notifications and the National Rescue Service

1.15.1.1 The helicopter was equipped with an emergency locator transmitter (ELT), type Artex C406-N HM. This activated automatically and functioned as intended.

1.15.1.2 The police, ambulance personnel and personnel from the fire and rescue service were present at the crash site in connection with the traffic accident. They immediately started life-saving work on the three people on board. More ambulances eventually arrived at the site. The second ambulance helicopter (Helidoc 45, LN-OOM), which was stationed on the base in Lørenskog was redirected and landed at the crash site at 1113 hours. The helicopter then landed on the site where the LN-OOI had originally planned to land. LN-OOM transported the severely injured HEMS crew member to Ullevål University Hospital.

1.15.2 Structural loads on the helicopter

1.15.2.1 The point where the helicopter collided with the power line was approx. 25 metres above ground. Examination of available video material shows that the helicopter fell for approx. 2.7 seconds before it hit the ground. Given an approximate constant acceleration, this entails that the helicopter had a vertical speed of 18 - 19 m/s when it hit the ground (just under 70 km/h).

1.15.2.2 A significant survival factor is the helicopter structure's ability to withstand the forces of the crash. The following table lists European certification requirements (EASA Certification Specifications CS-27) and Airbus Helicopters Deutschlands design criteria with regard to attachment of main components such as gearbox/rotor and engines.

	EASA CS 27.561	EC135
Forward	12G	16G
Backward	1.5G	6G
Down	12G	20G
Up	1.5G	4G
Lateral	6G	8G

The LN-OOI banked approximately 50° to the left when it hit the ground. This is reflected in the fact that the entire cabin structure was pushed to the left.

1.15.2.3 Roughly, the cockpit was relatively intact; hence, there remained adequate survival space after the crash. Both windshields were broken and the doors had come loose, it was accordingly relatively easy to gain access to the two people in the cockpit in order to start life-saving work. The side walls in the cabin were deformed and the ceiling had been pushed down. Furthermore, part of the ceiling had come loose along with the main gearbox. In this connection, some technical medical equipment installed in the ceiling had come loose and fell down. Most of the other equipment was still in place, although much of it had shifted to the left. There was still adequate survival space left in the cabin.

1.15.3 Personal protection

1.15.3.1 The three people on board wore helmets during the flight. The commander's and HEMS crew member's helmets were seemingly completely undamaged. The physician's helmet had minor damage on the top right and the visor shield had come off. The commander and HEMS crew member were both buckled in five-point harnesses. The physician wore a four-point harness. However, it has not been possible to confirm whether the physician used the shoulder harnesss.

1.15.3.2 Everyone on board was sitting in shock-absorbing seats from Fischer+Entwicklungen, model 230/260 H110. The seats reduce shock by giving in and slide down in the event of vertical loads that exceed 1500 lbs (680 kg) [21]. The seats can be pushed down 80 – 160 mm, depending on the seat's height adjustment. The compression of two shock-absorbing units takes place individually on the right and left sides of the seat.

1.15.3.3 The commander's seat was removed from the helicopter and disassembled by AIBN with experts from Airbus Helicopters and Fischer+Entwicklungen present. Measurement of the compression showed that the left side of the seat was pushed down 26 mm. The right side was first pushed down 14 mm, but the mechanism was then pulled back to near its original position. Fischer+Entwicklungen had not experienced anything similar prior to this, but assumed that it could have been caused by the helicopter falling at an angle, so the horizontal loads towards the left pulled the seat up on the right side at the end of incident sequence. The uneven load distribution could have been amplified by the fact that the cockpit ceiling also pushed the seat somewhat down and to the left.

1.15.3.4 The seats used by the physician and HEMS crew member, respectively, were both pushed down and to the left, and could not be removed without removing the helicopter's cabin ceiling. Consequently, the compression of these seats was not measured. A brief assessment indicates that the seats were compressed in the same manner as the commander's seat.

1.15.3.5 The seat structure in the three seats that were occupied has been overloaded, causing both the seat plate and back to tear (see Figure 18). The seats are designed and tested to withstand loads of 20 G vertically and 8 G sideways (horizontally). Fischer+Entwicklungen has stated that the loads that occur during collisions at speeds of 18.5 m/s, far exceed the loads which the seats are designed to withstand.

[21] Tested in accordance with ETSO C-127.

Figure 18: The HEMS crew member's seat after seat cushions and padding were removed. Both the seat back and seat plate tore. On the top you can see the headrest, which is crushed down to the left of the cockpit ceiling. The seatbelts were cut in connection with the rescue operation. Photo: AIBN

1.16 Tests and research

1.16.1 <u>Information from the engines' Data Collection Unit (DCU)</u>

1.16.1.1 Each engine has a unit (DCU) that records engine data if pre-determined parameters are exceeded. In order to better understand what happened to the engines, the collection units (serial number PD004-2937 and 12-133) were sent to the engine manufacturer Pratt & Whitney Canada for downloading and interpretation. The Accident Investigation Board received the following feedback:

- The first recorded message was for high torque on the left engine (125%). At this time, the right engine had 106% torque. The error messages cannot be related to actual time, but to the engine's total time. Consequently, it is not possible to determine at what time the error message was recorded in relation to the crash sequence.

- A new message was recorded 0.2 seconds later. The left engine now had 128% torque and the right engine had 138% torque.

- The left engine was switched to manual control 0.2 seconds later. The engine then had 101% torque and the right engine had 70% torque.

- The electronic engine control for the left engine lost contact with the right engine 0.1 seconds later.

- The last message was recorded 2.8 seconds after this. This was an ARINC error message (faults 45 & 30), stating that the electronic engine control for the left engine had lost signals from the right engine.

Pratt & Whitney Canada concluded that the engines were functioning normally up to the accident, and that the excess torque was most likely the result of raising the collective lever while simultaneously twisting the twist grip.[22] The error messages were probably a result of the crash.

1.17 Organisation and management information

1.17.1 Norsk Luftambulanse AS (a Norwegian Air Ambulance operator)

1.17.1.1 *General information about the company*

Norsk Luftambulanse AS was founded in 1977 and is a wholly-owned subsidiary of NLA Holding AS. NLA Holding AS is a wholly-owned subsidiary of Stiftelsen Norsk Luftambulanse AS (the Norwegian Air Ambulance Foundation). Norsk Luftambulanse AS has a contract with Luftambulansetjenesten ANS (see Chapter 1.17.3) relating to the operation of eight of the country's eleven air ambulance helicopter bases: Trondheim, Førde, Bergen, Stavanger, Arendal, Lørenskog, Dombås and Ål. Two helicopters are on stand-by at the Lørenskog base.

At the time of the accident, Norsk Luftambulanse AS operated ten EC 135 helicopters and one EC145 helicopter.

The company is headquartered in Drøbak, and had 116 employees at the time of the accident.

1.17.1.2 *Organisation chart*

The general organisation in Norsk Luftambulanse AS is as follows according to the company's quality manual:

[22] Manual engine control

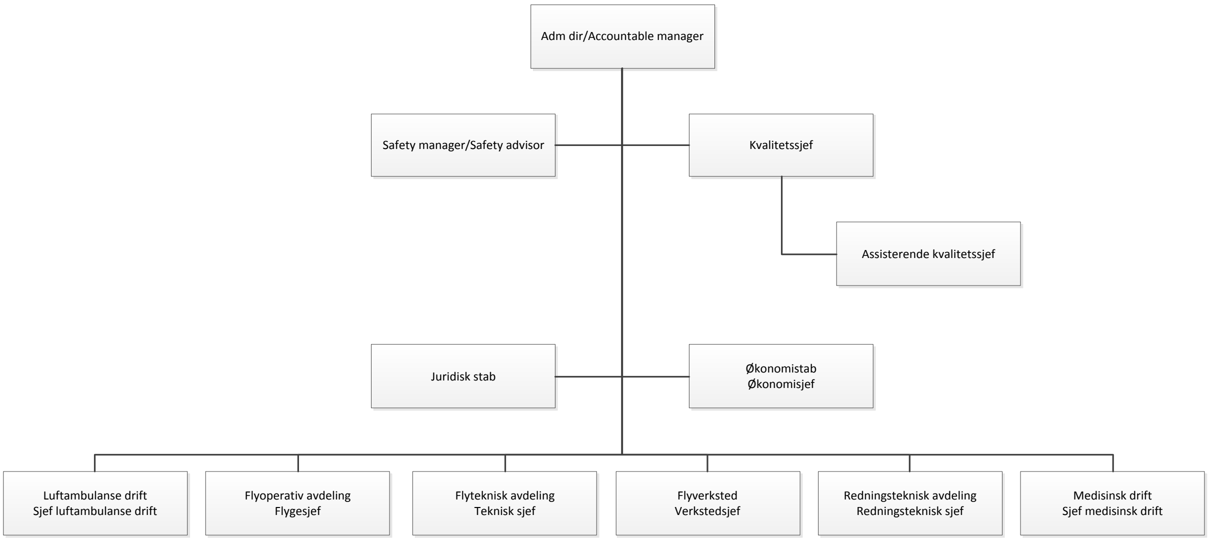

Figure 19: General organisation chart. Source: NLA Quality Manual

1.17.1.3 *Objective*

The quality manual describes the following objective of the air ambulance operation:

> *The air ambulance operations will primarily comprise helicopter operations in service for the regional health authorities. The primary objective is to produce and deliver total services where administrative, operative, technical, medical and technical rescue resources work together in an integrated concept. The aviation activities will consist of helicopter operations related to the above and to aircraft maintenance. The activities will be performed in an established and accepted management system, where regulatory requirements, client requirements and the company's own requirements are incorporated in a comprehensive quality system for the entire enterprise.*

1.17.1.4 *Flight operations department*

The flight operations department is organised in the following manner according to Operations Manual Part A:

