Accident Investigation Board Norway

Issued November 2012

REPORT SL 2012/13

REPORT ON AIR ACCIDENT AT DALAMOT IN ULLENSVANG, HORDALAND COUNTY, NORWAY ON 4 JULY 2011 WITH EUROCOPTER AS 350 B3, LN-OXC, OPERATED BY AIRLIFT AS

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Photos: AIBN and Trond Isaksen/OSL

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AIR ACCIDENT REPORT

Aircraft type:	Eurocopter AS 350 B3 Ecureuil
Nationality and registration:	Norwegian, LN-OXC
Owner:	Blueway AS, P.O. Box 2545 Solli, 0202 Oslo
Operator:	Airlift AS, Førde Airport, 6977 Bygstad
Place of Accident:	Dalamot in Ullensvang Municipality, Hordaland county Position N60° 24.442’ E006° 58.311’
Date and time:	Monday, 4 July 2011 at 1830 hours

All hours stated in this report are local time (UTC + 2 hours) unless otherwise indicated.

NOTIFICATION

On 4 July 2011 at 1950 hours, the operations centre at Hordaland police headquarters notified the Accident Investigation Board Norway (AIBN) that a helicopter with five people on board had crashed and caught fire at Dalamot in Ullensvang.

AIBN travelled to the site with four accident investigators, who started their investigation at the accident site the next afternoon. In accordance with ICAO Annex 13, Aircraft Accident and Incident Investigation, the AIBN notified the authorities in the manufacturing country France about the accident. The French accident investigation authorities, Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA), appointed an accredited representative who has assisted the AIBN in its investigation, together with representatives from the manufacturer. The European Aviation Safety Agency (EASA) was notified and assisted with one advisor during the investigation.

SUMMARY

The helicopter was used to transport people to a cabin site in the mountains. The weather was good with fine flying conditions. The first flight with five passengers had been completed. There were four passengers on board during the second flight. As the helicopter started the descent towards the cabin site, the passengers of the first flight witnessed the helicopter turning tightly to the right. The witnesses have explained that during the turn, control of the helicopter appeared to be lost with an estimated bank angle of 60-90 degrees in a steep descent. At the end, it seemed as if control was about to be regained, but the helicopter hit the ground hard about 500 metres short of the planned landing site and immediately caught fire. All five persons on board were fatally injured. The helicopter was a total loss.

The forward speed at ground impact has been calculated to about 105 kt (194 km/h) based on tracks at the accident site. The helicopter hit the ground with a nearly flat pitch angle and about 45° of bank to the right. The investigation has not revealed any technical defects or irregularities that could have influenced the course of events. The extensive fire damage made parts of the helicopter unavailable for examination, but it was possible to establish that the engine was delivering power to the rotors when the accident happened. It was also possible to verify that key parts of the flight controls were intact prior to ground impact.

The AIBN considers it likely that abrupt manoeuvring initiated a sequence where control of the helicopter was partly lost for a period, and that the height was insufficient for the commander to recover in time.

The AIBN believes that the hydraulic system may have reached its limitation during the manoeuvring, resulting in the phenomenon servo transparency, (also called jack stall) occurring. When this phenomenon occurs in a right turn, it can cause the helicopter to deviate substantially from the intended flight path and simultaneously counter the pilot's efforts to recover. The AIBN believes that warnings about this hazard should be made clearer in the Rotorcraft Flight Manual. This type of helicopter has no warning light or other means to provide warning of imminent servo overload. In addition to high mass, high speed and high torque, high density altitude ('thin air') are among the factors that precipitate overload. This means that servo transparency will occur more easily when flying a heavily loaded helicopter in the mountains on a hot day, as the case was with LN-OXC.

It is not possible to conclude with certainty what flight attitudes and loads the helicopter was subjected to, which airspeed it held and the flight path it followed in the turn preceding the crash. Current regulations do not require use of flight recorders in light aircraft. The Accident Investigation Board believes that the time has come to utilise available, light flight recorders to provide a better data basis for accident investigations and other safety enhancing activities.

As part of its investigation, the AIBN has carried out an anonymous questionnaire survey among pilots and loadmasters in Airlift. The replies mainly indicate that elements assumed to be of importance for a good safety culture were properly addressed in the company. A large majority of the respondents were very happy with the company's safety work in a broad sense. The Civil Aviation Authority in Norway also made a positive statement concerning the air safety work during its latest inspection. However, the survey revealed that hazardous manoeuvring with passengers on board has occurred previously also in this company. The AIBN believes that the same applies for most of the operators in this part of the industry. After the accident Airlift introduced safety measures, including specific manoeuvring limitations at altitudes of less than 500 ft above ground with passengers on board.

The Accident Investigation Board Norway (AIBN) issues three safety recommendations in this report.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The helicopter company Airlift had been contracted to fly people and building materials from Klyvet in Kvamsdalen in Eidfjord to a cabin site in Vasslia in Ullensvang, up in the mountains approximately 13 km east of Kinsarvik (see map in Figure 4). The cabin site is situated about 940 metres above sea level (m.a.s.l.). The first part of the task had been completed two weeks previously. Part two of the task was scheduled for the weekend 2-3 July, but was postponed until the afternoon on 4 July to wait for weather improvement.

1.1.2 The same commander who flew the first part of the task would also be flying the second part. There was fog in the morning of Monday 4 July, and as a result, the flight from Airlift's base in Kinsarvik on this day did not start until 1100 hours. The commander used the waiting time to travel to his commuter home nearby to sleep. His first flight of the day was a short, local flight, before he and the loadmaster took off at approx.1300 hours to fly some underslung load tasks. They returned to base at 1720 hours and refuelled to 90% tank capacity before taking off at approx. 1730 hours, headed for the loading site at Klyvet in Kvamsdalen. They flew over the mountain where their final destination was, and the loadmaster has explained that the weather conditions in the area were good. At 1745 hours, they landed at the loading site at Klyvet, where the persons who were to travel to the cabin site in Vasslia were ready.

1.1.3 The loadmaster disembarked and started readying the sling loads – i.e. the construction materials that were to be transported under the helicopter. Two trips with people and some provisions were scheduled to take place first. The pilot removed the flight controls on the left side and routinely briefed the passengers about the applicable safety rules and emergency procedures. The passenger in the front seat was given a special briefing in handling doors, etc.

1.1.4 The first flight had five passengers on board, which is the maximum. Two crates of provisions were put in the cargo hold, and some light backpacks were put in the cargo basket attached to the left skid. Several of the passengers had been on such flights before. They have explained that the flight went as expected. The landing below the cabin site was into wind, in the north-northwest direction (cf. Figure 6 page 19). The four persons in the seats in the rear of the cabin disembarked there. The passenger in the front seat had business to attend to at Nosi-sætra, a few kilometres southeast in higher terrain, and disembarked there on the way back.

1.1.5 After about 15 minutes, the helicopter returned to the loading site at Klyvet to pick up the last of the passengers and the rest of the provisions; two or three crates and some light bags. The loadmaster placed the cargo in the cargo hold and the external cargo basket, with a locked lid. There was no loose cargo in the cabin, and everyone on board had fastened their seat belts. The commander wore a helmet, while the passengers had headphones and could participate in the communication on board. The loadmaster had understood that a total of ten passengers would be going to the cabin site, and expected that there would be five passengers on the second flight as well. He did therefore not come along, but remained at Klyvet to prepare the sling loads. In reality, there were only four passengers, one in the front and three in the back. The passengers were aged 18-29. Departure from Klyvet was at 1825 hours.

1.1.6 The passenger who was dropped off at Nosi-sætra on the previous flight has explained that he saw the helicopter come from the northeast on the second trip. The helicopter first headed in his direction, but then turned to the right on a more westerly heading and continued on the north side of the Geitelvi river down towards Vasslia. This witness has described how the helicopter moved at a fair speed, and estimates the flight altitude to about 100 metres above the terrain. He could see that the helicopter dropped its nose some and followed the terrain downwards. The helicopter then disappeared from view behind a cliff, probably at the same moment, or just before it passed over the slope where it made its right turn in towards the landing site at the cabin site. After this, the witness neither heard nor saw anything to indicate that something had happened. At this time, he was still wearing ear plugs. He saw some white steam or smoke that he thought was from moist air and water from the waterfall. He has stated that there was no wind and good visibility in the area, and that there were no nearby clouds that could create problems for the flight.

1.1.7 The passengers who had disembarked at the cabin site on the first flight have explained that they heard the helicopter approaching. One of them saw the helicopter with the Gråskallen mountain ridge behind it, while two others have explained that they only saw it when it came over the slope at Geitdalsfossen waterfall. It was travelling at a relatively high speed. All of them have explained that they saw the helicopter make a sharp turn to the right shortly after passing the slope. They saw the belly/underside of the helicopter as it turned, and one of them commented that “now they are showing off”.

1.1.8 The witnesses at the cabin site have described how the right turn continued towards the rising terrain, a little past where it would be natural to roll out the helicopter to fly towards them and the landing site. The helicopter banked considerably and reached a high descent rate. One witness has estimated the bank to 60°, while another remembers seeing the main rotor stand almost vertical (which corresponds to 90°). Forward speed seemed to drop, and the direction of movement seemed to become somewhat askew/sideways. The witness perceived the helicopter to be out of control, and saw that this could not end well. Just before hitting the ground, they saw the helicopter start to level out. One witness has indicated that the banking was reduced to an estimated 45°, and he noticed a pitch up (some uncertainty whether the pitch up was just before or after impacting the ground). For a brief moment, they hoped that it could still end well, but then splinters flew in all directions, and the helicopter was thrown into the air. An explosion-like fire started immediately.

1.1.9 The witnesses were about 550 m north of where the helicopter hit the ground. They immediately started running towards the crash site. The first person on the scene saw a seat with one of the passengers lying outside of the burning wreckage. He pulled the person in the seat to safety away from the flames before he looked to see if anyone else had made it out. There was no one else outside, and it became clear that everyone on board had died in the accident.

1.1.10 As there was no mobile phone coverage in the area, the witnesses agreed that one of them had to run up on Nosifjellet mountain to make a call to notify of the accident. On his way up the mountain, he met the passenger from the first flight coming down from Nosi-sætra, still unaware of the accident. The latter took over responsibility for notifying of the accident and ran up the mountain where he called emergency services at 1916 hours (45 minutes after the accident) and established contact with the emergency medical services communication centre (AMK centre). AMK then notified the Joint Rescue Coordination Centre for Southern Norway (JRCC-S), and the rescue operation was initiated.

1.1.11 The loadmaster expected that the second flight would also take about 15 minutes. After 30 minutes, the helicopter had still not returned. He called the company's traffic centre to enquire if there was any news concerning LN-OXC. At the time, the company had no up-to-date information. Another of the company's helicopters, aircraft registration LN-OPP, was in the area south of Kinsarvik. The crew on board LN-OPP was first asked to call and listen for LN-OXC on the company frequency. They were also asked to listen if there were any signals from the emergency locator transmitter (ELT).

1.1.12 LN-OPP had called LN-OXC repeatedly on several relevant frequencies without any reply when it landed at the base in Kinsarvik and let off the customer at 1930 hours. The pilot and the loadmaster then took off again to look for LN-OXC. They passed fairly high over the cabin site at Vasslia without observing anyone, and then flew east towards the loading site at Klyvet. They established radio contact with LN-OXC's loadmaster, which had nothing to report. They made a U-turn and set course back to Dalamot south of Vasslia. On the way back, they got the message that the Joint Rescue Coordination Centre had called the company and reported that LN-OXC had crashed. They then observed a faint column of smoke visible against the sun.

1.1.13 LN-OPP landed near the burned-out wreckage of LN-OXC at 1942 hours, about 1 hour and 12 minutes after the accident. The first HEMS helicopter arrived 10 minutes later, and a total of three HEMS helicopters arrived at the site as well as one Sea King SAR helicopter, carrying police, fire fighting and medical personnel to the crash site. The loadmaster on LN-

OPP fetched some water in a backpack and contributed to extinguishing the last of the fire. The witnesses were flown out of the area at around 2200 hours.

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Total
Fatal	1	4	5
Serious			
Minor/none			

1.3 Damage to aircraft

The helicopter was destroyed completely on impact with the ground, and the wreckage immediately caught fire. See Item 1.12 for details.

1.4 Other damage

Fire damage to the terrain over an area covering approx. 250 m^2.

1.5 Personnel information

1.5.1 The commander, male, 39 years' old, started his private pilot training for airplanes in Bergen in 2004 and continued with helicopter training in the US. Han received a Norwegian Commercial Pilot licence for helicopters (CPL (H)) in autumn 2008. His Class 1 medical certificate without limitations was valid at the time of the accident. He had a valid type rating on AS350/ B3. His type rating training had been carried out at Airlift's TRTO (Type Rating Training Organisation) in 2009. His last OPC (Operator’s Proficiency Check) was completed on 26 January 2011.

1.5.2 The commander was hired as a loadmaster in Airlift in the summer of 2006. He was promoted to a trainee helicopter pilot in 2009, and hired as a helicopter pilot in 2010. At the time of the accident he was authorised to fly assignments involving ferry flights/public transport/taxi, cargo sling operations and power line inspection.

Table 2: Flying experience commander

Flying hours	All types	Relevant type
Last 24 hours	2:50	2:50
Last 3 days	2:50	2:50
Last 30 days	62:35	62:35
Last 90 days	116:10	116:10
Total	Approximately 860	Approximately 700

1.5.3 The company has documented that the commander had passed the necessary checks and participated in a number of courses and briefings in the period 2009-2011, including emergency training, line check and annual accident/incident review. He had received theoretical and practical training in the servo transparency phenomenon as part of his type rating (see Item 1.18.1 and 1.18.5).

1.5.4 According to colleagues and managerial staff interviewed by the AIBN after the accident, the commander appeared to be a structured, calm and deliberate person. He was in good physical shape. Managerial staff has stated that they did not have any knowledge or information indicating that he performed his duties in a manner that entailed a higher risk than was considered normal. The base chief pilot had only had one case of feedback to the effect that the commander might need some more guidance to optimise his sling operations technique, and was planning to handle this as soon as the vacation period was over.

1.5.5 The pilot had a work schedule that generally entailed 14 days continuous work followed by 14 days off. The plan was flexible, and the schedule could vary more during high season. The accident took place on the first day of a new working period after 13 days off.

1.5.6 The commander had spent the last days of his off-period in a cabin in the mountains. A witness told the Accident Investigation Board that the commander went to bed early and slept well in the cabin the next-to-last night before the accident. On the evening before the accident, he walked down to Kinsarvik. He was down at the base at around 2200 hours, and then drove his own car back to Bergen. He was probably not home before almost 0100 hours. Next morning, he rose at around 0500 hours and drove to the base at Kinsarvik, where he was at work at 0800 hours. However, the weather was foggy, and he went to his commuter home nearby to sleep while waiting for better weather. He was back at the base around 1100 hours. Colleagues have described the commander as happy and content, awake and energetic before the accident.

1.5.7 The commander had brought with him a packed lunch from Bergen. Witnesses have confirmed that he ate both in the morning and about an hour before the accident, when the helicopter was on the base to refuel.

1.6 Aircraft information

1.6.1 <u>General</u>

Eurocopter AS 350 B3 is a light helicopter which normally seats six, two in separate seats in the front in the cockpit, and four in the back on a row of seats in the cabin. The minimum crew is one pilot.

Manufacturer:	Eurocopter France
Type designation:	AS 350 B3 Ecureuil
Serial No.:	4260
Nationality and registration:	Norwegian, LN-OXC
Year of manufacturing:	2007
Airworthiness Review Certificate (ARC):	Valid until 22 June 2012

Accumulated flying hours: Approx. 2 630 hours / 13 300 landings

Flying hours since last inspection: Approx. 39 flying hours since the 100-hour inspection

Engine:	1 Turbomeca Arriel 2B1
Fuel:	Jet A-1, 100% fuel tank capacity corresponding to 540 litres (427 kg)
Empty mass:	1 331 kg

Maximum take-off mass without external load: 2 250 kg

Maximum permitted speed, V_{NE}: 155 KIAS, 3 kt reduction for each 1 000 ft above sea level

As of 1 January 2012, there were 53 individual Eurocopter AS 350 series helicopters registered in the Norwegian aircraft register.

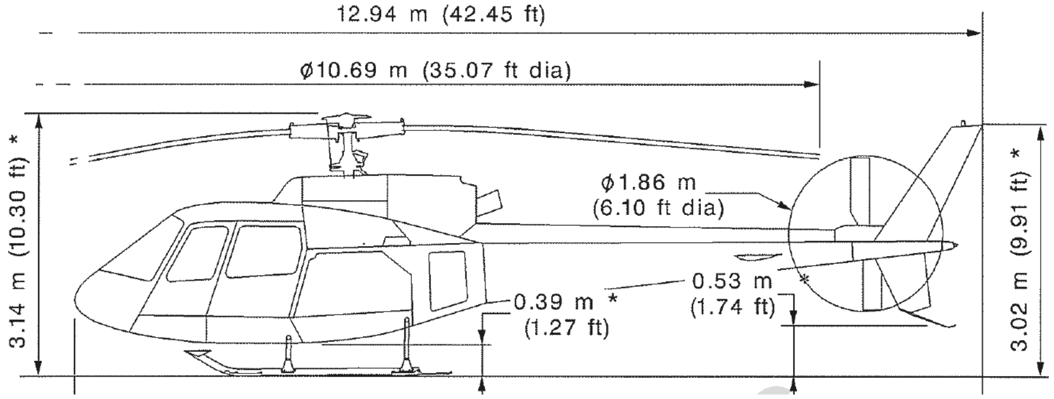

Figure 1: Diagram with dimensions for the helicopter type Eurocopter AS 350.

Figure 2: Eurocopter AS 350 B3. (Illustration photo)

1.6.2 Equipment

1.6.2.1 LN-OXC was not equipped for instrument flying and had no floats fitted to the landing gear. A cargo basket approved by the authorities[1] had been installed on the left skid (cf. Figure 2). The basket can take up to 100 kg of cargo. The maximum speed V_{NE} was reduced to 124 KIAS with the basket installed. The flight manual states that one can expect the cruise speed to be reduced by up to 15 kt, that the climb rate can be reduced by up to 200 ft/minute and that the descent rate during autorotation can increase by up to 100 ft/minute with this cargo basket installed. Airlift has stated that this is the best suited cargo basket type in their experience. Eurocopter was not aware of any cases where this type of cargo basket has created problems of any sort.

[1] *Heli-Utility-Basket Installation, Dart Aerospace, Transport Canada STC SH94-14, EASA STC 10016996*

1.6.2.2 LN-OXC had a bubble window on the right hand side and a large window in the floor. The fuselage had been modified to handle lateral loads, to enable the helicopter to operate a side mounted hook. The helicopter was equipped with double controls, but both witness observations and findings at the accident site confirm that both control sticks and the pedals on the passenger side (left) had been removed and were in the cargo hold during the passenger transport.

1.6.3 Mass and balance

1.6.3.1 The amount of fuel at the time of the accident has been estimated to about 80%, based on the fact that the helicopter refuelled to 90% at the base in Kinsarvik and then flew for approx. 25 minutes.

1.6.3.2 In addition to the passengers, the cargo consisted of two light cardboard boxes containing food in a cargo hold. These crates have been estimated at 20 kg by the loadmaster. In addition, there were two light bags in the cargo basket on the left side of the helicopter, estimated to about 20 kg in total.

1.6.3.3 There is no requirement to carry out a detailed mass and balance calculation before flights such as these. In retrospect, the company has presented mass and balance calculations showing values within the current limitations (dry mass includes the pilot's mass):

Operational mass (dry mass)	1 426 kg
4 passengers (85 kg each)	340 kg[2]
Fuel (80%)	342 kg
Cargo	40 kg
Total mass	2 148 kg[3]

1.6.3.4 The centre of gravity was, according to the calculations, at 3.24 m, which is within the approved range (permitted values are between 3.19 and 3.45 m).

1.6.4 Fuel

The fuel tank was destroyed in the crash and the fuel burned in the subsequent fire, making it impossible to take a fuel sample at the site. A fuel sample was secured on the evening of the day of the accident from the tank at the base in Kinsarvik where the helicopter refuelled for the last time. This sample has been analysed at SGS' laboratory in Larvik, and it has been established that it was Jet A1 of the correct quality and with contamination levels below the maximum permitted values.

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[2] *In accordance with the applicable provisions, either actual weighed mass or standard mass must be used for people and baggage. For male and female passengers, the applicable standard mass for helicopters with 1- 5 passengers seats is 98 kg and 80 kg, respectively, plus 6 kg hand baggage if relevant (cf. BSL JAR-OPS 3.620).*

[3] *Maximum mass is 2 250 kg*

1.6.5 Maintenance

Table 3: Last inspection on LN-OXC[4]

Type of inspection (interval)	Date	Total time
100-hour inspection	20 June 2011	2 591 hours
150-hour inspection	2 June 2011	2 535 hours
300-hour inspection	25 March 2011	2 385 hours

1.6.5.1 An aircraft maintenance technician carried out the daily pre-flight inspection at the base in Kinsarvik before the flight started for the day. The documentation of this inspection was lost in the accident, but the AIBN has been informed that the inspection was carried out without remarks.

1.6.5.2 Maintenance was performed on the tail rotor controls on the day of the accident *(Yaw potmeter need adjustment. 80% max R/H pedal. Adjust to 90 % iaw AMM)*. This work was performed due to comments from pilots stating that the "machine seemed a bit sluggish". A track and balance check of the main rotor was carried out on 1 July 2011, and the tail rotor was balanced on 30 June. Both these procedures were carried out following comments from pilots stating that the helicopter "ran a bit rough". None of the comments from the pilot have been entered in the helicopter Technical/Journey log (tech log), but both maintenance tasks were documented with work cards and entered in the tech log.

1.6.6 Flight controls and associated hydraulic system

1.6.6.1 The helicopter type is equipped with conventional flight controls, which means that the cyclic and collective sticks are connected to the main rotor via rods and a swash plate. The pedals are connected with the tail rotor in a similar fashion. The sticks and the pedals must overcome aerodynamic forces that impact the rotor blades. The helicopter has been equipped with a hydraulic system and servos to make the flight controls easier to operate. The servos receive signals from the flight controls via the rods and transfer the movement to the rotor blades, controlling the blade angles.

1.6.6.2 The helicopter is equipped with three servos for the main rotor and one servo for the tail rotor. The three servos that control the blade angle of the main rotor are installed between the main rotor gearbox and the swash plate (see Figure 3). The servo on the forward left controls the pitch and the servo on the forward right controls the roll along with the servo on the rear left. All three servos together control changes in collective pitch. The three servos connected to the main rotor are in principle identical and are described in further detail in Appendix C. LN-OXC was equipped with SAMM servos. The following part numbers (P/N) were installed:

- SC5084-1 main rotor
- SC5083-1 (2 pcs.) main rotor
- SC5072 tail rotor

[4] *Airlift had approval to use extended intervals between certain inspections.*

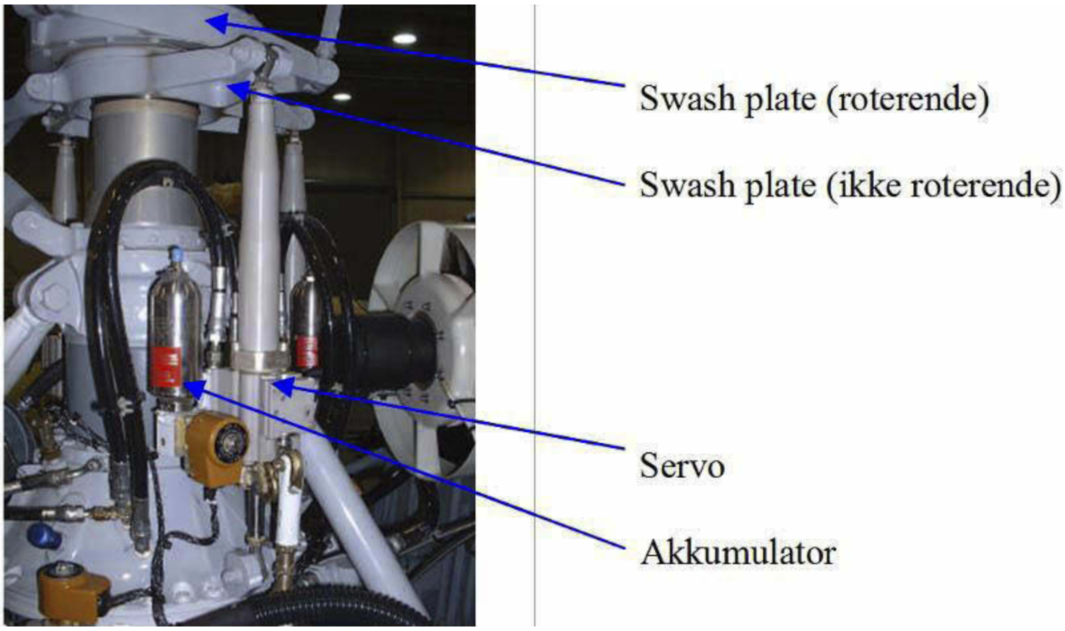

Figure 3: The rotor mast with hydraulic servos, accumulator and swash plate. (Illustration photo)

1.6.6.3 A hydraulic pump supplies a system pressure of 600 psi (40 bar) to the servos. In the unlikely event that hydraulic pressure is lost completely, the flight controls become heavy to operate. Each servo is therefore equipped with an accumulator that can maintain pressure for up to 30 seconds if system pressure is lost. This should provide sufficient time to land from hover or establish the recommended speed for further flight. Training in flight without hydraulic pressure is mandatory for all AS 350 pilots. If the system pressure falls below a given value, a red HYD light will be lit and a warning sound activated in the cockpit.

1.6.6.4 To avoid overloading the main rotor system, the maximum force of the servos is set to 185 daN. If this value is exceeded, the hydraulic system reaches its limitation, and the remaining required force has to be supplied by the pilot via the flight controls. This can be felt by an apparent stiffening of the controls, which become gradually heavier to operate. The phenomenon which then arises is called servo transparency, described in further detail in Chapter 1.18.1.

1.6.6.5 Eurocopter has developed a Technical Improvement Proposal TIP-350-29-10-01, where the original hydraulic system in the helicopter type Eurocopter AS 350 is replaced by a duplicated hydraulic system. This duplicated system equals the system installed on the twin-engine version, Eurocopter AS 355. The modification increases the helicopters load capacity by 100 kg. The modification is comprehensive, time-consuming and costly (estimated at about EUR 380 000). It was introduced to meet a need of operators who would use the helicopter type for instrument flying.