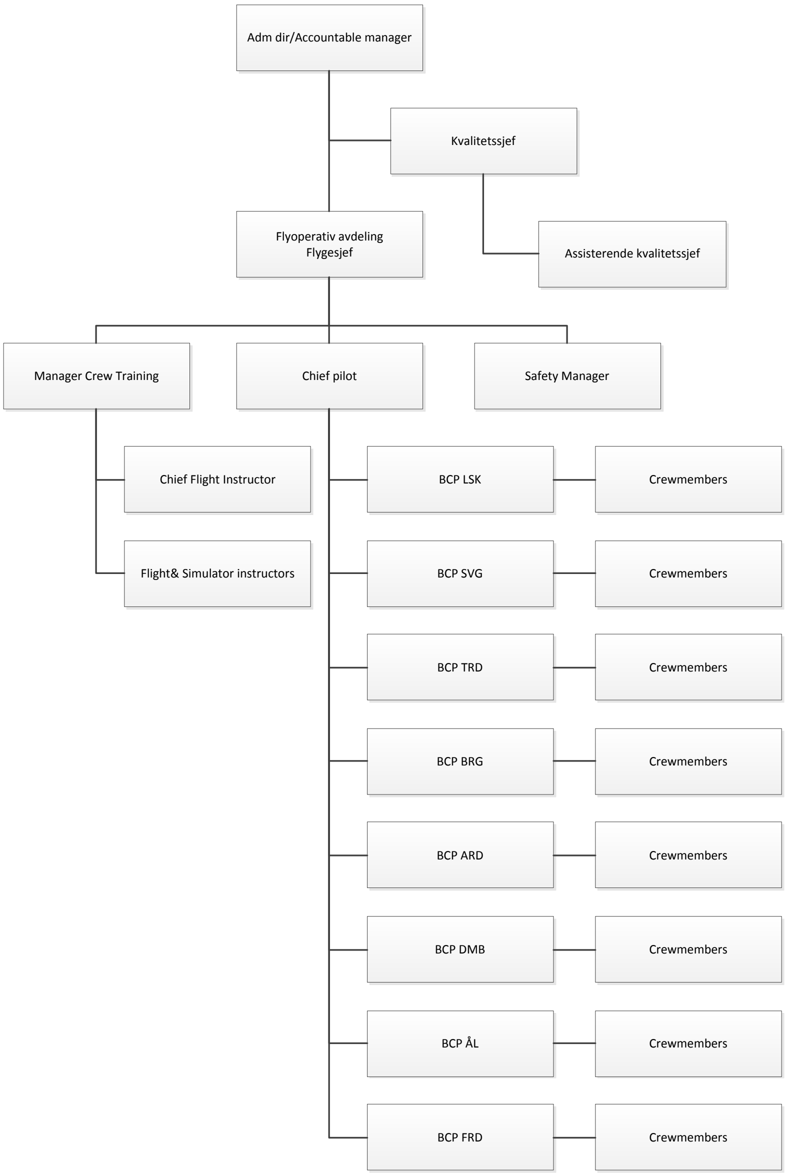

Figure 20: Organisation chart flight operations department. Source: NLA Operations Manual Part A

The responsibilities and tasks in the flight operations department are described as follows:

Managers and supervisors

All managers and supervisors are responsible for the safety of the employees who report to, or work under their direction or control, and for the safety of individuals who enter their departments or work areas. To fulfill this duty, each manager must:

1. *Review applicable safety and health laws and regulations.*
2. *Review company safety rules and policies.*
3. *Be familiar with the safety aspects of the portion of the operations under your control.*
4. *Train employees in general safe work practices.*
5. *Train employees in hazards specific to each employee's job assignment.*

6. *Submit verification of training to the Manager Flight Operations so that the appropriate entries can be made in the Employee Training Records for all safety and health training.*
7. *Regularly inspect their area of responsibility for hazards. Submit a report to the Safety Manager of corrective action taken.*
8. *Take positive steps to avoid unsafe work conditions for employees under your supervision.*
9. *Periodically observe flight department personnel to ensure they follow safe work practices.*
10. *Correct unsafe work conditions promptly.*
11. *In your area of responsibility, report all accidents, injuries, illnesses, or near misses on Aletheia.*
12. *Encourage employees under your supervision to submit Report in Aletheia on unsafe practices or conditions they observe.*

All Flight Department Personnel

All flight department personnel are responsible for working safely and maintaining a safe work environment. Personnel are required to conduct themselves in a manner that is consistent with the Company's safety rules and policies. To fulfill their requirement, each individual must:

1. *Attend all required meetings (include safety meetings).*
2. *Review all applicable safety and health laws and regulations.*
3. *Review company safety rules and policies.*
4. *Be familiar with the safety aspects of the portion of the operation where you work.*
5. *Participate in training in general safe work practice.*
6. *Participate in training in hazards specific to each job assignment.*
7. *Regularly inspect your area of responsibility for hazards.*
8. *Submit a report in Aletheia when you identify a hazard in the work environment.*
9. *Take positive steps to avoid unsafe work conditions.*
10. *Correct unsafe work conditions promptly.*
11. *In your work area, report all accidents, injuries, illnesses, or near misses on Aletheia.*
12. *Submit Report on Aletheia on unsafe practices or conditions you observe.*

1.17.1.5 *The company's flight safety programme*

BSL JAR-OPS 3, Amendment 3, stipulated the requirement that a company must have a quality system (Chapter 3.035) and a flight safety programme (Chapter 3.037). Chapter 2.3 of the company's OM-A contains a description of the ”Accident prevention and flight safety programme”. The all-encompassing goal is no accidents or injuries as a result of the company's operations. Otherwise, the programme contains a few general preconditions and formulations that can be recognised from corresponding safety programmes from other operators. Not all formulations in the programme are equally specific, and it can be difficult to document activities. For example, it states that *"Safety Program Objectives will be published annually and reviewed regularly to determine the progress in achieving them",* without reference to where this programme can be found or how this annual review takes place in practice.

The description of the safety training and training according to *"Flight Safety and Flight Operations Training Topics"* lists a number of topics, but aviation obstacles is not a topic in the list.

At the time of the accident, the company was in the process of transitioning from the described flight safety programme to a safety management system (SMS). This was described in the company's revised documentation that was delivered to the Civil Aviation Authority for approval. In practice, this was in effect for the company's flight safety programme at the time of the accident.

1.17.1.6 *Introduction of safety management system (SMS) requirements*

In the autumn of 2014, EU Commission Regulation 965/2012 relating to aviation operations (EASA-OPS) entered into force for Norwegian companies. This means introduction of safety management requirements. The provisions stipulate that the management system must include, as an example:

> *…the identification of aviation safety hazards entailed by the activities of the operator, their evaluation and the management of associated risks, including taking actions to mitigate the risk and verify their effectiveness.* (ORO.GEN.200 a(3))

The management system must be aligned with the company's size and type of operations:

> *The management system shall correspond to the size of the operator and the nature and complexity of its activities, taking into account the hazards and associated risks inherent in these activities.* (ORO.GEN.200 (b))

In other words, this new concept entails that the companies must to a greater extent perform systematic risk assessments of all of their operations, introduce risk-mitigating measures where required, as well as to verify their efficiency.

1.17.1.7 *Reporting and non-conformance procedures*

The company has developed a designated web-based system for non-conformance reporting that is accessible to all employees. The system was introduced in 2010 and is linked to the flight reporting system. After each flight, the aircraft commander must indicate whether or not a nonconformity is being reported. The Safety Manager in the company manages the system and ensures the reports are distributed to leading personnel in the respective departments. Non-conformance reports relating to flight operations must be handled by the flight operations manager. Norsk Luftambulanse AS has facilitated for commanders to follow up their duty to report incidents that are considered reportable to the authorities in accordance with Norwegian air regulations. The reporting system is also used for statistical basis material for status reporting with regard to flight safety to the management and board of directors.

A database search revealed that 119 flight operations reports were registered in all of 2013. A total of 129 flight operations reports had not been fully processed in the autumn of 2014. A significant portion of these dealt with operating issues with the communications system and EURONAV. The database contained two reports that dealt with hazardous situations with aviation obstacles.

When unknown aviation obstacles are discovered, this is reported via the company's technical rescue manager, who in turn reports to the Norwegian Mapping Authority for updating the "*National register of aviation obstacles"*.

1.17.2 The company's flight operations procedures

1.17.2.1 The operative procedures are described in four documents in accordance with requirements stipulated by the aviation authority:

- OM-A (Operations Manual Part A) contains instructions and procedures that are general for the flight operations and not specific for helicopter types.

- OM-B contains instructions and procedures for flight operations with specific helicopter types. Thus, there is an OM-B for EC 135, and an OM-B for EC 145 in Norsk Luftambulanse AS.

- OM-C contains instructions and information for use at helicopter bases. This means that each helicopter base has its own OM-C "Base Route Manual" with a detailed description of the area of operation and associated procedures. This comes in addition to the navigation map from Jeppesen.

- OM-D describes air crew training and qualification requirements.

The company has also prepared a technical rescue operations manual (ROM), which places particular emphasis on the HEMS crew member's and physician's tasks, as well as application of various rescue equipment. This manual does not contain a noteworthy description of the HEMS crew member's flight operations tasks.

1.17.2.2 AIBN has reviewed the company's OM-A. Below are a few relevant quotes and observations:

Item 1.4.1: The commander has overall responsibility for safe operation of the helicopter. This includes a thorough crew briefing before each mission.

Item 1.5.2: The HEMS crew member must actively participate during flights by performing tasks described in "*Concept of Crew Coordination and procedures"* (however, the Concept of Crew Coordination and procedures are not described in further detail). Furthermore, the HEMS crew member shall operate "the tactical radio for medical services", as well as monitor the helicopter's instruments.

Item 8.1: The chapter provides the following warning: *"NOTE TO RESTRICTED AREAS – HAZARDS TO FLIGHT Before flight the pilot shall check for restricted areas, and obstructions such as; masts, wires,……"*

Item 8.3.2(a) (3): *"Call-outs for speed and height should be used whenever it can improve safety on final approach and landing. The HCM/PNF should provide such call outs when the situation dictates regardless of whether the PF has requested it. This includes approaches over featureless terrain, water and dark areas."*

OM-A does not describe a special procedure for landing in areas where the moving map indicates that there is a power line or other aviation obstacles. OM-A also does not contain a description of how the crew should use their eyes to look for aviation obstacles in the most critical final part of approach and landing.