1.6.6.6 The duplicated hydraulic system has double servos in the sense that the system pressure is supplied from two hydraulic pumps. If hydraulic pressure in one system is lost, the helicopter's servos can continue to function with pressure from the remaining hydraulic system. Simply stated, the servo has two hydraulic pistons installed on a common piston rod. Each of these pistons must separately be able to overcome the aerodynamic forces imposed on the main rotor blades. When both the systems work together, the servos can, however, transmit more force than the main rotor can tolerate. To reduce the risk of such overloads, the servos have been equipped with an integrated load sensor. When the load reaches a set limit, a LIMIT warning light is activated on the instrument panel.

1.7 Meteorological information

1.7.1 Witness statements

1.7.1.1 Witnesses have stated that the temperature at the time of the accident was about 18 °C, with only light winds from the north/northwest. They especially noted that wind was almost calm, as the mosquitos were bothersome. There were hardly any clouds as far as they could see, and no noticeable turbulence on the first flight from Klyvet to the cabin site.

1.7.1.2 The commander of the company's other helicopter in the area, who was the first to land at the accident site, has described that the visibility and light conditions were as good as they could be. There was no turbulence or downdraft in the area. He described the wind during the landing as merely a light breath of wind from the north.

1.7.1.3 A privately operated weather station in Kinsarvik (107 m.a.s.l.) recorded 23 °C in the period in question.

1.7.2 Report from the Norwegian Meteorological Institute

1.7.2.1 The weather forecast service for western Norway, the Norwegian Meteorological Institute, has prepared a report on the weather situation in the area Dalamot/Indre Eidfjord on the day of the accident. It concludes that the weather and wind conditions in the afternoon and evening of 4 July 2011 were calm in the area in question. Their model calculations and registered observations indicate wind speeds of less than 10 knots at the relevant altitudes. Any wind in the area was generated by the topography and other local effects, such as from solar radiation. There were few or no clouds in the relevant area, and no precipitation was registered.

1.7.2.2 Observations show that the maximum temperature in the area in general was reached between 1500 and 1800 hours local time. At lower altitudes, the temperature reached 21-24 °C, while it was around 17-19 °C in the Dalamot area at the time in question. At 500 ft above ground, the temperature would be about 1.5 °C lower. The mean relative humidity was about 70-80% at the time in question. The air pressure at the weather stations in Fet in Eidfjord, 765 msl, was 930 hPa. Reduced to sea level, this equals a QNH of 1012 hPa. At 1820 hours, the QNH at Bergen Airport Flesland was 1015 hPa. The density altitude at about 3,150 ft at the accident site was 4,130 ft, or 4,500 ft if humidity is taken into consideration.

1.8 Aids to navigation

LN-OXC was equipped with a satellite receiver of the type GARMIN GPSMap 246, installed in a bracket on top of the instrument panel. It was set to log position and altitude automatically with the track log "resolution" set to 82 ft, time 00:00:30 and distance 0.05 NM. The receiver was not connected to an external antenna.

1.9 Communications

Nothing out of the ordinary has been reported. The flight took place outside of controlled airspace (Class G airspace), and therefore did not need to establish radio contact with any air traffic service unit. Communication during the flight took place on VHF radio on the company frequency 123.5 MHz, and on a bracket-mounted mobile phone.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

Neither flight data recorder nor cockpit voice recorder were required for aircraft with this take-off mass, nor were they installed in LN-OXC. The stored track log in the GPS receiver installed in the helicopter was successfully downloaded (cf. 1.16).

1.12 Wreckage and impact information

1.12.1 The accident site is on the bottom of a broad mountain valley running roughly north-south (cf. Figure 4). The valley floor terrain is slightly undulating with sparse vegetation, mainly heather, scrub and grass, with some low birch trees. The floor of the valley is generally wet with small creeks, water puddles and stretches of bog, but the helicopter hit the ground and came to a rest on a relatively dry outcropping that was about 2-4 metres higher than the surrounding stretches of bog (cf. Figure 5). The height above sea level is about 950 metres.

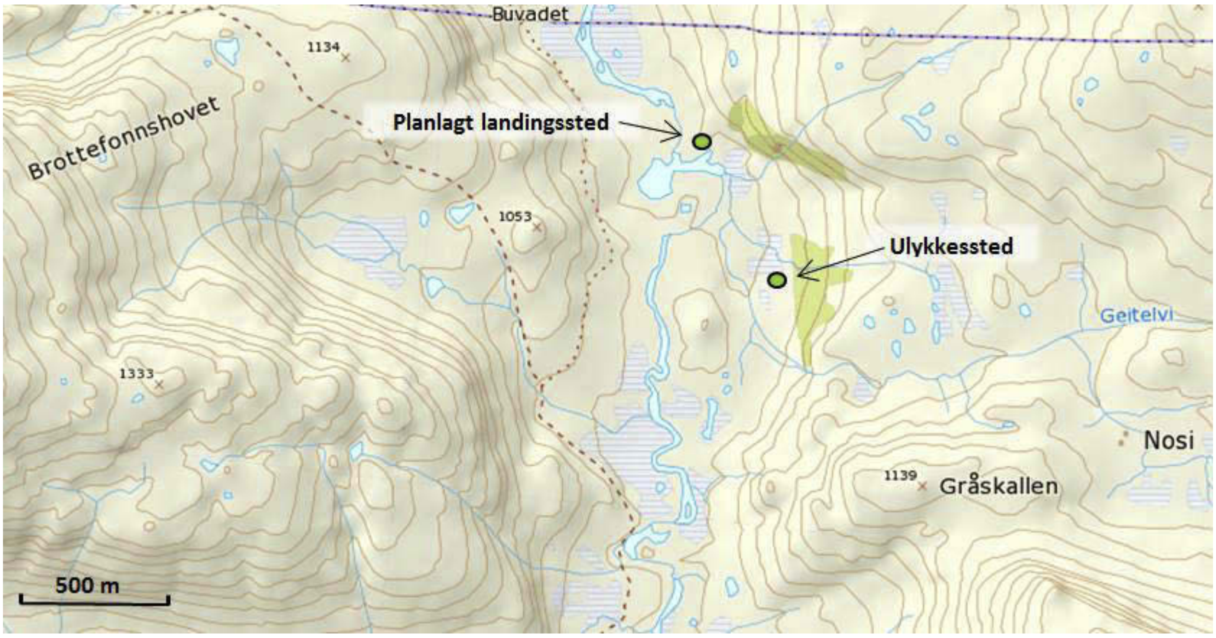

Figure 4: Map section of the Vasslia area. Planned landing site and accident site indicated. (Map information: Statens kartverk, Geovekst og kommuner)

Figure 5: The accident site seen from the east. The helicopter moved from the left to the right in the picture and hit the ground to the far left of the burned area. Cf. also site mapping in Appendix B.

1.12.2 The distance from the south end of the crash site, where there was a visible hollow where the helicopter fuselage first hit the ground, to where the main wreckage came to rest, was about 25 metres. The compass heading for the first part of the trail was 005°. Vegetation in an area up to 15 metres wide that ran from the point of impact to the helicopter had burned. Wreckage was also scattered outside of the burned area, cf. Appendix B.

1.12.3 The main section of the wreckage came to a rest with the nose pointing about 90 degrees to the left of the direction the wreckage had travelled. The main wreckage included parts of the instrument panel, the cockpit floor, the landing gear, main gearbox, mast, rotor head with all three rotor blades and the engine. All these parts were significantly damaged by fire. The aft part of the tail boom with the tail rotor was less damaged by fire. The main section of the wreckage with its components was located as one would expect in relation to each other.

1.12.4 One part of the right skid, just behind the attachment for the forward X tube, was driven into the ground leaning forward at the point of impact. Seen from the rear, it was leaning markedly to the right. The rest of the right skid and the right section of the rear X tube, right cargo hold hatch and right rear cabin door were located in this same area. There were also other parts of the fuselage in and around the point of impact, as well as a piece of the fuel tank.

1.12.5 There were some faint scratch marks on top of a one-metre high rock that was about 4.5 metres behind and about 0.5 metres to the right of the rear end of the right skid.

1.12.6 The wreckage trail from the impact hollow included the right cockpit door, the forward part of the tail rotor shaft, the central post between the front cockpit windows and the instrument roof panel. On the left side of the trail, within 5 metres of the main section of the wreckage, were the left cabin door and a panel from the forward part of the belly. The left cockpit door was located about 10 metres forward and to the right of the main section of the wreckage. The external cargo basket was found to the left of the main trail, before the main section of the wreckage. A backpack that had been in the basket was lying nearby, soaked in fuel.

1.12.7 The helicopter's GPS was found almost undamaged about 7 metres to the left of the main section of the wreckage, and the bracket-mounted mobile phone was found 10 metres to the right, not far from the right cockpit door.

1.12.8 There were clear ground impact marks from the main rotor blades about 4 metres to the right of the right skid. At least 7 tracks were counted, each 1-2 metres long. This row of tracks was 17 metres in total and started about 6 metres ahead of where the rear end of the right skid was stuck in the ground. The distance between the first and second rotor impact was about 2.9 metres, and the distance between the second and third impact was measured to about 2.8 metres.

1.12.9 Tracks in the terrain and damage to the helicopter wreckage indicate that the bank angle on impact was about 45 degrees to the right.

1.13 Medical and pathological information

1.13.1 The commander was autopsied. No sign of illness or traces of intoxicants or anaesthetics were found that could have influenced his ability to perform his duties.

1.13.2 The commander was issued with a medical certificate as a private pilot in 2004. In that connection, he submitted a mandatory declaration concerning epilepsy, where someone who had known the commander for several years attested that he had not suffered from epileptic fits, consciousness problems, loss of consciousness or seizures, or sudden bouts of dizziness.

1.13.3 In 2005, the commander underwent routine specialist examination at the Norwegian Aero-Medical Centre[5] (Flymedisinsk institutt - FMI) in connection with his first application for a Class 1 medical certificate (Commercial Pilot licence).

1.13.4 No new medical information was presented in the application form, and the clinical examination at FMI did not produce any untoward results. The Civil Aviation Authority, the aviation medicine department issued a medical certificate without limitations to the commander. This certificate was later renewed as per the regulations by an aviation physician, most recently in December 2010.

1.13.5 In connection with the investigation of this accident, the Civil Aviation Authority stated that a test result existed following a routine EEG examination of the commander in 2005, administered by a medical specialist. The conclusion from the EEG was as follows:

> *"Pathological EEG with paroxysmally characterised generalised irregular Theta activity. Consistent epileptic potentials were not observed. Recommend sleep-deprived EEG."*

1.13.6 The recommendation for further examination was not followed up by the Civil Aviation Authority. At the time, common European provisions concerning medical requirements for flight crew (JAR-FCL 3, Flight Crew Licensing) contained a requirement for routine EEG examination prior to issuing a Commercial Pilot licence. The requirement was amended in 2008 to make EEG required only if the applicant's medical history or clinical results so warrant (JAR-FCL 3.210 Neurological requirements (c) Amdt. 5).

1.13.7 The Civil Aviation Authority's aviation medicine department has stated to the Accident Investigation Board that it does not have direct knowledge of the underlying discussion that caused the removal of the requirement for routine EEG examination at the initial examination

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[5] *FMI is the national aviation medicine centre in Norway, and is a department of the Norwegian Armed Forces' Medical Corps. The institute covers all aspects of aviation medicine, including aviation-related medical examinations for civil aviation crew members.*

of commercial pilots, but that it knows that the evaluation of the same EEG with different neurologists can result in different conclusions – anything from normal to abnormal. When asked by the AIBN how many (number and/or percentage) healthy pilots had seemingly abnormal results from this same test, the chief physician replied that they had not researched this and were therefore unable to answer.

1.13.8 Following the accident, the aviation medicine department had concluded the following in their assessments of the commander's health:

> *"Overall, there are no certain indications of known health issues that could have contributed to acute incapacitation during flight. The EEG finding is left isolated without any clinical information about seizure problems."*

1.13.9 The Accident Investigation Board presented the findings and information about sleep patterns and other circumstances to experts at the Oslo University Hospital, department of complex epilepsy. The following quote is from their assessment:

> *"The discovery is non-specific, and it is hard to reach certain conclusions as regards the clinical importance of the finding without further examination. We cannot completely disregard a weak disposition to epilepsy, but if he had latent epilepsy, we would be speaking of a generalised form of epilepsy. In that case, it would be strange if he had no epileptic manifestations during his teens. That he was exposed to some form of flicker stimulation in the cockpit that we know can trigger epileptic seizures, especially in patients with generalised forms of epilepsy, can of course not be ruled out.*
>
> *However, this is speculation, and I would, on the basis of the data available in the case, consider it unlikely (less than 5% probability) that the helicopter crash was caused by [the commander] having an epileptic seizure."*

1.14 Fire

According to the witnesses, an explosive fire started when the helicopter collided with the ground, i.e. before it came to a rest 25 metres away. There was a pronounced fire trail from the impact zone to the helicopter wreckage. A brush fire spread a few metres each side of the trail and around the wreckage, before burning out. All fuel and combustible material, including large parts of the helicopter, burned. The temperature was high enough to melt the aluminium (above 600 °C). The available information indicates that the fire lasted for more than 1 ½ hours.

1.15 Survival aspects

1.15.1 One of the passengers was found fatally injured outside, in front of the wreckage, strapped into a seat that had been torn out of the attachments in the floor. The four others on board were found in the burned-out helicopter wreckage. The autopsy reports show that everyone on board suffered fatal injuries from the collision forces of the impact.

1.15.2 No transmissions were received from the ELT[6]. It was located in the main wreckage and was destroyed in the post-crash fire. The installation was in compliance with regulations.