OM-A does not define what are prioritised tasks in connection with landings and what needs to wait until after landing is complete, i.e. a form of “sterile cockpit”

See Chapter 1.8.6 of the report for a list of specific procedures for using the moving map system.

1.17.2.3 AIBN has reviewed the company's OM-B for EC 135. Below are a few relevant quotes and observations.

OM-B contains a normal checklist. It contains the following points under the title *”Before landing”.*

1. Warning & Cautions Normal
2. Instruments Normal
3. **Row Alt DH** **”xx” feet**
4. **Radar** **Off/Stdby**
5. **Landing Brief** **Performed**
6. **Checklist completed**

An expanded checklist describes this further in the following manner:

BEFORE LANDING
To be performed prior to visual manoeuvring for landing

1. Warnings & Cautions Normal
   HCM/PNF checks Warning lights and CAD
2. Instruments Normal
   HCM/PNF checks oil pressures and temperatures in normal range
3. **Rad alt DH** **”xx” feet**
   PF orders desired setting of DH bug and HCM/PNF sets bug accordingly
4. **Radar** **Off/Stdby**
   PF sets or orders desired setting of radar
5. **Landing Brief** **Performed**
   PF states intentions for landing, to include DP, direction for landing, obstacles and plan in case of a go around
6. **Checklist completed**

Points marked with bold text shall be read aloud.

1.17.3 Luftambulansetjenesten ANS

1.17.3.1 Helseforetakenes Nasjonale Luftambulansetjeneste ANS, abbreviated as Luftambulansetjenesten ANS, is owned by the four regional health authorities in Norway. On behalf of the owners, the company is responsible for the administration and supervision of the air ambulance operators. This is e.g. done by Luftambulansetjenesten ANS entering into tender contracts with airplane and helicopter companies that perform ambulance operations.

1.17.3.2 Luftambulansetjenesten ANS works to maintain a high level of flight safety, in part through:

- Setting higher requirements for the airplane and helicopter companies than the applicable regulatory requirements
- Organising workshops and a network building for operative personnel and medical personnel
- Participating in projects and acting as coordinator in issues relating to the air ambulance service
- Carrying out audits of operators
- Conducting proactive safety work (introduction of safety gear, standardisation, follow-up of training level, etc.)

1.17.3.3 Luftambulansetjenesten ANS has 26 employees, of which 10 work at the main office in Bodø. The organisation has operative helicopter expertise, technical communications expertise and expertise within quality and quality audits, among other things.

1.17.3.4 In a meeting with the Accident Investigation Board, Luftambulansetjenesten ANS stated that they attempted to moderate any tendencies for competition with regards to response time among the operating companies. The operators registered a response time of more than 15 minutes with causal factors. Statistics were not collected for response times within the norm of 15 minutes. Luftambulansetjenesten ANS also stated that they also did not try to influence the ambulance helicopters to land as close as possible to the patient at the expense of flight safety. To the extent there was such pressure, it was self-inflicted by the operating companies.

1.17.3.5 Luftambulansetjenesten ANS was of the opinion that the project introducing the digital emergency communication network (TETRA) was too slow to consider that the system was to be used in helicopters. This was pointed out, without the input being taken under advisement, which had negative consequences for procurement of equipment and development of the system. Accordingly, the air ambulance's needs were poorly taken into account. However, a number of improvements, also introduced after the accident, have increased the reliability and user-friendliness.

1.17.3.6 Luftambulansetjenesten ANS told the Accident Investigation Board that they preferred relatively long contract periods. This was in the interest of achieving stability and predictability. They thus entered into a contract with Norsk Luftambulanse AS on 1 June 2008, with a duration of 6 years, and an option to extend for 2 x 2 years. Both options were used, so that the contract period lasts until 31 May 2018.

1.17.3.7 Luftambulansetjenesten ANS had contributed with procurement of equipment and financing of significant changes and safety improvements, also within a contract period. Examples of this include use of Night Vision Goggles (NVG) and increased use of simulators.

1.17.3.8 Luftambulansetjenesten ANS believed there was a considerable potential for improving the functions of the emergency medical services communication centres (AMKs). Increasing the expertise at the centres could improve coordination and flow of information. This could help relieve the crew in the ambulance helicopters.

1.17.3.9 Luftambulansetjenesten ANS wanted to participate in the Flight Safety Forum for operators of domestic helicopters, but this was not approved by the Civil Aviation Authority.

1.17.4 The Civil Aviation Authority's oversight

1.17.4.1 The Civil Aviation Authority carries out oversight with Norwegian helicopter companies, among others. The two last audits with Norsk Luftambulanse AS were carried out in 2013 by the Civil Aviation Authority's operative department.

1.17.4.2 One of the audits focussed on the company's secondary bases and took place in August and September. According to the Civil Aviation Authority's report No. 2013O-41, no nonconformities were detected during the inspections that were completed with a basis in BSL JAR-OPS 3. A few factors were noted in the report, but these do not apply to the relevant accident.

1.17.4.3 The other audit was carried out at the company's headquarters in Drøbak on 11 December 2013. According to the Civil Aviation Authority's report No. 2013O-73, a basis was taken in BSL JAR-OPS 3, in the following areas:

- The base's organisation and management
- Quality system, flight safety programme
- Training
- Incident reporting, including internal processing and trends

1.17.4.4 The inspection report is very brief and provides no further documentation of what was investigated during the inspection. The report contains no nonconformities or required actions. However, it did include a recommendation to introduce emergency training with night vision goggles (NVIS) as part of the simulator training.

1.17.5 Relevant regulations concerning aviation obstacles

1.17.5.1 *Regulations relating to reporting, registering and physical marking of aviation obstacles*

At the time of the accident, the regulation that dealt with reporting, registration and physical marking of aviation obstacles was split into BSL E 2-1 (reporting and registration) and BSL E 2-2 (physical marking). An aviation obstacle was defined as follows in BSL E 2-1:

> *Aviation obstacles outside developed areas is to be interpreted as any building, structure or facility, temporary or permanent, with a height above ground or water of 15 metres or more, including the fundament and anchoring. The corresponding height in developed areas is 30 metres or more.*

The above definition partially contradicts the definition of an aviation obstacle in BSL E 2-2 Section 3(2):

> ***Aviation obstacle:*** *Any structure or object, temporary or permanent, that generally has a height of 60 metres or higher above the ground or the water. Following concrete assessment, the Civil Aviation Authority can make a special decision for certain structures or objects to not be considered aviation obstacles, even if they are 60 metres or higher. Correspondingly, the Civil Aviation Authority can make a special decision for certain structures or objects to be considered aviation obstacles, even if they are lower than 60 m. An aviation obstacle could be a building, wind power plant, tower, stack, power line, pylon, antenna, bridge, etc. and associated cable stays, backstays and anchoring, etc.*

When the accident happened, a new version of the *regulation relating to reporting, registration and physical marking of aviation obstacles* was under way. The consultation was carried out during the period 3 December 2013 – 1 March 2014 and the regulation entered into force on 1 September 2014[23]. A significant amendment was that the previous regulation for notification and registration was merged with the marking regulation. Furthermore, the physical marking requirements were made considerably more stringent.

In connection with the consultation for the regulation, several of the consultation bodies wrote that they wanted a stronger focus on digital databases and GPS-based systems for warning against aviation obstacles. This is emphasised both by aviation operators and owners of aviation obstacles. As an example, the Royal Norwegian Air Force wrote the following in its consultation response:

> *In order to increase safety, all aviation obstacles must be registered within the National register of aviation obstacles (NRL) and be physical marked at a lower height than the current regulation stipulates, and obstacles subject to marking requirements must also be physically marked within a reasonable time.*

As an example, Energy Norway wrote the following in its consultation response:

> *It is the opinion of Energy Norway that other measures must therefore be introduced in order to achieve the vision of zero accidents; such as electronic reporting of all aviation obstacles. Energy Norway wants a stronger focus on electronic reporting of* ***all*** *aviation obstacles, and therefore, together with Statnett SF, we have joined forces with Nobilesoft who will develop the system "Obstacle Warning GPS System (OWGS)" for automatic warning of aviation obstacles. The costs of developing such a solution are relatively modest, estimated at approx. NOK 6 million, but requires extensive registration of power lines that are not currently registered with the Norwegian Mapping Authority.*

[23] BSL E 2-1 Regulation relating to reporting, registration and physical marking of aviation obstacles

As an example, Norsk Luftambulanse AS wrote the following in its consultation response:

> *The Norwegian Armed Forces and the Police operate in the same segment and with the same airspace dispensations as us. These operators are increasingly using more helicopters with digital moving map systems and will have an increasing need for relevant, updated obstacle databases containing everything that could constitute a risk to their operations. The technology is developing in the direction of more and more civilian players with handheld units having a moving map where a relevant and updated obstacle database with everything registered, could potentially constitute a major improvement for flight safety.*

And furthermore:

> *A database that includes all obstacles, regardless of height, must be prepared. Such a database is within range and under development at the initiative of the Norwegian Mapping Authority in cooperation with other Geovekst parties. The project is called FKB Ledning 4.5. We are of the opinion that the database must be completed as soon as possible. An extraction produced from this database, showing elements that are elevated or stretched through the air, will be sufficient to form a obstacle database together with NRL, which following processing in a digital map programme, could provide a more complete picture than what is currently the case. Along with geographical height information, the height information in the specifications for FKB Ledning 4.5 could possibly enable the presentation of power lines in different colours and thus provide a better picture of their heights.*

The company also referenced the previous consultations on the topic. According to Norsk Luftambulanse AS, the text was still just as relevant:

> *For us, it is very significant that the database is not restricted to what falls under the definition of aviation obstacles, but includes all structures in the air, regardless of height.*

As an example, Norsk luftsportsforbund wrote the following in its consultation response:

> *Furthermore, NLF believes that in addition to traditional physical marking, it is very important to invest in a GPS-based warning system. For example the FLARM system. Here, exhaustive and updated obstacle data is a precondition in order for the system to work.*

The Civil Aviation Authority's responce related to making the requirements for reporting and registration of aviation obstacles more stringent, was that this topic would be considered at a later revision of the regulations. Aviation obstacles are defined as follows in Section 2 of the new *regulation relating to reporting, registration and physical marking of aviation obstacles*:

> *An aviation obstacle is any building, structure or facility, temporary or permanent, with a height of 15 metres or more above ground or water, for example wind turbine, tower, stack, pylon, antenna, bridge, and power line. Associated cable stays, backstays, anchoring or the like is also regarded as being part of the aviation obstacle. However, in areas for industry and commercial and*

industrial activities and in cities and densely developed areas, buildings, structures or facilities are only considered to be aviation obstacles when they are 30 metres or higher.