[6] *ELT of the SERP Kannad 406 AF-H type with ID, transmitter at 406 and 121.5 MHz*

1.15.3 The Joint Rescue Coordination Centre for Southern Norway (JRCC-S) was notified of the accident at 1916 hours. JRCC-S was in charge of the operation. Sea King SAR helicopters from both Florø and Sola were initially dispatched to the accident site. One of the rescue helicopters was, however, recalled before arriving, as JRCC-S, on the basis of the available information, considered that two large helicopters were not required. While the rescue helicopter was assigned to flying necessary staff from Kinsarvik and up to the accident site, JRCC-S directed the state air ambulance helicopter from Bergen to the location to assist.

1.15.4 In addition, the health service/AMK centres sent HEMS helicopters from Ål, Førde and Stavanger to the accident site. One of these helicopters was recalled, so that there were at one time three air ambulances on location, in addition to one Sea King and Airlift's LN-OPP helicopter. JRCC-S has in retrospect been critical of deficiencies in the health services' coordination of own resources, and deficient communication. The following is quoted from JRCC-S' evaluation:

> *"What JRCC on several occasions has seen to be deficient coordination and use of resources could also pose a threat to flight safety"*

1.15.5 The Accident Investigation Board has not received reports from involved aircraft commanders concerning any serious aircraft incidents/airprox incidents in connection with the rescue operation.

1.16 Tests and research

1.16.1.1 The GPS in LN-OXC used an internal antenna and was installed near the windscreen. According to Airlift, this provided good reception in their experience. The accuracy of the position reading varies continuously, depending on the number of available satellites, their angle relative to the GPS receiver and any reception shadows cast by the terrain. Officially, the horizontal margin of error is less than 15 m for 95% of the time. Under normal conditions, the accuracy is 3 - 5 m. Favourable conditions are achieved when there is a clear line of sight to four or more satellites, and they are well spread out. The vertical position inaccuracy is 50% higher (normally 4.5 - 7.5 m).

1.16.1.2 The track log showed logged positions along the registered flown route to the accident site (cf. Figure 6). Only three points were recorded during the last 10 seconds of the flight. The altitude where the GPS ended up was about 3 120 ft, while the last recording made by the receiver in approximately the same location showed 3 591 ft (cf. Figure 7). The precise time of the impact is not known. The GPS receiver was off when found after the crash.

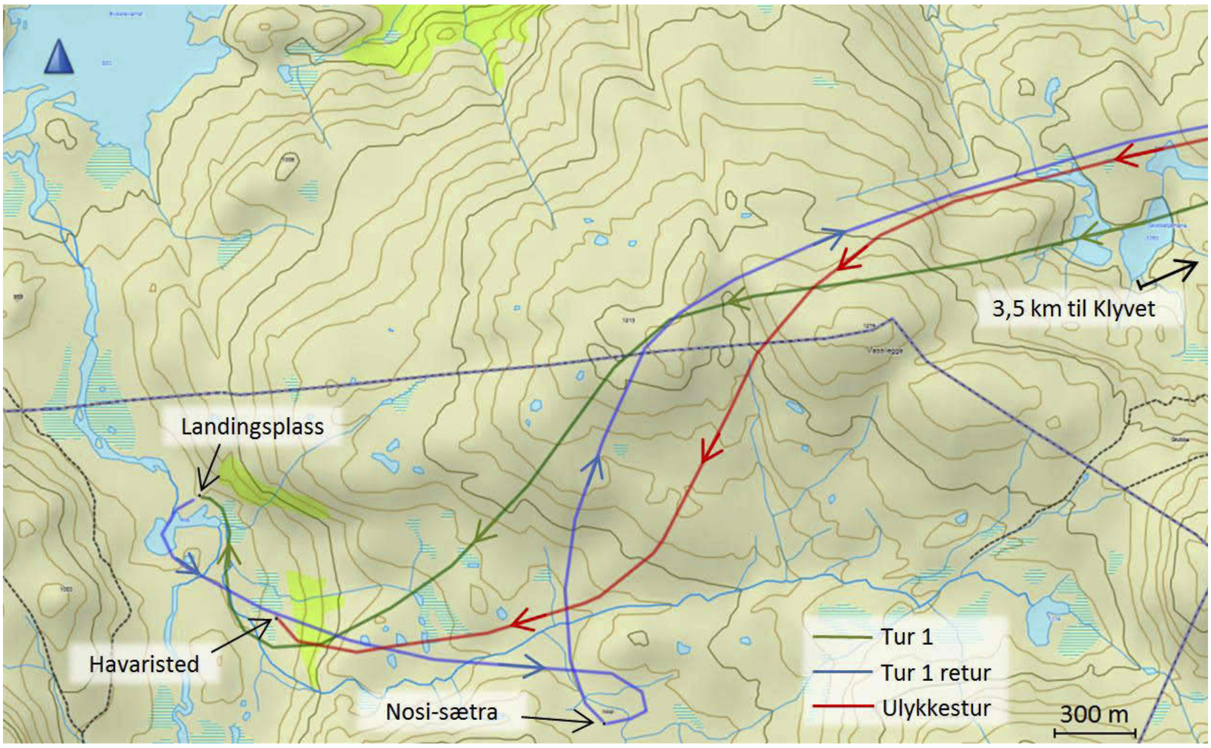

Figure 6: Map section showing lines between the registered GPS positions from the first flight from Klyvet to the cabin site, the return flight via Nosi-sætra and the accident flight. There is some uncertainty with regard to the final points from the accident flight. Cf. also Figure 8. (Map information: Startens kartverk)

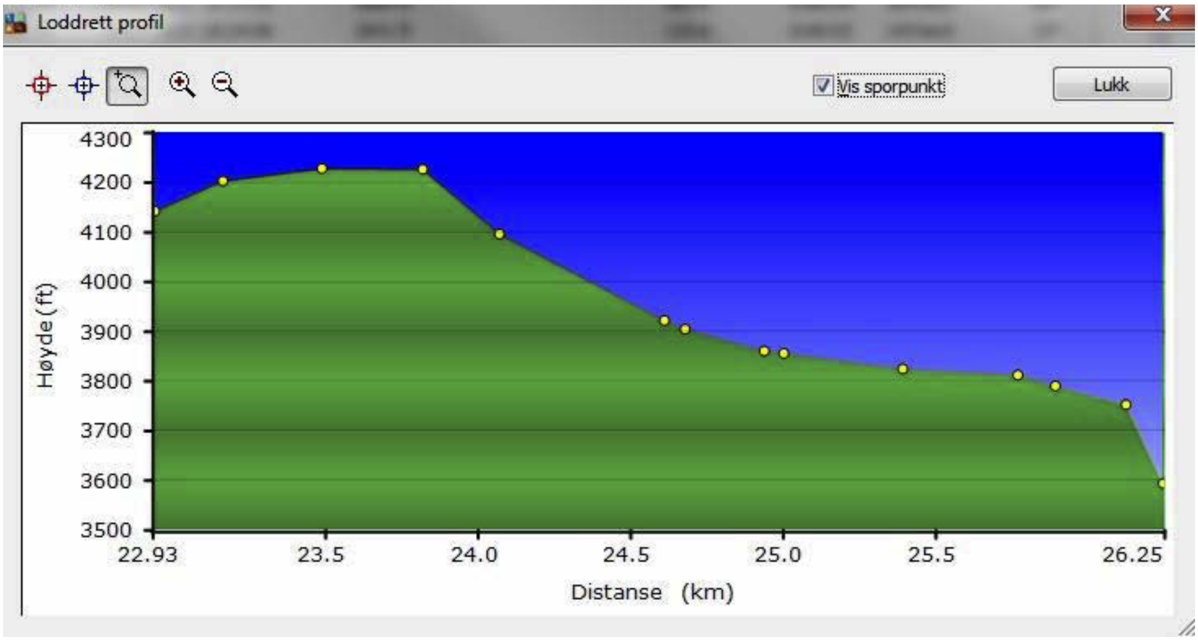

Figure 7: Vertical profile recorded in the GPS receiver on board LN-OXC (Garmin Base Camp). Note that the position of the final point is very near the crash site, but 470 ft. above ground level.

1.16.1.3 The track log was sent to both Garmin Norway and BEA for analysis. Garmin reacted to the unusually large error in the last altitude recording, 471 ft (143 metres) in total, but could not provide any good explanation of why, or help establish why the error may have arisen.

1.16.1.4 The BEA experts believe that the last point was probably predicted, and that it should be completely disregarded when making calculations. They evaluated the accuracy of the rest of the recorded positions by correlating against known positions where the helicopter had landed previously (the loading site at Klyvet, the cabin site and Nosi-sætra). There were sources of error, including the map material used, but BEA concluded that the positional error was about 15 metres both laterally and vertically. This introduces sources of error for ground speed and vertical speed calculations, especially if the readings are based on just a few points from the GPS receiver.

1.16.1.5 Based on the GPS, the average speed between the last two points which BEA considered reliable was 113 kt, while it was 121 kt in the preceding seconds. Average ground speed over the last 36 seconds was about 125 kt, reducing somewhat just before the impact.

1.16.1.6 The obvious altitude deviation caused uncertainty with regard to the quality of the final registrations. Eye witnesses are insistent that the helicopter flew further south than indicated by the final GPS points prior to the impact, cf. Figure 8.

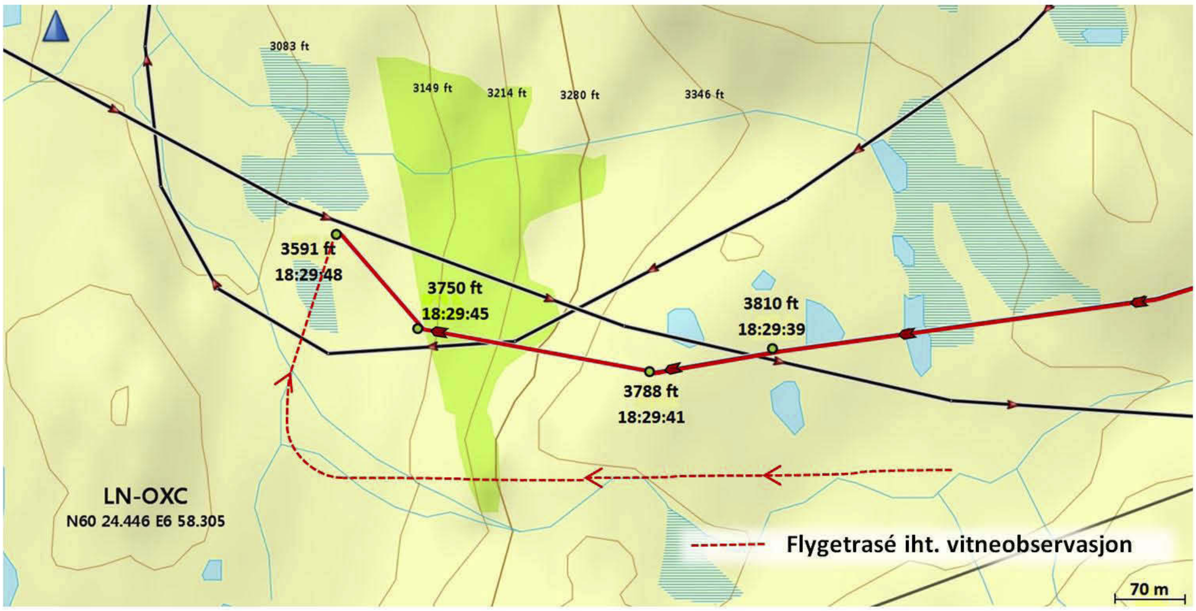

Figure 8: Part of the track log of LN-OXC superimposed on a topographical map. The accident flight is marked in solid red, with altitude and time indicated for the last four positions. The final position is directly above the accident site, but there is uncertainty with respect to some of the points. The dotted red line is the route according to the eye witnesses.

1.16.2 <u>Flight path calculation</u>

1.16.2.1 An expert from the manufacturer Eurocopter undertook various calculations based on the registered parameters in the GPS from the accident flight. Torque values could be determined at some points on basis of the vertical speed. In the shallow descend at the beginning of the turn, the torque was estimated at 50-60% with speed at 120-130 kt.

1.16.2.2 Calculations made by Eurocopter revealed that the last point in the GPS could not merely be substituted by the speed and elevation calculated from the observations at the accident site. Height loss at the end would have been so formidable that the flight path could not be explained with parameters for normal flight. To reach the point of impact at the anticipated speed, g-load, flight attitude and direction, the turn radius and rate of descent would have had to be larger than the GPS log indicated. Based on iterative calculations, the Eurocopter expert concluded that it was more likely that the helicopter had followed a route somewhat further south and west than indicated by the final GPS positions, i.e. a slightly longer flight path. His calculations indicated that servo transparency was not encountered during the turn, but the phenomenon could have occurred and resulted in feedback forces the very last seconds before impact.

1.16.3 Technical investigation

1.16.3.1 Both the helicopter's digital engine control unit (DECU) and the LCD screen Vehicle and Engine Multifunction Display (VEMD) have memory functions which can later show whether some failures have occurred during flight, or if certain limitations have been exceeded. Both units were sent for examination by specialists with the French accident investigation authority BEA. They concluded that the components had been exposed to high temperatures and that all stored information had been lost (more than 600 °C).

1.16.3.2 The helicopter wreckage was transported to AIBN's premises at Lillestrøm for closer examination. All wreckage components were examined and a simplified reconstruction prepared (cf. Figure 9). In general, the remaining wreckage components were those made of steel, plus parts thrown off because of the impact and therefore not burned. There were also some flight control linkages, i.e. controls in the forward part of the cockpit, which were in such a condition that an examination could be carried out. Engine controls and other aluminium alloy components melted in the fire and were only to a limited extent available for examination.

Figure 9: Simplified reconstruction of the wreckage in the Accident Investigation Board's hangar.

1.16.3.3 A team consisting of experts from the helicopter manufacturer Eurocopter, the engine manufacturer Turbomeca and the French accident investigation authority BEA assisted the AIBN in thorough examinations of the wreckage. All signs of mechanical failure in the parts of the flight controls that could be examined were consistent with impact damage and the subsequent fire. No damage was found in the engine, drive gear or tail rotor that could have occurred before the accident. A selection of examination results and observations are listed below.

1.16.3.4 It was established that the engine was running, supplying power to the rotors, when the helicopter hit the ground. The examinations showed that the damage had been caused by a sudden stop of the main rotor system, collision forces and fire. For example, the drive gear securing nut was found to have rotated approx. 4 mm. This movement indicates, according to the BEA, an overtorque corresponding to three times the normal load, which is a clear sign that the engine was delivering power when the main rotor blades hit the ground.

1.16.3.5 The conclusion following the engine examination was:

> *"The examination of the engine established that the deteriorations observed were the result of the sudden stoppage of the main rotor system, the impact and the fire.*
>
> *Based on the physical evidences that indicate that engine was rotating at the time of impact, all parties of the investigation agreed that the engine was delivering power at the moment of the accident.*
>
> *On the module 5, it was noticed that the drive gear securing nut had a rotational displacement of approximately 4 mm which put in evidence an overtorque at the time of impact."*

1.16.3.6 Extensive damage to the main gearbox and main rotor system indicated high torque when the helicopter collided with the ground. The position of each of the three servo control actuators could be determined, and these corresponded to a control position that would give a significant bank to the right. Similar to the passenger seat in front, the cyclic stick had been bent forcefully to the right, consistent with the forces that arise during impact with a right bank.

1.16.3.7 The damage to the tail section indicated that the rear end of the helicopter was exposed to upward forces. Laterally, the relative impact angle to the ground was about 45° to the right.

1.16.3.8 The nose was probably almost horizontal, facing slightly rising terrain. The remains of the right undercarriage skid show that it was exposed to a considerable upwards force and a moderate sideways force. The cabin floor had been bent upwards in front of the forward seats. The damage on the energy-attenuating structure on the passenger seat that did not burn, indicated that the vertical acceleration ('g'-load) was probably in excess of 15 G, while the sideways force was probably less than 13 G.

1.16.3.9 As shown in Figure 10, the turbine blades on the power turbine[7] detached and penetrated the surrounding containment shield.

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[7] *Each turbine blade has a calibrated weak point designed to break during overspeed. This is to prevent disintegration of the whole turbine disc (blade shedding).*

Figure 10: The penetrated containment shield.

1.17 Organisational and management information

1.17.1 Airlift AS

1.17.1.1 The helicopter company Airlift was established in 1986. The main base is at Førde Airport Bringeland (ENBL). The Company has a license to perform commercial air transport activities with an Air Operators Certificate (AOC) based on BSL JAR-OPS 3. The approvals include transport of passengers and cargo/freight in helicopters. Furthermore, the company has a permit for aerial work activities such as A to A flights, aerial application, aerial photography and advertising flights, survey and training flights.

1.17.1.2 At the time of the accident, the company had a total of 18 helicopters, of which 14 were of the Eurocopter AS 350 type. The company conducted onshore operations[8] from Bringeland and the base in Kinsarvik, and search and rescue operations with larger helicopters on Svalbard. The onshore operations included services for both companies and private persons. The company markets itself as the leading helicopter onshore company in the Nordic countries (source: www.Airlift.no).

1.17.1.3 The company had 25 pilots based in Kinsarvik and Bringeland at the time of the accident. The company's flight operations manager worked at the main base. In order to strengthen daily follow-up, a position of chief base pilot had been established. The chief base pilot at Kinsarvik was on long-term sick leave during the winter preceding the accident. Nobody had been appointed to fill his position during the sick leave.

1.17.1.4 Airlift's training department was approved as a FTO (Flight Training Organisation) in February 2011, which means that this part of the organisation was made capable to provide training and education for pilot licences in addition to type privileges for own employees and external customers.

[8] *The term onshore operations is mainly used for flights with single-engine helicopters in connection with aerial work and transport of passengers outside of prepared landing sites.*

1.17.1.5 In addition, Airlift had an approved maintenance scheme in accordance with EASA Part M, as well as an EASA Part 145 workshop approval and approval as a Design Organisation (DOA Part 21J). In the summer of 2011, three of the company's 20 technicians were permanently stationed in Kinsarvik.

1.17.1.6 Airlift has a combined quality, safety and HSE system that is managed by the company's quality manager. The quality manager is also the flight safety and HSE manager, and a member of the management team. Four employee representatives and four management members form a combined working environment committee (AMU) and flight safety forum, which meet four times a year. The committee processes relevant individual incidents and measures in connection with such incidents. Safety related issues and reports are prepared for presentation to the management team.

1.17.1.7 The management team meets regularly, usually every fortnight. “Flight safety issues” is a fixed agenda item. The managing director presents plans and decisions to the board of directors for further processing. The board of directors meets at least four times a year. “Quality, Safety and HSE” is a fixed agenda item. In connection with special incidents, discipline managers and/or the quality manager are summoned to give an account. In addition, the management reviews the quality system annually, in accordance with applicable regulations.

1.17.2 Training, regulations and operational procedures

1.17.2.1 *Commander under Supervision*

Airlift's policy is to train their own pilots through hiring them as loadmasters, rather than hiring experienced pilots. The candidates are usually between the age of 20 and 30. The loadmaster period is commonly 1 - 2 years, followed by a period of 1 - 2 years as a trainee pilot, where transfer of experience and training take place by flying with an experienced pilot in the company. This scheme is called Pilot in Command under Supervision (PICUS). Following the trainee period, the pilot is qualified to fly with passengers as a regular commander and is employed as pilot. Rating as commander on different types of aerial work is phased into the programme. The company's management has stated that they are very content with this arrangement. The pilots and the Civil Aviation Authority have also been positive to this way of training and building experience (cf. 1.17.3 and 1.17.4.2).

1.17.2.2 *Relevant regulations*

Airlift performs both operations that are subject to regulations based on common European guidelines for commercial air transport with helicopter (BSL JAR-OPS 3) and operations that are regulated in national operating provisions (Regulations relating to commercial aviation with helicopter, BSL D 2-2). Cargo sling operations are an example of aerial work regulated by the national regulations. The accident in question occurred during a passenger flight in connection with aerial work. Airlift has stated to the AIBN that they consider such transport to be aerial work. This interpretation means that it is not mandatory to prepare a passenger manifest[9].

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[9] *The N-CAA has pointed out that such air transport with helicopter from A to B where people are not strictly needed for the sling operations, cannot be considered aerial work, but come under the rules for commercial air transport (passenger flights) by helicopter.*

Provisions relating to safe manoeuvring and minimum heights are included in the *Rules of the air (BSL F), visual flight rules* and are the same regardless of which regulations are applied to the operations:

> *"Section 2-6. Negligent or reckless operation of aircraft*
>
> *An aircraft shall not be operated in a negligent or reckless manner so as to endanger life or property or cause inconvenience to others, including unnecessary noise".*
>
> *Section 2-7. Minimum height*
>
> *Except when necessary for take-off or landing, or except by special permission from the Civil Aviation Authority, aircraft shall not be flown over the congested areas of cities, towns or settlements or over an open-air assembly of persons, unless at such a height as will permit, in the event of an emergency arising, a landing to be made without undue hazard to persons or property on the surface.*
>
> *[…]*
>
> *Section 3-5. Minimum height*
>
> *VFR flights shall not be flown at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft over the congested areas of cities, towns or settlements or over an open-air assembly of persons, or elsewhere at a height less than 150 m (500 ft) above the ground or water.*
>
> *The minimum height requirements could be deviated from when necessary for take-off or landing and when flights are conducted by helicopters in accordance with Provisions regarding Commercial Air Transport, or by special permission from the Civil Aviation Authority."*

The Eurocopter AS 350 B3 flight manual has manoeuvring limitations (cf. 1.18.1.6) and states that aerobatic manoeuvres are not permitted. In accordance with the Rules of the air (BSL F) the definition of aerobatic manoeuvres is *"an intentional manoeuvre involving an abrupt change in an aircraft's attitude, an abnormal attitude, or abnormal acceleration."*[10]

1.17.2.3 *Operational procedures*

Airlift has prepared written procedures for special types of operations as required by the applicable provisions. At the time of the accident, there were procedures for 23 different types of aerial work, in addition to search and rescue missions and a selection of other special tasks. These included a description for Sightseeing and Pleasure Flying. This type of passenger transport, taking off and landing at the same location (A to A) is considered the simplest form of assignment. Requirements relating to safety briefings are described for all assignments involving passenger transport. There were no other specific procedures or risk assessments for this type of "mountain flight" with passengers on board.

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[10] *This rather vague definition is in compliance with ICAO's definition, however, some countries have specified what the term aerobatics means. The CAA in New Zealand for instance, uses a more specific definition of aerobatic manoeuvres, and has recently included a definition of «Adventure aviation operation» as well.*

1.17.3 Safety questionnaire survey

1.17.3.1 As part of the investigation of the accident with LN-OXC, the AIBN conducted a relatively comprehensive, anonymous questionnaire survey among Airlift's pilots and loadmasters based at Bringeland and Kinsarvik. The survey consisted of an electronic form with more than 70 questions relating to training, procedures, practice, collaboration, reporting of noncompliance and safety prioritisation. The intention of the AIBN with this was to obtain a basis for assessing if there was a need to investigate any underlying conditions more thoroughly.

1.17.3.2 The response percentage among pilots was 96 and 54 among loadmasters. This provided the AIBN with a good impression of how the pilots in particular assessed the safety culture in their own company. The low response rate from the loadmasters is probably due to holding the survey outside of the high season. Furthermore, many of them had been recently hired and had little experience on which to base their responses. Other sources of error are discussed in the analysis section of this report.

1.17.3.3 The results were not alarming, and the Accident Investigation Board saw no need to follow up with in-depth interviews, etc. Only a minor selection of the survey results is mentioned here. Some diagrams have been included to show how the replies were distributed. The replies from pilots and loadmasters, experienced personnel as well as inexperienced personnel, based at both Bringeland and Kinsarvik, mainly show that they perceived that elements of significance for a good safety culture in the company seemed to be well handled in Airlift (cf. Figure 11-12).

1.17.3.4 There were differences between the bases for some topics. The replies in Figure 12 indicate that those working at the main base at Bringeland agree most with the statement *that managers actively follow up that the work is conducted in a safe manner*. 80% agreed fully or partly with this statement, and only 5% (1 person) slightly disagreed. 61% of the employees at the base at Kinsarvik replied that they agreed fully or partly, while 38% (5 persons) said they disagreed slightly or strongly with this statement.

1.17.3.5 The feedback on the training scheme was very good. There was agreement that the pilots receive sufficient training to perform their tasks safely and everyone believed that the PICUS scheme is useful and contributes to important transfer of experience.

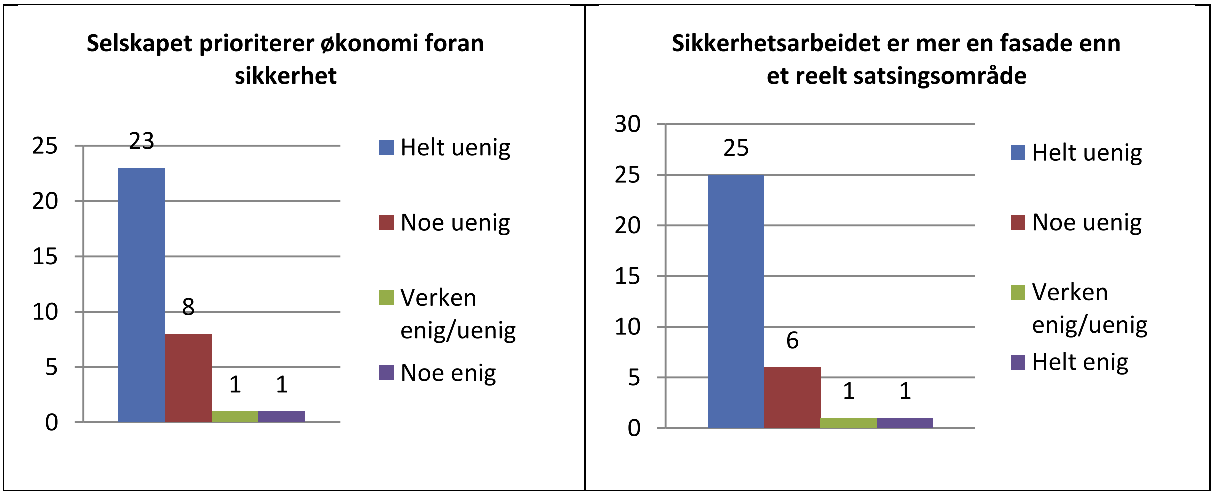


Figure 11: Examples of questions and replies in the category 'Management's prioritisation of safety'.