1.17.5.2 *The Civil Aviation Authority's further work on aviation obstacles*

In a meeting between the Accident Investigation Board and airport department of the Civil Aviation Authority on 19 November 2014, the Accident Investigation Board provided information about the investigation and which measures the Board believes can help prevent these types of accidents. The Civil Aviation Authority then stated that the reporting aspect of the regulation would be revised in the near future. Furthermore, the Civil Aviation Authority stated that it had been working to have the entire country laser-scanned. This initiative was taken in part due to implementation of requirements in ICAO Annex 15 (Aeronautical Information Services) through EU Commission Regulation 73/2010 relating to Aeronautical Data Quality (ADQ). A number of state agencies would benefit from such a digital mapping of the country, but they had been rather unwilling to share the expenses. The Civil Aviation Authority clearly saw the safety potential of improving the overview of aviation obstacles in Norway, but does not have the authority or financial capacity to take on this task alone. They were willing to take an active role in the matter, but believed than an interdepartmental collaboration and financing model needed to be in place first.

1.18 Additional information

1.18.1 The company's internal investigation

1.18.1.1 Immediately following the accident, the company established an internal investigation group. This group has provided useful and good information to the Accident Investigation Board. On 12 May 2014, the group submitted an extensive internal investigation report. Among other things, the report contains 13 safety recommendations that are directed both at internal conditions and factors outside of the company's control.

1.18.1.2 Multiple safety recommendations relate to standardisation of the procedures during VFR approaches to unknown landing sites. Key topics are reconnoitring, communication, visual verification of aviation obstacles and sterile cockpit concept in the final part of the approach. Furthermore, the report recommends several improvements as regards aviation obstacles, databases, digital maps and power line detection systems. The report also recommends improvements in communications, training and reporting of nonconformities. The investigation group also provided recommendations to limit the extent of damage and simplify accident investigations by e.g. recommending improvements in flight following and by recommending that future helicopters are outfitted with flight recorders and cockpit voice recorders.

1.18.2 Interviews with employees in Norsk Luftambulanse AS

1.18.2.1 The Accident Investigation Board has interviewed pilots, HEMS crew members and doctors working for Norsk Luftambulanse AS. A standardised questionnaire was used, adapted to the various discipline groups. The questions have primarily focused on procedures, operative practice, communication, aviation obstacles, reporting and non-conformance procedures. Everyone spoke very well of their workplace. They all agreed that they worked in a dedicated and professional organisation. The answers were very similar in most areas, but the routines during landing in unknown landing sites varied somewhat. Below is a compilation of some expressed viewpoints:

- They perceive that operative personnel are of a high standard.

- The procedures are good and exhaustive. A few people were of the opinion that it could be difficult to specify the VFR procedures to a particularly greater extent than what is the case. This was due to the vast variation in missions.

- Agreement that the cooperation and sharing of workload on board are good and expedient. The three-crew concept worked very well.

- There was a high degree of standardisation in the work on board. Accordingly, it was not very significant as regards who flew together.

- Different missions could result in different levels of stress. However, safety was not unduly challenged by the severity of the mission.

- Disregarding the power line, the accident landing site was considered to be highly suitable for landing, and was in no way perceived as extreme.

- Predesignated landing sites may yield a safety gain in a few cases, but cannot be used for most missions. Some people were of the opinion that such sites should rather be viewed as a place for meeting ambulances.

- The company has a good system for non-conformance procedures and a good reporting culture. However, it was mentioned that it could sometimes take a long time before nonconformities were fully processed.

- Aviation obstacles are a constant threat that is always taken seriously.

- Only one of the interviewees had experienced being frighteningly close to an aviation obstacle during his time in Norsk Luftambulanse AS.

- EURONAV was a good aid, but it was not possible to trust that all aviation obstacles were shown on the moving map.

- There were varying levels of familiarity with the warning system associated with EURONAV. The warning system was not emphasised, and there was agreement that the system could not be trusted to provide a warning in all instances.

- A newly established position as ambulance helicopter coordinator at AMK O/A was a great help during missions and relieved the crew during periods with intensive work loads.

1.18.2.2 Viewpoints regarding communications are listed in Chapter 1.9.4.

1.18.3 Detection and warning systems for aviation obstacles

1.18.3.1 Several warning systems for aviation obstacles have been developed. An example of this is Powerline Detection System from the company Safe Flight Instrument Corporation, USA. The system has a receiver located in the aircraft, which registers the electromagnetic field around a line power line. The system triggers an audible alarm and lights in the cockpit when a power line is registered. However, this system cannot detect transport cables and other installations that are not surrounded by an electromagnetic field. In order to detect such hazards, the aircraft must be equipped with other systems, for example radar sensors. Such systems are often expensive, and have resulted in major modifications and substantial weight increases. The systems were primarily developed for the military market. An overview of such equipment that was available in 2008 is discussed in an extensive study conducted by the US civil aviation authority, FAA Safety Study of Wire Strike Devices Installed on Civil and Military Helicopters

1.18.3.2 The Swiss firm FLARM has developed an anti-collision system that was originally intended to prevent collisions between gliders. The system is GPS-based and provides a warning if aircraft with FLARM come too close to each other. The installation is light, cheap and requires little power. FLARM, which was introduced in 2004, can also upload databases with aviation obstacles. Currently, FLARM has aviation obstacles databases for Italy, Switzerland, Austria, France and Germany.

1.18.3.3 With a basis in the obstacle database from NRL, the glider community in Norway attempted to use FLARM. Data from NRL was sent to FLARM so that the company could convert the data to fit the system. The attempt was successful, but NRL's database did not contain information about the lowest obstacles. The glider community realised that the low obstacles were in fact the largest risk during, for example, landing outside airport. Further work on the project was therefore terminated.

1.18.3.4 In 2005, the Civil Aviation Authority approved a system to warn aircraft of aviation obstacles. The installations of the Obstacle Collision Avoidance System (OCAS) were expensive and mainly intended for large power lines, wind turbines and similar. Questions were eventually raised with regard to the system's function and operational reliability. No aviation obstacles were equipped with a functioning OCAS when the accident occurred. Regardless, it would not have been relevant to install OCAS on the power line that LN-OOI hit.

1.18.4 Previous collisions with aviation obstacles

1.18.4.1 According to the Civil Aviation Authority, a total of 16 accidents occurred during the period 1994 - 2014 where civilian manned aircraft collided with aviation obstacles. Six of these accidents were fatal, with 15 fatalities altogether. There have been no fatal accidents during the period between 2001 and 2014. The Civil Aviation Authority's statistics for accidents and near-collisions between aviation obstacles and helicopters also shows that 14 instances happened with power lines/overhead lines that were lower than 60 m above ground, whereas only two involved power lines/overhead lines that were higher than 60 m above ground.

1.18.4.2 The Accident Investigation Board has investigated all the mentioned accidents. Most recently, the Accident Investigation Board published report SL No. 2014/10 concerning LN-OCF which came close to tearing down a line in Lyngen in Troms on 18 March 2014 and report SL No. 2013/14 concerning LN-TOS, whose wings were severely damaged in a cableway in Kåfjorden in Troms on 7 April 2010.

1.18.4.3 The Accident Investigation Board published safety recommendation SL No. 2013/04T in connection with the accident in Kåfjorden:

The Accident Investigation Board Norway is of the opinion that future systems for obstacle warning to aircraft in flight should be based on readily available equipment/methods such as the use of GPS and electronic maps. A database of obstacles already exists at NRL.

The Accident Investigation Board Norway therefore recommends that the Norwegian Civil Aviation Authority, in collaboration with a map provider find a solution so that this information can be made conveniently available to actual user groups.

1.18.4.4 With a background in the safety recommendation, the Civil Aviation Authority sent a letter to the Ministry of Transport and Communications on 31 October 2014, explaining their follow-up of the matter. The letter references EU Commission Regulation 73/2010 relating to Aeronautical Data Quality (ADQ) and the project ”New National Digital Height Model” and requirements stipulated by ICAO concerning terrain and obstacle data called electronic Terrain and Obstacle Data (eTOD). The Civil Aviation Authority considers this to be the State's responsibility, but ends the letter with:

The financing and implementation of these measures is outside the Civil Aviation Authority's scope.

For these reasons, the Civil Aviation Authority believes that safety recommendation SL 2013/04T must be solved at a higher level between the various involved ministries. We therefore ask that the Ministry of Transport and Communications take the initiative to continue following up this case.

1.18.4.5 The Norwegian Mapping Authority stated that they were familiar with the recommendation, but that as far as they knew, the Civil Aviation Authority had not implemented measures to implement the safety recommendation. The safety recommendation was still open, which meant that the Civil Aviation Authority had not finished processing and completion at 1 January 2015.

1.18.4.6 The Norwegian Armed Forces has also had a number of incidents and accidents involving collisions with aviation obstacles. Several of these led to the loss of human lives.

1.18.5 Laser scanning in Sweden

A representative from the Swedish Transport Agency has stated that 75 – 80% of the country has already been laser-scanned. The work took place as a collaboration between Lantmäteriet (equivalent to the Norwegian Mapping Authority), LFV (a parallel to Avinor) and Forsvarsmakten (Swedish Armed Forces), among others. The objective was to quality-assure the obstacle data which the Swedish Armed Forces was already managing. The grounds for performing laser scanning was also one of the requirements in EU Commission Regulation 73/2010 concerning ADQ.

1.18.6 Safety study domestic helicopters

1.18.6.1 Helicopter operations in mainland Norway have been exposed to accidents, and safety work directed at this activity has in recent years been a prioritised mission for the Civil Aviation Authority. A step in this work was the establishment of a flight safety forum for domestic helicopter operators (FsF) in 2009. At the initiative of FsF, the Ministry of Transport and Communications hired the consulting firm Safetec to conduct a safety study for the purpose of mapping the situation[24]. The objective was to highlight risk areas and to provide recommendations in order to improve the safety of domestic helicopter operations.

1.18.6.2 The study was delivered in 2013 and showed that ambulance activities had the lowest accident risk out of all types of operations. Furthermore, it was estimated in the study that GPS systems for warning of unmarked obstacles could reduce the accident frequency by 2%.

1.19 Useful or effective investigation techniques

No methods qualifying for special mention have been used in this investigation.

2. ANALYSIS

2.1 Introduction

2.1.1 <u>General</u>

2.1.1.1 This accident generally seems easy to explain because the course of events is well documented. During approach for landing, the helicopter flew into a power line that destroyed the main rotor. Thus, it was no longer possible to control the helicopter, and it fell almost vertically and hit the ground with substantial force.

2.1.1.2 The accident took place during a highly ordinary mission with a very experienced crew in weather conditions that should not pose problems. The chosen landing site was seemingly very suitable, but the crew did not detect in time that a power line ran across the final part of the approach.

2.1.1.3 Only when looking beyond the completely obvious cause and effect can you see that the accident is more complicated. An analysis of underlying factors of a safety-related significance is important because it can form the basis for lasting improvements that can help prevent similar accidents in the future.

2.1.1.4 In this investigation, the Accident Investigation Board has not found technical failure or irregularities in the helicopter that could have had an effect on the course of events.

2.1.1.5 There was also no special conditions associated with the crew members' qualifications, suitability, physical health condition or the like that would have led to a more in-depth examination to find causalities in this area. The Accident Investigation Board has noted that the experienced commander had not flown much recently (see Item 1.5.1.4), but there is no proven correlation between this and his performance.

2.1.2 <u>Structure of the analysis</u>

2.1.2.1 The Accident Investigation Board's analysis starts with a discussion of the actual course of events and circumstances surrounding this. This means the choice of landing site, approach, the crash and triggering factors. This is followed by analysis of the survival aspects and forces of the crash that were involved at the time the helicopter hit the

[24] cf. http://www.helikoptersikkerhet.no/?ac_id=246

ground. Factors that could have prevented the accident, are evaluated on a continuous basis.

2.1.2.2 The subsequent chapters of the analysis delve deeper into the underlying circumstances surrounding how and why the accident occurred. Why the power line was not detected and a selection of barriers that could potentially have mitigated the threat represented by the power line, are discussed here.

2.1.2.3 The final part of the analysis consists of more thorough discussions of possible improvements in moving maps and obstacle warning, conditions associated with communications and the company's work to prevent accidents when landing at unknown landing sites. The analysis ends with conclusions and safety recommendations that are meant to help reduce the accident risk associated with aviation obstacles.

2.2 Course of events

2.2.1 Access to information

The final part of the approach and actual crash were thoroughly documented by video and the helicopter wreckage has been available for further examination. The HEMS crew member has also contributed with useful information. It was therefore possible to describe the course of events in detail and with a high degree of certainty.

2.2.2 Suitability of the landing site

2.2.2.1 The crew chose to land in an emergency lay-by located just south of the southern entrance to the Nes tunnel. It is in many ways understandable why this site was chosen. The emergency lay-by was located near the traffic accident and had a seemingly good location with regard to the approach. The emergency lay-by was established by the Norwegian Public Roads Administration in connection with construction of the tunnel. The Accident Investigation Board understands that these are primarily intended for vehicles experiencing trouble and various service functions for operating the tunnel, but ambulance helicopters are often used in connection with traffic accidents and it could be expedient for them to also land on such emergency lay-bys.

2.2.2.2 In instances where it is practically feasible and the level of urgency is acceptable, increased use of predefined landing sites rather than landing at an unknown site in the terrain could contribute to increased safety. AIBN believes emergency lay-bys should be designed so they could also serve as suitable landing sites for helicopters. The process for establishing new emergency lay-bys should include an assessment of the approach conditions and actual landing site. The approach must be free of power lines, traffic signs and the like, and the area immediately surrounding the emergency lay-by must be cleared of high trees, lighting pylons, etc. that could collide with the rotors. Furthermore, the sites must be cleared of snow. AIBN assumes that this does not necessarily need to result in major changes from the current practice. The same criteria should also be emphasised when designing picnic areas along roads. Technical helicopter expertise should be involved in this work.

2.2.2.3 It is the opinion of the Accident Investigation Board that the Norwegian Public Roads Administration should therefore describe a standard for future design of both picnic areas and emergency lay-bys along Norwegian roads where the above-mentioned conditions are emphasised. A safety recommendation is issued in connection with this.

2.2.3 Reconnaissance and approach

2.2.3.1 The reconnaissance that took place was neither particularly thorough nor particularly superficial. The landing site was in many ways suitable, provided that you were aware of the location of all obstacles in the area. Speed during the approach was low as expected. The fact that the commander yawed the helicopter and flew sideways was beneficial, as it gave him good visibility looking ahead and down at the chosen landing site (see Item 1.1.9). The HEMS crew member helped verify that they cleared the line between the lamp posts along the road by opening the door and looking out (see Item 1.1.10).

2.2.3.2 The helicopter was flying mostly horizontally for the final part of the approach and could not start final descent until it had passed the lamp posts. Landing was imminent, and it is natural to assume that both the commander and HEMS crew member were focusing forward and downward towards the chosen landing site at the time of the collision. However, since they were flying horizontally, the eyes must have been directed forward or at an angle upward in order to detect the lines that collided with the helicopter above the cockpit.

2.2.3.3 It can be speculated whether the commander assumed that the power line he previously saw shown on the moving map was behind the landing site, whether he became distracted and forgot, or whether he confused the power line with the line between the lamp posts. The last alternative was ruled out by the HEMS crew member. The commander's potential thoughts about power lines during the final phase are unknown. Based on the HEMS crew member's explanation, it seems clear the crew did not discuss or verified the existence and location of the power line they previously saw on the moving map (see Item 1.1.4).

2.2.3.4 In one of the video recordings, you can see that the helicopter's nose was raised immediately before the first line became stuck in the wire cutter. This could indicate that the power line was detected just before the collision, and that the manoeuvre was an instinctive attempt to stop the helicopter. However, the main rotor had already come under the live lines at this point. More possible explanations of why the power line was not detected in time, are discussed in Chapter 2.4.1.

2.2.3.5 In retrospect, it can be questioned whether the crew allowed enough time. Could more thorough reconnoitring and a more elaborate review of map information and the terrain have revealed that a power line was intersecting with the approach path? The surveys conducted by the Accident Investigation Board did not indicate that the time pressure was considerably great for this mission (see also 2.6.3.1). A commander must always prioritise with regard to the need for urgency and proximity and decide how to conduct reconnaissance, approach and landing. The company's stated premises and decision support for safe approaches to unknown landing sites are discussed in more detail in Chapter 2.7.

2.2.4 The crash

2.2.4.1 The first contact with the power lines occurred when the helicopter's top *wire cutter* hooked on to the ground wire (see Figure 2). The line was not cut due to the low speed (see Chapter 1.6.4). The slowing down due to the contact with the line, in combination with the fact that the helicopter's centre of mass was located below the *wire cutter*, also led to the lifting of the helicopter's nose. The main rotor blades thus struck the live lines that were somewhat higher than the groundwire.

2.2.4.2 The main rotor cut the three live lines and caused a short-circuit. During this sequence, one line coiled around the mast below the rotor head, thereby cutting all four pitch-links (see Figure 17). This led to the loss of the lift from the main rotor and it became impossible to control the helicopter. The contact between the main rotor and lines also caused a main rotor blade to break (see Item 1.12.2.6). This in turn led to major imbalance in the main rotor. The strain on the main rotor was so powerful that the entire main gearbox and parts of the cabin ceiling were ripped loose, and were about to fall completely off just before the helicopter hit the ground.

2.2.4.3 The main gearbox and engines are connected via the drive shaft. When the main gearbox was ripped loose, this led to major strain and movement in the entire installation up on the cabin ceiling. It is possible in this connection that foreign objects could enter the engines, that engine controls could be disturbed and the electronic control systems were damaged. The vibrations may also have been powerful enough to damage the engines. The right engine may have stopped due to this, which would explain the white smoke coming out of the right engine while the helicopter fell. Furthermore, such a scenario could help explain the severe damage found in the turbine in the right engine (see Item 1.12.2.5).

2.2.4.4 Large volumes of foreign objects were sucked into the air intake in the left engine. The actual engine, however, only sustained minor damage. It could therefore be imagined that the left engine continued to run until the fuel supply stopped shortly after the helicopter hit the ground, and that this produced the white cloud of steam that was observed after the impact (see Item 1.1.15).

2.3 Survival aspects

2.3.1 Because emergency agencies were already present due to the road traffic accident, the signals from the emergency locator transmitter had no real significance for search and rescue in connection with this helicopter accident.

2.3.2 As regards crash forces, the human body will sustain injuries if it is exposed to a vertical load exceeding 20 G for more than 0.1 seconds[25]. Survival is doubtful if this load is increased to 30 G. Survival is improbable at 40 G. Another source[26] states that humans can withstand 18 – 20 G vertically with a velocity change of up to 17.5 m/s. This was previously used as an acceptable standard when developing ejection seats.

2.3.3 The commander and physician died as a result of extensive injuries. The fact that two people died, while one survived with severe injuries, helps confirm that the loads during the accident where on the limit for what can be survived. The largest uncertainty factor is how the sideways load impacted the outcome. Neither the seats, dampening mechanism in the seats nor the seatbelts are designed to provide support laterally. When the upper body is pushed sideways, only the shoulder harness can restrict the movement, to a certain extent. The Accident Investigation Board is of the opinion that it will be difficult to give the people sitting in the seats good support and cushioning from lateral crash

[25] Source: Air Force Publications AFP 127-1 from the US Air Force
[26] Source: Fundamentals of Aerospace Medicine, Jeffery R. Davis

forces without this posing a hindrance to necessary freedom of movement. However, it is assumed than an airbag solution can provide the desired effect in certain cases.