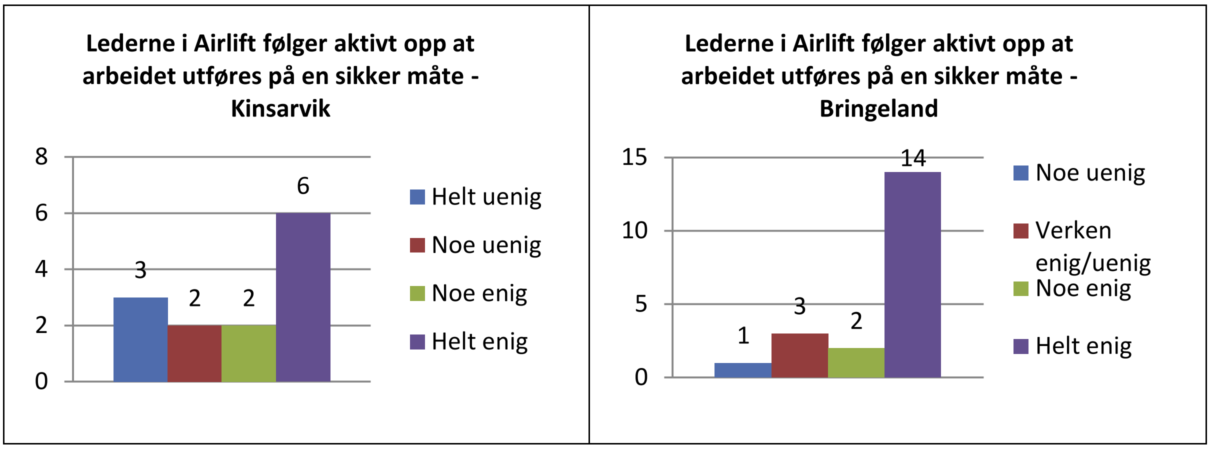
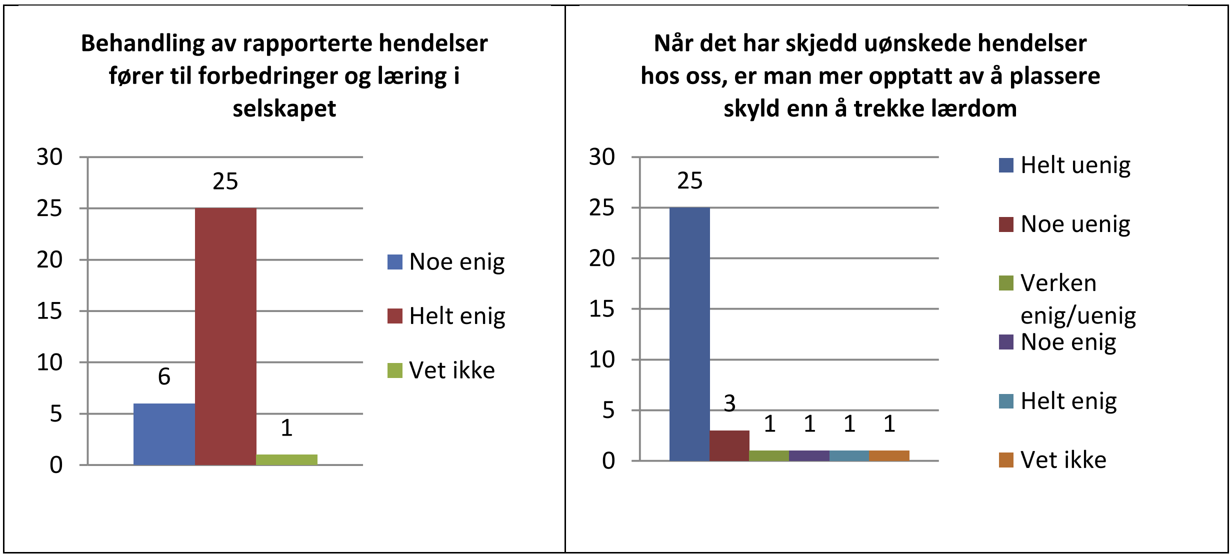


Figure 12: Example in the category 'Management's prioritisation of safety' where the distribution of the results differed between the two bases Kinsarvik and Bringeland.

1.17.3.6 With regard to procedures, the replies also indicated that a large majority were happy with the scope, quality and training. To the extent that procedures were not complied with, this was primarily due to the fact that procedures were not always compatible with the task. Most replied that they never or rarely had participated in tasks for which there were no procedures.

1.17.3.7 The willingness to report, based on the replies to the survey, seemed to be high, and most considered that they received constructive feedback if they raised safety-related issues. Most also believed that the processing of reported incidents resulted in improvements and learning in the company. The large majority replied that they felt certain that the management would support them if they prioritised safety and cancelled a mission, and that they never or rarely felt pressured to work if they believed that safety might be compromised. However, three respondents replied that they sometimes felt such pressure (cf. Figure 13).



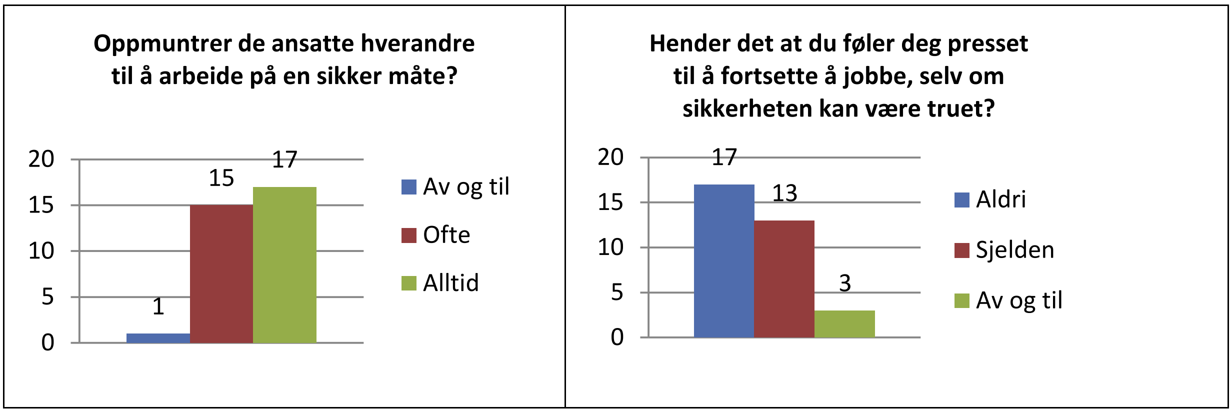


Figure 13: A range of questions and replies in the categories reporting, learning, change and coordination.

1.17.3.8 The survey also contained questions aimed at illuminating the inclination for aggressive manoeuvring or other risk behaviour. For example, the respondents were asked to state how often/rarely the following has occurred:

- *I have been involved in flying below the minimum height specified in BSL F (500'/1000') with passengers on board*
- *I have been involved in flying below the minimum height specified in BSL F (500'/1000') when it was necessary to reach the destination due to weather conditions*
- *I have been involved in flying with more than 60°of bank*
- *I have been involved in flying extra low or manoeuvring aggressively to give the passengers a thrill*

1.17.3.9 There were five graded reply alternatives for each of the statements above. The replies to the two example questions that were specifically related to flying with passengers on board had a distribution as shown in Figure 14.

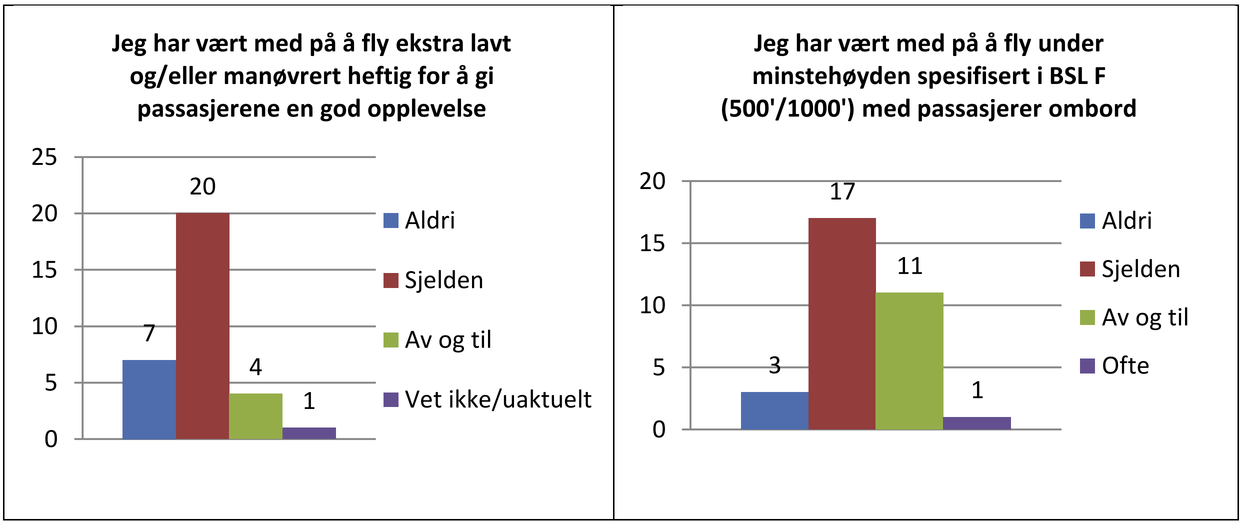


Figure 14: A range of questions and replies in the category 'Work practices/operational conditions.

1.17.3.10 Among the seven that responded that *they had on occasion («Av og til») been* involved in low flying or aggressively manoeuvring to give the passengers a thrill, four were pilots (the others were loadmasters). All of them had an experience exceeding 1000 flying hours. The majority of the pilots (68%) stated that they *rarely* had been involved in such flying, and this also applied to those with a low number of flying hours (less than 500 hours). Only three out of 25 pilots (12%) replied that they had *never* been involved in such manoeuvring. All of them belonged to the group with more than 2000 flying hours, a group which included two-thirds of the pilots that participated in the survey. The study provides no basis to conclude that the hazardous manoeuvring happened during flight in Airlift. It may also have occurred during training or flying for other operators previously.

1.17.3.11 The questionnaire survey gave ample opportunity for free comments if anyone wanted to provide additional information or comment on a reply. Among the comments to questions and replies illustrated above, the following are quoted:

> *«Noncompliance with applicable rules under Item […]: As loadmaster (assistant) some 12-13 years ago. Furthermore early in the pilot career, when you unfortunately did not know any better. The attitudes have improved now. Carrying out jobs in accordance with the applicable rules.»*

> *«Don't have to manoeuvre aggressively or fly low to give the passengers a thrill.»*

> *«With respect to a 60-degree bank, this is not dangerous as such. However, combined with high weight, temp, ALT and speed, this is a recipe for a jack stall.»*

1.17.3.12 One of the questions of the survey was which conditions the respondent believed would most probably contribute to a potential future accident in Airlift's onshore operations. This question gave the opportunity to check three out of a list of 12 alternatives, plus selecting "Other" and specifying this in the free text box. «Judgment error» was top with 21 checks, followed by «weather conditions» (14), «lack of time/busyness» (13) and «fatigue» (11). «The customer's expectations» and «flying at low height» was only checked once each.

1.17.4 <u>The Civil Aviation Authority's safety oversight of Airlift's flight operations</u>

1.17.4.1 Authority inspections are part of the routine safety oversight of operators, and aim to verify that the operator meets applicable regulatory requirements. The Civil Aviation Authority conducted an inspection of the flight operations organisation at Airlift's main base at Bringeland, Førde, on 17 – 18 March 2010. It was then 2 years and 4 months since the previous inspection.

1.17.4.2 The inspection report states that previously issued findings had been closed. Praise was given to the system of training new loadmasters and pilots, and the Civil Aviation Authority writes that it got the impression of an open and welcoming culture with a great willingness to report among the personnel. The company's annual two day technical briefing seminars, covering the flight safety programme, seasonal operational conditions and reported incidents, were praised – however with a request to consider whether two days were sufficient. The inspection resulted in two findings, both in connection with the position "Nominated Post Holder Ground Operations".

1.17.4.3 A flight-operational inspection was conducted at the secondary base at Svalbard in November 2010. No findings were issued.

1.17.5 <u>Accident statistics onshore helicopter operations</u>

1.17.5.1 In its annual report and on its website, the Civil Aviation Authority publishes the flight safety level measured as the number of accidents and the accident rate for different types of operations. As of January 2012, the status for onshore helicopter operations was as shown in Figure 15:[11]

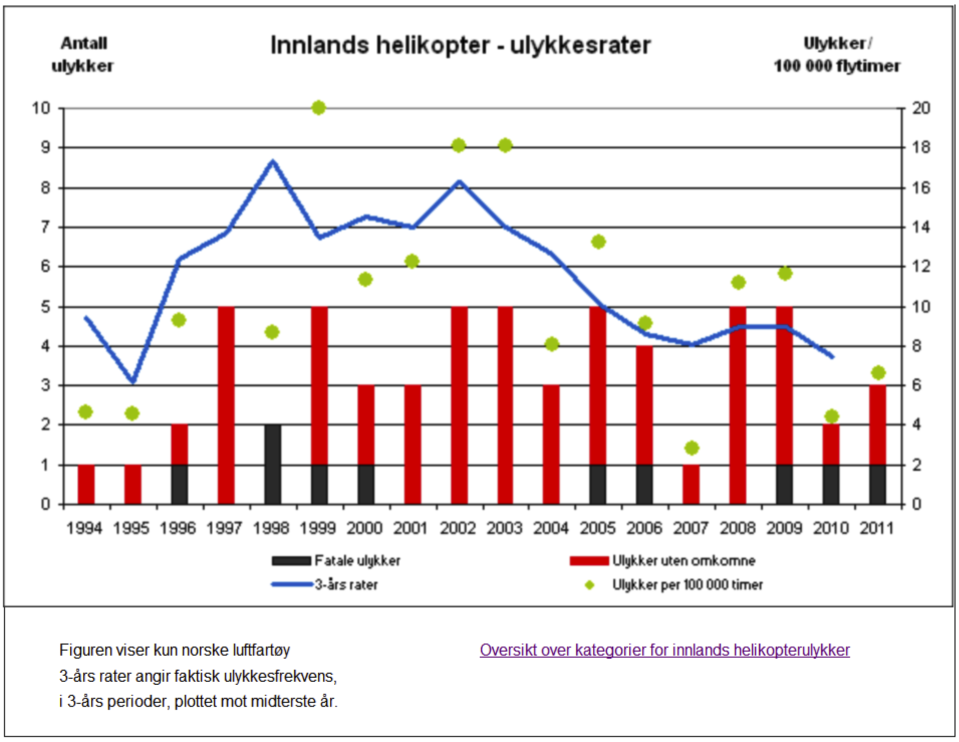


Figure 15: Norwegian accident statistics for onshore helicopter operations in the period 1994-2011.