2.3.4 The commander sustained injuries in the neck region, which could indicate that he was partially held back by the shoulder harness. The physician had no such injuries. It therefore cannot be excluded that he had removed the shoulder harness in order to have greater freedom to prepare for his duties after the landing. He also may have removed the shoulder harness for the purpose of having more freedom to look down on the ground. Regardless of whether this happened in the relevant case, AIBN wants to emphasise the importance of everyone on board being buckled in until the helicopter is safely on the ground.

2.3.5 The HEMS crew member survived even though he was sitting on the side of the helicopter that hit the ground first. An explanation could be that the left cockpit door provided support against sideways movement. The door eventually hit the ground, which further limited sideways movement. This may have resulted in a more even distribution of crash forces over larger parts of the body. Another factor may be that the HEMS crew member was physically strong and in good shape.

2.3.6 The upper part of the cockpit and helicopter's cabin were parallel displaced to the left. The cabin height was accordingly reduced. A large part of the cabin ceiling came loose at the same time. However, there is nothing to indicate that the physician was struck by the loose gearbox or that insufficient survival space was the cause of the fatal outcome.

2.3.7 Based on the video recordings, the Accident Investigation Board has arrived at the conclusion that the helicopter hit the ground with a terminal velocity of 18 - 19 m/s with a bank of approx. 50° to the left. The helicopter hit an embankment with the left skid first, which came off from the impact. This absorbed some of the energy. However, the layer of snow was probably too thin to cushion the impact to any significant degree.

2.3.8 The attachment of the helicopter's main components is designed to withstand 20 G vertically. The cockpit and cabin are robust, with a honeycomb composite structure, among other things. This means that the helicopter can withstand significantly larger loads than the design criteria from EASA (see Item 1.15.2.2). An evaluation of the impact forces during the accident is complicated by the fact that there were also lateral loads (sideways). Based on an overall assessment of the injuries and damage sustained by the crew and the helicopter, viewed in relation to what they could be expected to withstand, the Accident Investigation Board believes the load when the helicopter hit the ground exceeded 20 G.

2.4 Underlying circumstances

2.4.1 <u>Why the power line was not detected</u>

2.4.1.1 During the flight, the crew had seen from the moving map that there was a power line in the area where they were about to land. The means at their disposal for detecting the power line upon arrival were visual detection during reconnaissance and approach, potential communication calls from people on the ground and information from the moving map on board.

2.4.1.2 The Accident Investigation Board's investigations have revealed that several barriers that could potentially have prevented the threat this power line represented, were not functioning or were missing when the accident occurred:

- Neither the lines nor the poles were physical marked, and it was unusually difficult to detect the power line.

- The helicopter had no sensors that could have detected and provided a warning about the obstacle.

- The helicopter's moving map system had a visual warning function, but the system had weaknesses and was not used during the final part of the approach.

- The preparations for landing do not appear to have included a positive verification of where in the terrain the power line they saw on the map was actually located. They probably also did not discuss whether the overhead line may have been removed, or whether it was actually the line between the lamp posts that was shown on the map.

- The police did not succeed in achieving contact with the crew via communications to inform about the landing conditions.

- The crew was not successful in achieving contact with personnel on the ground via communications.

- The helicopter's wire cutter did not work due to the low speed.

- Latent weaknesses in the company's established system for creating and maintaining sufficient safety margins during approach to unknown landing sites and approaches during time pressure may have influenced the crew's decisions.

2.4.1.3 Physical marking of all power lines of this height may seem quite unrealistic. However, some power lines constitute a greater risk than others, and marking of these should be considered. This particularly applies to power lines in areas where aircraft are often flying at low altitudes, for example along roads.

2.4.1.4 Historically, sensors for detecting power lines, wires and similar have been expensive to purchase, and resulted in major modifications and substantial weight increase. Accordingly, it has so far not been realistic to equip the ambulance helicopters with such equipment. Although it is not possible to achieve fully satisfactory safety with sensors and physical protection systems, they can make a positive contribution. Smaller and cheaper systems will eventually become available, and the Accident Investigation Board believes helicopter operators should on a continuous basis assess whether installation of such equipment could be beneficial.

2.4.1.5 The Accident Investigation Board believes that access to reliable technical solutions that can help crews prevent the helicopter from unintentionally coming too close to aviation obstacles, would be a good measure. Naturally, knowledge about an obstacle's exact location and height make it much easier to detect and avoid it. AIBN believes that it has become clear through this investigation that the technology development now has come far enough for Norway to immediately invest resources to take advantage of digitised obstacle data as a real flight safety measure. This is discussed and substantiated further in Chapter 2.5.

2.4.2 Deficient visual detection

2.4.2.1 As mentioned above, approach was started without the digitally presented power line being clearly verified and communicated amongst the crew members. In practice, the crew was using only observation to assess whether the flight path contained no obstacles. Thus making cooperation in the cockpit, observation pattern and good eyesight significant factors.

2.4.2.2 It was unusually difficult to spot the power line which the helicopter hit, and nearly impossible to detect visually from the angle in which the helicopter was flying. There was no snow on the lines. It was difficult to spot the grey colour against the busy backdrop (see Figure 14). The southwestern poles were the same colour as the trees they were hidden behind, and the northeastern poles were hidden amongst trees. It was also difficult to see signs of power line corridors through the forest. The Accident Investigation Board therefore believes that the circumstances indicate that the accident could have happened to any crew in the company.

2.4.2.3 It is speculative to imply that a person who satisfied the Norwegian Armed Forces' visual requirements would have detected the relevant power lines, but it can be questioned whether military and civilian visual requirements should be identical (see Item 1.5.1.4). Helicopter pilots in the Norwegian Armed Forces and in air ambulances are exposed to very similar challenges during visual approach to unknown landing sites. AIBN believes it is unrealistic to expect that civilian regulatory requirements will be made more stringent in this area. An increasing share of regulations within aviation is based on the players identifying relevant hazards and implementing necessary preventive measures through their safety management system. In other words, operators must independently consider whether they see a need to increase the safety margins through introducing more stringent vision requirements for their pilots.

2.4.3 Why the digital map with built-in obstacle warning did not help prevent the accident

2.4.3.1 The helicopter collided with a power line that was shown on a moving map with built-in obstacle warning that was available in the cockpit. It is therefore reasonable to ask why this advanced safety barrier did not prevent the accident.

2.4.3.2 The Accident Investigation Board believes it is important to note the following when assessing this question:

- The crews in Norsk Luftambulanse AS have never had access to fully reliable and exhaustive map information.

- Important aviation obstacles have been left out, and there are examples of aviation obstacles that have been physically removed several years ago still being shown on the maps.

- The map and warning system for aviation obstacles was known for being unreliable, which resulted in little faith in the warning system in the moving map.

- The relevant power line was shown on the moving map, but the height was not specified.

- There was no audible warning that could call on the crew's attention in the event of collision risk, the warning was just a symbol change on the display.

- When it comes to preventing collision with aviation obstacles, the moving map systems have historically been a supplement.

- The company's operative personnel appear to have had varying levels of familiarity with the EURONAV warning system. Although required training was provided, there were no suitable procedures for use (see Item 1.8.6.3).

- The procedure describing that the moving map should be visible when landing in unknown locations, focused on missed approaches rather than detection of obstacles in connection with landing (see Item 1.8.6.1).

2.4.3.3 The Accident Investigation Board has noted that the map database in LN-OOI not was updated in accordance with applicable routines. However, since the relevant power line was already shown on the map in this case, it had no impact on the course of events.

2.4.3.4 The fact that the HEMS crew member removed the moving map from the display before the final part of the approach was started, was not in compliance with the procedures (see Item 1.1.9). In hindsight, it can be claimed that the obstacle warning that would have been visible on the display would have alerted the crew to the obstacle, thus preventing the collision. This assumes the HEMS crew member regularly checked the display. AIBN believes that weaknesses in the database, deficient familiarity with the warning system and the lack of procedures for systematic utilisation of the system during approach to unknown landing sites, show that the system was not yet mature and under development. The obstacle warning function in EURONAV was considered a supplement that could not be trusted.

2.4.3.5 Based on this, AIBN concludes that when the LN-OOI accident occurred, neither the moving map system nor the practical use of it were sufficiently mature in order to expect that the visual obstacle warning would have prevented the accident. Considerable luck and circumstance would have been involved if this worked as a safety net. Nevertheless, the accident illustrates a potential. It would theoretically have been possible to use information that was available on board to detect and alert the crew of an obstacle that they were not aware of. AIBN has therefore chosen to discuss possible improvements in maps and notification/warning.

2.5 Potential improvements in maps and warning systems

2.5.1 <u>Need for improvements in moving maps and technology</u>

2.5.1.1 Improvements in digital maps in combination with new technology can help increase safety with regard to aviation obstacles. A good obstacle database, in combination with a functional GPS-based warning system, including audible warnings, could constitute an additional safety net by alerting the crew to collision risk and thus preventing an accident. A reduction of the risk of colliding with aviation obstacles will also help in the ongoing work on improving the safety for domestic helicopter operations (see Chapter 1.18.6).

2.5.1.2 Aviation obstacles represent a constant threat for helicopters that occasionally need to fly low and land at unknown landing sites. This particularly applies to ambulance helicopters and police helicopters, because these operations can only be planned to a limited extent, and often take place with a sense of urgency. The Norwegian Armed Forces, helicopters that perform aerial work and gliders that need to carry out landings outside airport are examples of other players that need to relate to this threat.

2.5.2 Warning systems

2.5.2.1 An improvement of the moving map databases is essential in order for warning systems related to moving maps to function satisfactorily. With an improved map database, the Accident Investigation Board sees three possible safety gains associated with warning systems:

- The reliability of the existing visual warning in EURONAV increases so that the system can be a useful aid.
- Newer versions of EURONAV could have a reliable audible warning system (see Item 1.8.5.2).
- More suppliers of moving map systems can offer similar warning systems.

2.5.2.2 A safety improvement in this area presumes the following:

- The Norwegian Mapping Authority must be given the resources to prepare the most exhaustive database possible of obstacles that could constitute a safety risk for aviation. Much of the information already exists, but quality of the data must be assured and information coordinated in a better manner. Insofar as possible, the database must also include obstacles lower than 15 m. This work should include an imminent revision of the *regulation relating to reporting, registration and physical marking of aviation obstacles*. Furthermore, it should be made as easy as possible for users to report new obstacles or to have them deleted from the database if they no longer exist. Establishment of a new national height model will also help increase safety.
- It must be possible for the obstacle database (NRL) to be used by GPS-based systems for warning of aviation obstacles. In this connection, it is important that information from the map database can be exported in a format that satisfies the needs of the equipment manufacturers.

2.5.3 Affected players and ministries

2.5.3.1 A number of players and ministries are affected by this case. This is reflected by the answers provided in connection with the consultation round for the *regulation relating to reporting, registration and physical marking of aviation obstacles*. A modernisation of digital map information will affect or provide advantages for a number of players (see Item 1.17.5.1):

- The Civil Aviation Authority is appointed by the authorities to safeguard the civilian flight safety interests in this area. For this reason, the Civil Aviation Authority should play a key role in the work on improving the current digital map database (the Ministry of Transport and Communications).

- The Norwegian Mapping Authority must be given the mandate and the resources (the Ministry of Local Government and Modernisation).

- Luftambulansetjenesten ANS could achieve increased flight safety and safer patient transport (the Ministry of Health and Care Services).

- The police's helicopter service could achieve increased flight safety (the Ministry of Justice and Public Security).

- The Royal Norwegian Air Force could achieve increased flight safety (the Ministry of Defence).

- Owners of power lines will in certain instances have less requirements to relate to in connection with physical marking of power lines and pylons (the Ministry of Petroleum and Energy).

- Helicopter operators that perform work at low altitudes (for example line inspections, forest fire extinguishing, liming etc.) and gliders that occasionally need to land outside airports may achieve increased flight safety.

- Laser scanning of all of Norway will be an important contribution in the work on improving the current digital map databases. In addition to fulfilling the requirements in EU Commission Regulation 73/2010 concerning Aeronautical Data Quality (see Item 1.17.5.2), this laser scanning would be advantageous for a number of players.

2.5.3.2 As shown above, work on improving the current moving map database will include several players. The Accident Investigation Board is of the opinion that the Ministry of Transport and Communications must assume a coordinating role, and that the Civil Aviation Authority must be given a leading role in the implementation. A safety recommendation is issued in connection with this.

2.6 Communication between the helicopter and ground personnel

2.6.1 <u>Introduction</u>

2.6.1.1 When landing at unknown locations, the commander needs to make a lot of decisions in a short amount of time. Important factors that influence these decisions are experience, procedures, aids and communication between the individual players.

2.6.1.2 Both the helicopter crew and the police attempted to contact each other, to no avail. The police wanted to provide information about the conditions at the site. Such information can be good decision support for the commander in connection with landings. It is therefore important that there is a good channel of communication between the aircraft and the ground.

2.6.2 <u>Why the call from the police was not received by the crew</u>

2.6.2.1 When the helicopter arrived at the accident site and started landing preparations, personnel on the ground had already identified the risk represented by the power lines. The police tried to call up the helicopter via the analogue emergency communication network on channel 5 (Redning 1), but received no response. A potential warning from the police could have been the final barrier to prevent the accident. The HEMS crew member has explained that he did not receive a call.

2.6.2.2 Communications do not work if there is terrain between the sender and receiver (requires line of sight). This could explain why the two first calls were not received. Documented monitoring in one of the police cars indicates that the police's communications equipment was working and transmitting on the relevant frequency during the last call. The investigation has shown that the communications equipment was set so that both the HEMS crew member and physician could listen to the analogue radio (FM2) at the time of the crash. Furthermore, it emerged that the volume on channel 5 (Redning 1/guard) was set to an acceptable level. The faults discovered in the radio most likely did not prevent listening (see Item 1.9.2.4).

2.6.2.3 Despite extensive investigations, it has not been possible to find significant faults in the equipment or how it was used. It is thus possible that the call was not received because the crew was focused on the actual landing. The fact that the crew had experienced problems with communications and had low expectations concerning assistance from the ground, may also have been of significance (see Item 1.9.4.2).

2.6.3 Communications on medical channel 33

2.6.3.1 The HEMS crew member ensured medical channel 33 was opened so that he could communicate directly with the medical personnel on the ground. However, due to bad coverage in the area, he did not achieve contact. Good communication is important with regard to relevant updates of the situation on the ground. In the relevant case, the patient had already been transferred to an ambulance and was being treated, but the helicopter crew was not aware of this. It cannot be ruled out that this contributed to the commander having an incorrect perception of the degree of urgency. The Accident Investigation Board is of the opinion that the introduction of a dedicated air ambulance coordinator (see Item 1.9.4.4) is an important contribution for improving the access to information for the ambulance helicopter crews.

2.6.4 ”Emergency stop signal“

2.6.4.1 It has been claimed in connection with the accident that ground personnel (ambulance, fire department and police) should undergo better training in order to help with landings. The Accident Investigation Board agrees that the idea is initially interesting, but it raises a number of issues. As long as personnel on the ground have not undergone complete training in receiving helicopters, the commander can truly only trust their own and the rest of the crew's observations. Designation of landing sites and hand signals from ground personnel therefore cannot be particularly emphasised. In practice, it would be impossible to give everyone who might be on the landing site sufficient training.

2.6.4.2 However, it could be imagined that it would be an advantage in very special cases if people on the ground knew of a way to give hand signals to the helicopter if they saw that it was in immediate danger, without the crew being aware of this. ICAO Annex 2 contains an emergency stop signal that could be suitable:

Figure 21: Advisory emergency stop signal from people on the ground. Arms in front of head, crossed at wrists. Figure: ICAO Annex 2, Appendix 1

2.6.4.3 The Accident Investigation Board believes that an emergency stop signal from people on the ground can only be considered advisory. It will still be up to the commander to determine how this should be followed up. Incorrect use of an emergency stop signal could also entail increased risk in the form of distractions and unnecessary interrupted landings. The Accident Investigation Board therefore believes that the helicopter operators and the Civil Aviation Authority should cooperate on assessing advantages and disadvantages of potential introduction of such a signal among personnel in the emergency agencies, and how the helicopter crew should emphasise such signalling.

2.6.5 Digital emergency communication network

2.6.5.1 The accident occurred in a transition zone between the analogue emergency communication network (VHF FM in Northern Buskerud) and digital emergency communication network (TETRA in Oslo and Akershus)[27]. This complicated communications.

2.6.5.2 The Accident Investigation Board is aware that the introduction of the digital emergency communication network (TETRA communication) resulted in considerable challenges and major frustration. The problems were so significant that the crews largely did not rely on contact with personnel on the ground in connection with landings. This may have been a contributing factor to useful information not reaching the crew in connection with the accident.

2.6.5.3 Difficult operation, temporary function disruptions and issues in the transition zones between the analogue and digital emergency communication networks still characterised the work days when the helicopter accident occurred. This could indicate that the ambulance helicopters' needs were not sufficiently emphasised when the digital emergency communication network was planned and phased in. The fact that the problems with the emergency communication network had lasted since 2010, could also indicate that Norsk Luftambulanse AS has not adequately conveyed its concerns to Luftambulansetjenesten ANS and the Directorate for Emergency Communication.

2.6.5.4 Personnel from Norsk Luftambulance AS have told the Accident Investigation Board that the communications situation noticeably improved after the accident. The problems with

[27] A digital emergency communication network had already been installed with coverage in and around the Nes tunnel when the accident occurred.

the transition between the analogue and digital network will also disappear as the emergency communication network in Norway is completed. However, it is clear that all the challenges associated with the new digital emergency communication network have not been fully resolved, and that the work on improvements must continue.

2.7 The company's role

2.7.1 Safety policy

2.7.1.1 Air ambulance operations with helicopters are risky by nature. Landing at unknown sites, in variable visibility and light conditions, and with many players to relate to when carrying out missions, can be very demanding for the helicopter crews. In addition to these factors, the degree of urgency depending on the patients' condition could also influence the helicopter crews' operative decisions.

2.7.1.2 Decisions made by crews on an air ambulance helicopter will always need to be based on a consideration of the possibilities for completing a mission, versus the consideration to the crew's and helicopter's safety. Companies that perform air ambulance services should be very aware of the considerable flight safety challenges involved with these types of operations. This should be reflected in the companies' safety policy, and specified in the operative procedures and in training programmes for flight personnel.

2.7.2 The company's procedures seen in light of relevant risk factors

2.7.2.1 Norsk Luftambulanse AS has been operating under demanding conditions since 1991 without fatal accidents. A continuous high level of flight safety presumes systematic and dedicated work. Equipment and terms are constantly changing, and the company's ability to obtain a good overview of the flight operations risks and to handle and minimise these are crucial to their success.

2.7.2.1 Based on findings during the investigation of the LN-OOI accident, AIBN believes there are reasons to recommend that the company revitalise the work on mapping and managing risk associated with landing at unknown landing sites. The requirements to introduce a safety management system also emphasise this (see also Chapter 1.17.1.6). Further information and guidelines are provided in the ICAO Safety Management Manual (Doc 9859). The Accident Investigation Board's report No. SL 2010/02 is also mentioned as a reference, as this lists previous helicopter accidents and contains considerations relating to safety management systems/flight safety programmes that may be worth considering.

2.7.2.2 It is generally accepted that standardisation results in increased safety margins, however, there is a fine line here from preventing the procedures from becoming so detailed and rigid that they become useless. It is often the case that it is possible to standardise more than what operative personnel initially agree on. The Accident Investigation Board believes the claim that it is not expedient to have a rigid standardised procedure for VFR navigation since the HEMS missions are so different, should be challenged in light of this (see Chapter 1.8.6.1).