1.17.5.2 The statistics show that a total of ten fatal accidents have occurred with Norwegian-registered helicopters in Norway in this 18-year period. In comparison, there has been one fatal accident with offshore helicopters (1997), and no fatal accidents with Norwegian-registered aircraft in scheduled air transport in Norway in the same period[12].

1.18 Additional information

1.18.1 Servo transparency

1.18.1.1 As mentioned in Chapter 1.6.6, hydraulic servo actuators in the flight controls can be subjected to overloads so that servo transparency occurs (also called jack stall). On helicopters with a main rotor that rotates clockwise as seen from above, the blades have the highest blade angle when they pass aft on the right side of the helicopter. The high blade angle is necessary to compensate for the lower resultant speed (relative wind) when the blade moves aft while the helicopter is flying forward. The general load on the main rotor increases under the following conditions:

- High speed
- High torque (high collective pitch)
- High mass
- High g-load
- Increasing density altitude, i.e.:
    - *Increasing flying altitude*
    - *Increasing temperature*

[11] *Source: http://www.luftfartstilsynet.no/flysikkerhetsstatestikk/A_innlands_helikopter.htm*
[12] *(http://www.luftfartstilsynet.no/flysikkerhetstatistikk/article1263.ece).*

- *Increasing humidity*

1.18.1.2 Some of the factors above have clear limitations, for example maximum allowed take-off mass, but servo transparency can occur through a combination of values where the limit values for individual parameters are not exceeded. In addition, the load on the right side of the rotor increases when the helicopter banks to the left (rolling into a left turn) or is kept in a left turn. The load on the right side of the rotor also increases if the helicopter quickly rolls out of a bank to the right. One factor that increases the servo transparency margins is lowering the collective before making a steep turn.

1.18.1.3 There is no indicator or warning in this helicopter type to alert the pilot that it is about to enter servo transparency. There is also no single limitation that must be observed to avoid this phenomenon, and the flight manual, for instance, has no diagram you can refer to to find such limitations under the prevailing conditions. Servo transparency occurs with a combination of the factors referred to above. The fact that the total sum of factors has reached the threshold for servo transparency only becomes apparent when the phenomenon has occurred.

1.18.1.4 The figure below shows this schematically. The maximum force that a servo can deliver is 185 daN. In a situation where more force, for example 195 daN, is needed to adjust the blade angle of a main rotor blade, the pilot must add the additional force manually. Although the extra need for force comes gradually, it happens over a relatively short period of time. The cyclic on the AS 350 normally requires very little force. The pilot may, depending on how much friction he or she has added, experience that the stick force goes from almost zero to 10 daN (equivalent to about 10 kg) over a short period of time, and may perceive that the controls are jammed.

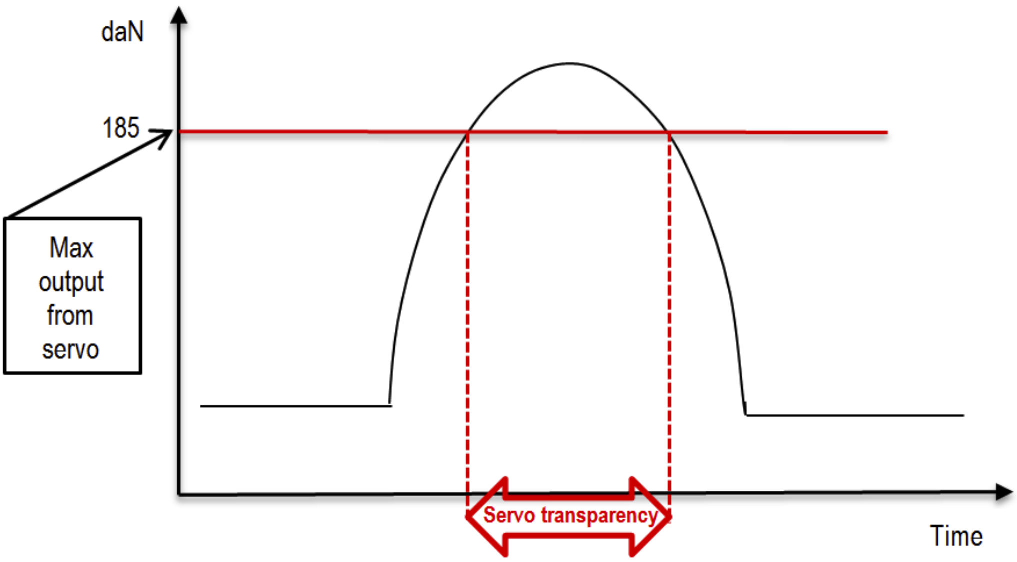


Figure 16: Illustration of servo transparency - the required force exceeds the servo's capacity in the period between the dotted red, vertical lines.

1.18.1.5 If the pilot is prepared and adds this extra force, the rotor system may become overloaded. If the pilot is surprised by the phenomenon, the helicopter's flight path (altitude and track) may change. As mentioned above, the lift from the rotor blade passing aft on the right side will become insufficient. This creates a rolling movement to the right. Due to the gyroscopic effect on the rotor, this will also cause the helicopter’s tail to drop and the nose to pitch up. Under normal circumstances, this pitch up causes the flying speed to drop. A result of the reduction in flying speed is that the loads decrease, which also reduces the likelihood of the servo transparency persisting. In a meeting with the AIBN, the manufacturer maintained that servo transparency normally lasts for 2-3 seconds.

1.18.1.6 How to avoid servo transparency and how to act if it occurs is described in the Eurocopter AS 350 B3 Flight Manual, EASA Approved Revision 6, Manoeuvring Limitations:

2.3.6 MANEUVERING LIMITATIONS

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

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

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

  Transparency will disappear as soon as excessive loads are relieved.
- In maximum power configuration, decrease collective pitch slightly before initiating a turn, as in this maneuver power requirement is increased.
- In hover, avoid rotation faster than 6 seconds for one full rotation.

1.18.1.7 On 4 December 2003, Eurocopter issued a service letter concerning servo transparency (Lettre-Service No. 1648-29-03). The circular, included in its entirety in Appendix D to this report, explores aspects mentioned in the manoeuvring limitations of the flight manual. Below is AIBN's summary of the content:

- Servo transparency can be encountered during excessive manoeuvring of any single hydraulic system equipped helicopter, if operated beyond its approved flight envelope.

- The phenomenon occurs smoothly and is not dangerous, if properly anticipated by a pilot during excessive manoeuvring.

- The hydraulic system is designed to protect against overstress in the event that the helicopter is manoeuvred outside the limits of the approved flight envelope.

- The right servo is overloaded first (as a consequence of the blade passing aft being on this side).

- The phenomenon usually lasts for less than two seconds, as the effect of it occurring will reduce the factors that caused it.

- It is important that the pilot immediately reduces the severity of the manoeuvre, allows the collective pitch to decrease and smoothly counteracts the right cyclic tendency to prevent an abrupt left cyclic movement as hydraulic assistance is restored.

1.18.1.8 A chart prepared by Eurocopter's training department, describing the phenomenon, has been reproduced in Appendix G.

1.18.1.9 The aviation authorities in several states (including the United Kingdom, USA, Canada and Australia) have published their own information circulars based on the content in Eurocopter's service letter. Two of the national circulars have been reproduced in Appendices E and F to this report. None of the documents discuss servo transparency in a right turn specifically. EASA has not published any specific information about this phenomenon.

1.18.2 Test flight with demonstration of continuing servo transparency

1.18.2.1 Eurocopter has presented results to the Accident Investigation Board from one test flight they made with an expert from the Federal Aviation Administration (FAA) in 2003. The test flight was made following an AS 350 accident in the USA where the FAA suspected that servo transparency could be a possible factor. The purpose was to show that it was fully possible to fly the helicopter without losing control even when deep in servo transparency. The helicopter used was an AS 350 B2[13] at maximum AUM (2250 kg). The test was made at 3000 ft. The temperature (OAT) was 4 °C.

1.18.2.2 During the test flight with the FAA, the helicopter was intentionally manoeuvred to induce servo transparency with duration of up to 8-10 seconds. The documentation shows seven measuring points, five in a left turn and two in connection with pull-up from a dive straight ahead. The speed was between 100 and 150 kt. In this case, it was verified that servo transparency could hardly occur at speeds of less than 100 kt, and that it was necessary with a torque of more than 50% to overload the system[14]. The tests were performed using a torque equal to Max Continuous Power (MCP). During the manoeuvring, the test pilot used force on the controls to maintain torque and loads on the main rotor to make the helicopter remain in a state of servo transparency for several seconds. Immediately upon the pilot lowering the collective, the helicopter recovered from servo transparency.

1.18.2.3 Some of the results from the test flight have been plotted in a diagram reproduced in Figure 17. The X and Y axes in the diagram in the figure show speed and load, respectively, on the main rotor during manoeuvring. Load values on the y axis depend on both helicopter mass (M) and air density (sigma, σ), making it impossible to read normal load (n, corresponding to what is usually called g-load) directly from this diagram.

1.18.2.4 The black line and the black points in the diagram show the limit for the flight envelope and measuring points from the certification of the helicopter. The red points in the diagram are outside of the approved area and show the lateral force applied by the test pilot to counter cyclic movements resulting from servo transparency. The data that form the basis for the diagram show that the forces on the collective were between 3.5 and 10 daN (not shown in the figure), while the cyclic was pushed to the left with a force of between 2.5 and 12 daN. During the last pull-out, the test pilot maintained a straight flight path (overcame the helicopter's tendency to turn to the right). The measurements show that the collective was

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[13] *In principle identical to AS 350 B3 for testing purposes*

[14] *In a lecture held by Eurocopter at Gardermoen in December 2011, it was stated that servo transparency does not occur when the speed is less than 90 kt, or torque is less than 50% on AS 350 B2 and less than 45% on AS 350 B3.*

then held up with a force of 6 daN, while the cyclic was pushed to the left with 12 daN and backwards with 5 daN.

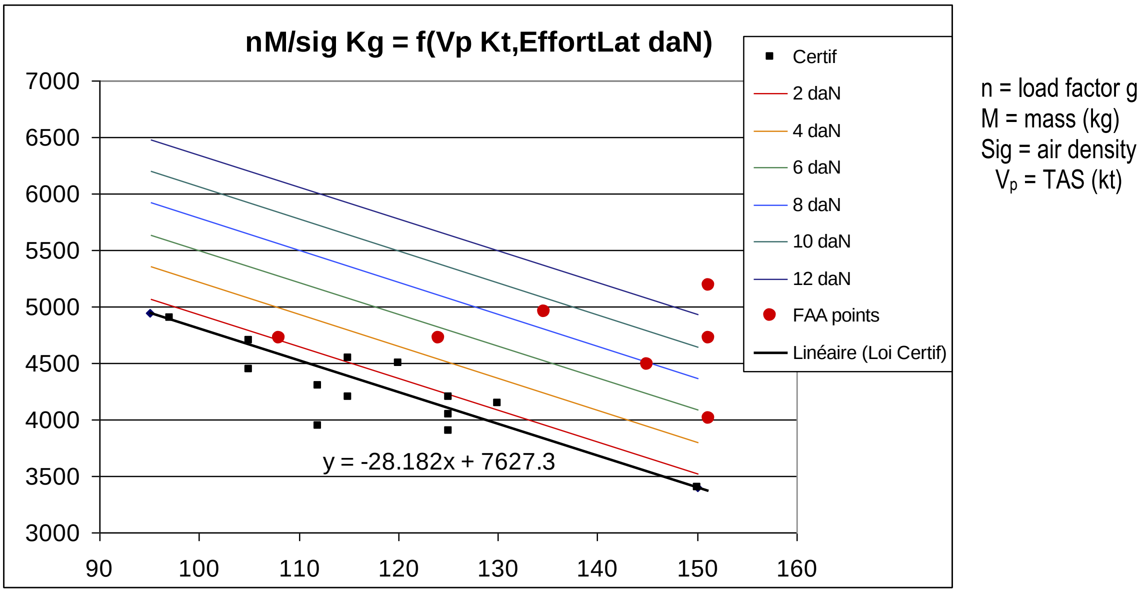

Figure 17: Results from the test flight. The red points are recorded stick forces on the cyclic during induced servo transparency at 3000 ft, 4 °C, mass 2250 kg. The black line shows the limit of the flight envelope. (Source: Eurocopter).