2.7.2.3 One argument for improving the procedures is transfer of experience. The company's helicopters are flown with only one pilot. This means that the training of new pilots in the company cannot take place during a period as first officer before receiving full responsibility as a commander. Commanders could therefore more easily start habits that deviate from best practice. Some harmonisation will take place naturally via the HEMS crew members, but in this investigation, commanders, HEMS crew members and physicians described differences in execution.

2.7.2.4 The Accident Investigation Board believes the following aspects should be included in the assessments recommended for implementation:

- That crew members update each other during landing brief regarding what threats to expect and how they will be handled.
- How to relate to obstacles shown on the map before landing, including both visual verification and approach if verification is not achieved.
- The functionality of moving maps and associated warning system and procedures for efficient utilization.
- Goal to establish radio communication with personnel on the ground before starting the final part of the approach.
- Sterile cockpit concept, i.e. that everyone on board is only working on flight operations tasks during take-off, approach and landing.
- A better description of the work load sharing and tasks in the cockpit during the final part of the approach and landing.
- Keep human performance and limitations (MYB) in mind when defining the HEMS crew member's work load and focus areas during approach and landing.
- Considerations when selecting landing sites.
- Establishment of predefined landing sites/ambulance meeting places, including a system for communicating information about these.
- Good communication concerning the status of relevant patients, so that the landing site decision can be made with the best possible basis, and also reduce unnecessary time pressure.

2.7.3 Authority inspections of the company

The Accident Investigation Board has noted that, before the accident, the Civil Aviation Authority carried out operator surveillance by the authority focusing on the company's quality system and flight safety programme, among other things, and no deviations were documented (see Chapter 1.17.4). The weaknesses identified in the company's procedures in connection with the investigation of this accident were not obvious and the AIBN believes it is understandable that they were missed by the CAA during the audit. Thus, there is no basis for claiming that the lack of findings indicates a failure in the surveillance work. However, the Accident Investigation Board cannot fail to remark that the two most recent flight operations inspections appear to have been superficial, judging from the reports.

3. CONCLUSION

The LN-OOI accident occurred because the helicopter collided with a power line during approach, which caused such extensive damage to the main rotor that it fell vertically down from an altitude of approx. 25 m. The impact with the ground was so severe that two of the crew members died and one was seriously injured. The helicopter was a destroyed.

3.1 Investigation results

3.1.1 General

a) The aircraft was registered in accordance with the regulations and had a valid airworthiness certificate.

b) The aircraft's mass and the location of its centre of gravity were within the permitted limits at the time of the incident.

c) In this investigation, the Accident Investigation Board has not uncovered failures or irregularities in the aircraft that could have had an effect on the course of events.

d) The crew members had valid licences and rights for the helicopter type and can be characterised as experienced with good local knowledge.

e) The mission can be characterised as ordinary and was carried out in weather conditions that should pose no problems.

f) The crew members appear to have been rested and fit for duty when the accident occurred.

g) The commander's vision met the current requirements for civilian flight operations.

3.1.2 The crash

a) The helicopter hit the power line at a low speed, about 8 – 10 kt, while flying nearly horizontally 25 m above ground.

b) The helicopter first hit the lower line in the power line, and the wire cutter did not cut the line due to the low speed. The main rotor then cut the three live lines.

c) One line coiled around the rotor mast, thereby cutting all four pitch-links. This led to the loss of lift and the helicopter fell straight down.

d) The contact with the lines caused a main rotor blade to break. The loads were so powerful that the entire main gearbox and parts of the ceiling were torn off the helicopter.

e) The helicopter banked 50° to the left and hit the ground with an assumed terminal velocity of 18 - 19 m/s.

f) Following a comprehensive assessment, the Accident Investigation Board believes that the load when the helicopter hit the ground exceeded 20 G, and that the accident was barely survivable.

g) Safety equipment in the helicopter intended to keep the crew in place and dampen loads during a crash did not work optimally because the impact caused major forces sideways (laterally).

h) The commander and physician died as a result of extensive injuries, including a right atrium rupture.

i) The HEMS crew member's survival could be attributed to the support from the door, and then the ground, distributing the crash forces over larger parts of the body.

j) The crash happened during the approach to an emergency lay-by that was located beneath a power line.

k) The emergency locator transmitter automatically switched on, but the signals had no real significance in this case because the emergency agencies were already at the site when the accident occurred.

l) A fire did not occur in connection with accident.

3.1.3 Communications

a) The accident took place in a transition zone between the analogue emergency communication network and digital emergency communication network, which complicated communications.

b) The police tried to call up the helicopter via the analogue emergency communication network on channel 5 (Rescue 1), but received no contact.

c) Despite extensive investigations, it has not been possible to find technical faults that can explain why the call was not received by the flight crew.

d) The HEMS crew member attempted to call personnel at the scene of the accident on medical channel 33, but did not achieve contact.

e) Introduction of the digital emergency communication network posed major challenges and considerable frustration for Norsk Luftambulanse AS.

f) The problems experienced with the emergency communication network could indicate that the ambulance helicopters' needs were not sufficiently emphasised when the digital emergency communication network was planned and phased in.

g) The problems were so considerable for a period that the crews largely did not rely on contact with personnel on the ground in connection with landings.

3.1.4 Aviation obstacles and moving maps

a) The power line that the helicopter hit was not physically marked and was unusually difficult to detect from the air.

b) The current National register of aviation obstacles (NRL) is incomplete and not easily compatible with GPS-based warning systems.

c) The helicopter was equipped with a map system (EURONAV with moving map) showing the power line which the helicopter collided with.

d) There were more power lines/overhead lines in the landing area than shown on the moving map.

e) The height of the power line that the helicopter hit was not specified on the moving map.

f) Before the approach started, the crew was aware that the moving map showed a power line in the landing area.

g) EURONAV had connected a visual warning system that would have provided warning about the power line. The warning system was not used in connection with the landing.

h) The moving map database in EURONAV was not exhaustive with regard to aviation obstacles, and the crews considered it and the built-in obstacle warning system to be supplements.

i) The company did not have specific procedures with regard to using the moving map system to identify obstacles during approach.

j) The crew probably did not verify amongst each other where in the terrain the power line they saw on the map was located.

k) The crew identified lines between lamp posts along the road near the landing area, and took them into consideration.

l) It cannot be determined with certainty why the relevant power line was not detected in time.

4. SAFETY RECOMMENDATIONS

The Accident Investigation Board Norway (AIBN) makes the following safety recommendations:

Safety recommendation SL No. 2015/04T[28]

The accident with Norsk Luftambulanse AS (Norwegian Air Ambulance) on 14 January 2014 occurred when the helicopter was in the process of landing at a road emergency lay-by and hit a power line that crossed the natural approach route. Increased use of predefined landing sites, rather than landing at unknown sites in the terrain, could contribute to increased safety. Properly adapted emergency lay-bys and rest areas along the roads can become suitable predefined landing sites. The Accident Investigation Board Norway is of the opinion that emergency lay-bys and picnic areas, insofar as possible, should be designed so they can also serve as safe landing sites for helicopters, and therefore recommends that the Norwegian Public Roads Administration incorporate assessment of obstacles and other relevant factors in the standard that applies for design of such places.

Safety recommendation SL No. 2015/05T

The current national aviation obstacle database (NRL) is incomplete and not easily compatible with GPS-based warning systems. The Accident Investigation Board Norway believes that a campaign to develop the obstacle database could prevent collisions and thus provide safety benefits for air ambulances as well as other aircraft operators. In order for such a campaign to succeed, multiple players from different ministries must contribute. Based on the above, the Accident Investigation Board Norway therefore recommends that the Ministry of Transport and Communications take responsibility for coordinating the work on further developing the current obstacle database with the aim of utilising the safety benefit that can be gained from modern GPS-based warning systems.

Safety recommendation SL No. 2015/06T

Aviation obstacles are a substantial risk factor when landing at unknown sites. The Accident Investigation Board Norway believes it has identified a potential for improvement in Norsk Luftambulanse AS' safety management in this area. This includes elements such as standardisation, suitability and use of obstacle warning on moving maps, as well as the best practice for work sharing between crew members. The Accident Investigation Board Norway recommends that Norsk Luftambulanse AS revitalise its work on identifying and handling risks associated with landing at unknown landing sites.

The Accident Investigation Board Norway

Lillestrøm, 16 June 2015

[28] The Ministry of Transport and Communications ensures that safety recommendations are presented to the aviation authorities and/or other relevant ministries for assessment and follow-up, cf. Section 17 of the Regulations relating to public investigation of air traffic accidents and incidents in civil aviation.

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APPENDICES

Appendix A: Relevant abbreviations

APPENDIX A: RELEVANT ABBREVIATIONS

ADQ	Aeronautical Data Quality
AIBN	The Accident Investigation Board Norway
AMK	Akuttmedisinsk kommunikasjonssentral (Emergency medical services communication centre)
AMK O/A	AMK Oslo and Akershus
ANS	General partnership
BSL	Norwegian Civil Aviation Regulations
CS	Certification Specifications
DH	Decision height
DP	Decision point
EASA	European Aviation Safety Agency
FKB	Joint map database
FM	Frequency modulated
ft	foot (feet) – (0.305 m)
G	Vertical load caused by the acceleration of gravity. 1G corresponds to the gravity acceleration on earth.
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HCM	HEMS Crew Member
HEMS	Helicopter Emergency Medical Services
ICAO	International Civil Aviation Organization
JAR-FCL	Joint Aviation Requirements – Flight Crew Licensing
JAR-OPS	Joint Aviation Requirements – Operations
kt	knot(s) –Nautical Mile(s) (1 852 m) per hour
kV	kilovolts
lb	pound(s) (0.454 kg)
NAT	Northern Airborne Technology LTD

NLA	Norsk Luftambulanse AS
NRL	Nasjonalt register over luftfartshindre (National register of aviation obstacles)
OM	Operating Manual
OPC	Operator Proficiency Check
PC	Proficiency Check
PF	Pilot Flying
PNF	Pilot Not Flying
PPL(H)	Private Pilot Licence Helicopter
SOP	Standard Operations Procedures
TETRA	TErrestrial Trunked RAadio
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency (30 – 300 MHz)