1.18.3 Demonstration of servo transparency

1.18.3.1 Servo transparency has been discussed in the Norwegian helicopter community earlier, e.g. after the Kolsås accident (cf. 1.18.7.3). After the accident with LN-OXC, the servo transparency issue was raised again. The Norwegian representative for the Eurocopter AS 350 helicopter type, Østnes Aero AS, arranged demonstration flights for operators who requested them. The programme was included in a Flight safety forum meeting for onshore helicopter operators at Gardermoen on 6 December 2011 (cf. 1.18.9.1). There, a test pilot from Eurocopter first held a lecture on servo transparency, before carrying out a number of flights. The helicopter used was a Eurocopter AS 350 B2. The operator was Pegasus Helicopter. The Pegasus pilot was the commander and sat in the right hand seat, while the manufacturer's test pilot sat in the left seat. The passengers in the rear seats wore headphones and were able to participate in the communication on board and observe what took place.

1.18.3.2 The demonstration flights were filmed from inside the helicopter with a light-weight Appareo Vision 1000 recorder[15]. The recorder also has a built-in GPS and accelerometers, and also derived position, altitude, ground speed, vertical speed, heading, pitch and roll. It was programmed with an event threshold when there would be a risk of servo transparency. The parameters that would trigger an event if occurring simultaneously, were:

> *"The absolute value of normal acceleration is greater than 1.5 G AND*
>
> *The absolute value of Roll is greater than 30 degrees AND*
>
> *Ground speed is greater than 135 Knots for a minimum of 0 seconds."*

---

[15] *Appareo Vision 1000 complies with approved standard and has an STC for installation in the Eurocopter AS 350.*

1.18.3.3 An accident investigator from the AIBN participated in one of the demonstration flights, and the AIBN has later received the recordings and analyses of the flights. Servo transparency was mainly demonstrated in connection with left turns, but the test pilot also demonstrated the phenomenon in a right turn upon request from one of the passengers.

1.18.3.4 The recordings show that the effect in a left turn was that the helicopter quickly corrected from a bank angle of more than 30 degrees. In a servo transparency demonstration in a right turn, the bank angle increased to a maximum value of 54 degrees. The maximum recorded g-load was 2G in a left turn and 2.15G in a right turn.

1.18.3.5 The Pegasus pilot that participated in the demonstration and several of the observers have expressed to the AIBN that the demonstration was useful. No one was frightened by the moderate effect of the phenomenon in a left turn, but the Pegasus pilot stated that it would be wrong and misleading to call the phenomenon self-correcting if it occurs in a right turn. The bank then increases and the helicopter "digs in”. In addition, they pointed out that aggressive manoeuvring was required to induce servo transparency. Pegasus Helicopter operates a helicopter school and will now demonstrate servo transparency to everyone who go through their courses.

1.18.4 <u>Estimation of the servo transparency onset threshold for LN-OXC</u>

1.18.4.1 The AIBN saw a need for a diagram that under the relevant conditions could illustrate which g-load would have result in encountering servo transparency on LN-OXC. Based on the diagram in Figure 17, the helicopter's mass and tables of the standard atmosphere, the AIBN developed Table 4 and Figure 18: . Eurocopter has verified that the calculations are correct. Note that true air speed (TAS) is used in the calculations, and that this is somewhat higher than indicated air speed (IAS)[16].

Table 4: Predicted conditions for servo transparency encounter at mass = 2 148 kg, sig. = 0.882[17]

True air speed (kt)	90	100	110	120	130	140	150
Load (‘g’- load)	2.09	1.97	1.86	1.74	1.63	1.51	1.40

1.18.4.2 The red continuous line in Figure 18: a) shows the situation at relevant mass, 2 148 kg. The servo transparency area is above the line. The slope of the line shows how servo transparency may be encountered at lower g-loads with increasing speed. For example, the threshold for LN-OXC in the ambient conditions would be approx. 2 G at 100 kt, while the phenomenon would occur at 1.5 G at a speed of 140 kt.

1.18.4.3 To show the importance of mass, dotted lines illustrating the situation if LN-OXC had been heavier (max. AUM) or lighter (resp. 3/2/1/0 passengers) are also included in the chart. It shows that the line is shifted in parallel downwards at higher mass, which means that the threshold is then reached earlier. E.g. at 130 kt it would have been around 1.93 G if the pilot had been the sole occupant on board LN-OXC (M = 1 808 kg). At the same speed with four passengers (M = 2 148 kg) it would have been approx. 1.63 G.

[16] *True air speed (TAS) is about 8% higher than the indicated air speed (IAS) at a density altitude of 5000 ft. For example, the permitted maximum indicated speed V_{NE} at 3000 ft. is 146 KIAS. This corresponds to a true air speed of 155 kt (cf. 1.6.1).*

[17] *The calculations use an air density (Sigma, σ) related to the standard atmosphere at sea level (σ_{ST}=1). The importance of humidity is negligible enough to disregard.*

1.18.4.4 Figure 18 b) is included to illustrate how the situation would be at sea level in standard atmospheric conditions compared to the situation in the mountains on a warm day. When comparing Figure 18 a) and b), one sees that the lines are higher in the diagram b). During manoeuvring at 130 kt in the ambient conditions at 3 150 ft, the threshold for encountering servo transparency was approx. 1.63 G. At the same speed near sea level on a "standard day" the threshold would be approx. 1.85 G.

1.18.4.5 Figure 18 c) is included to illustrate the effect of temperature, assuming max. AUM and an altitude of 3 000 ft. The figure shows that servo transparency will occur at lower g-loads on a warm day. When manoeuvring at 130 kt at this altitude it would be encountered at approx. 1.61 G if the temperature had been 9 °C, while at 24 °C at the same altitude it would be approx. 1.53 G.

1.18.4.6 Figure 18 d) illustrates the effect of altitude, assuming max. AUM at standard atmospheric conditions. The lines shift downwards as altitude increases. For example, the threshold for encountering servo transparency when manoeuvring at 130 kt at sea level would be approx. 1.8 G, while at 5 000 ft it would be at approx. 1.5 G.

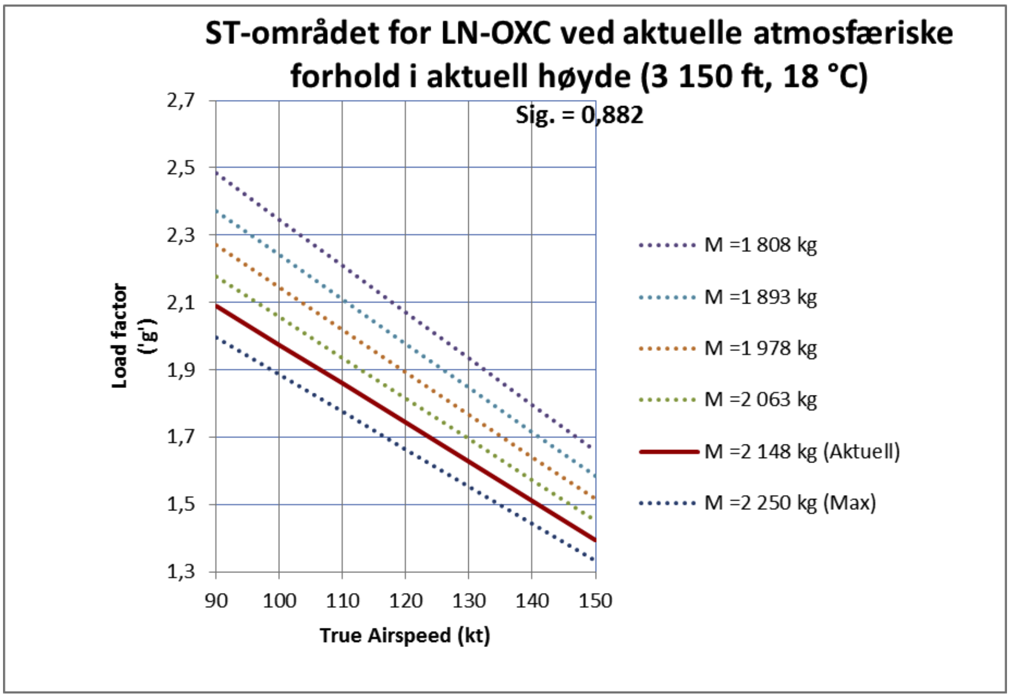

Figure 18 a): The situation for LN-OXC at the ambient atmospheric conditions (temperature at 3 150 ft. approx. 18 °C). The dotted lines show the effect of variation in mass.

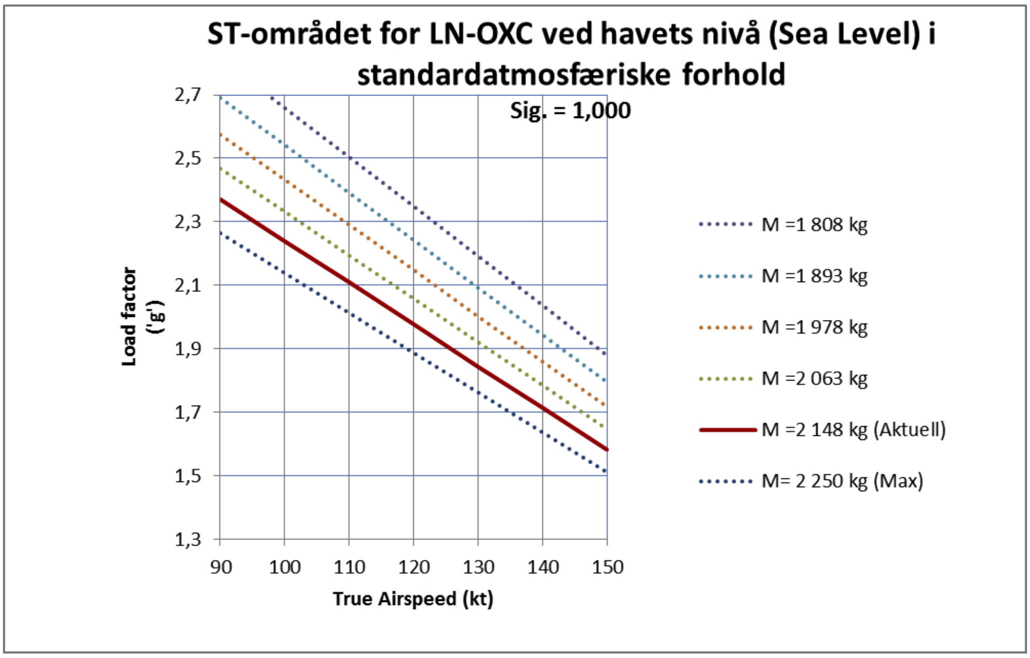

Figure 18 b): Theoretical situation where LN-OXC is operated at standard atmospheric conditions at sea level.

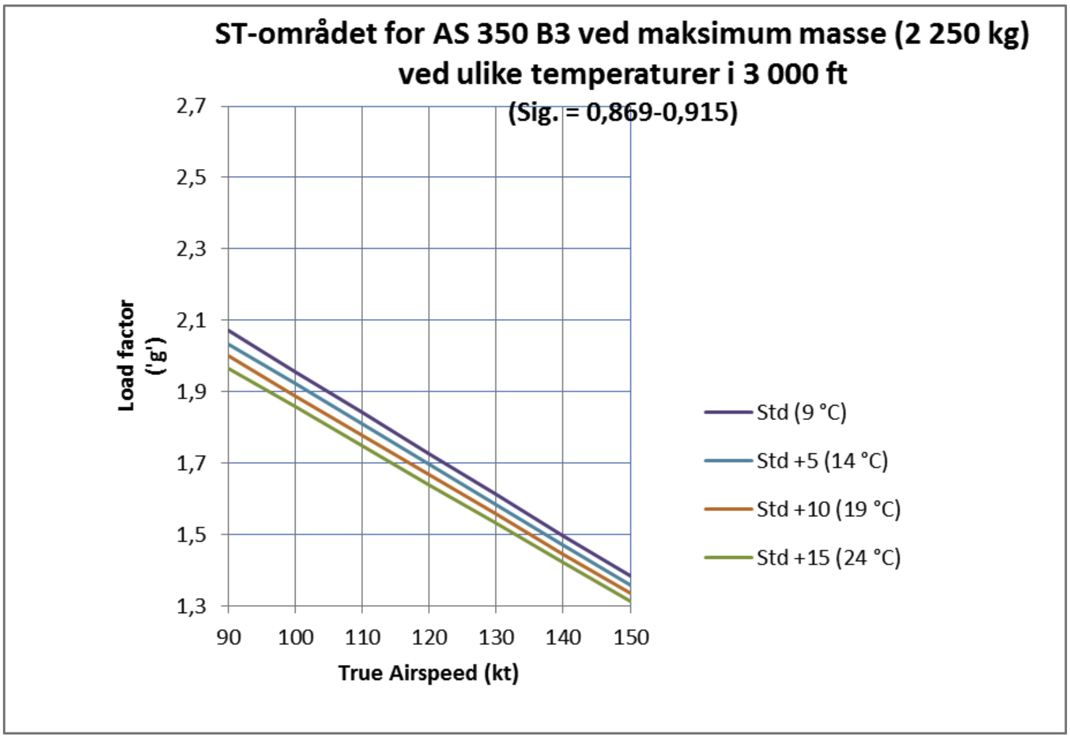

Figure 18 c): Theoretical situation where the mass is equal to 2 250 kg at a flight altitude of 3 000 ft. The lines show the effect of temperature.

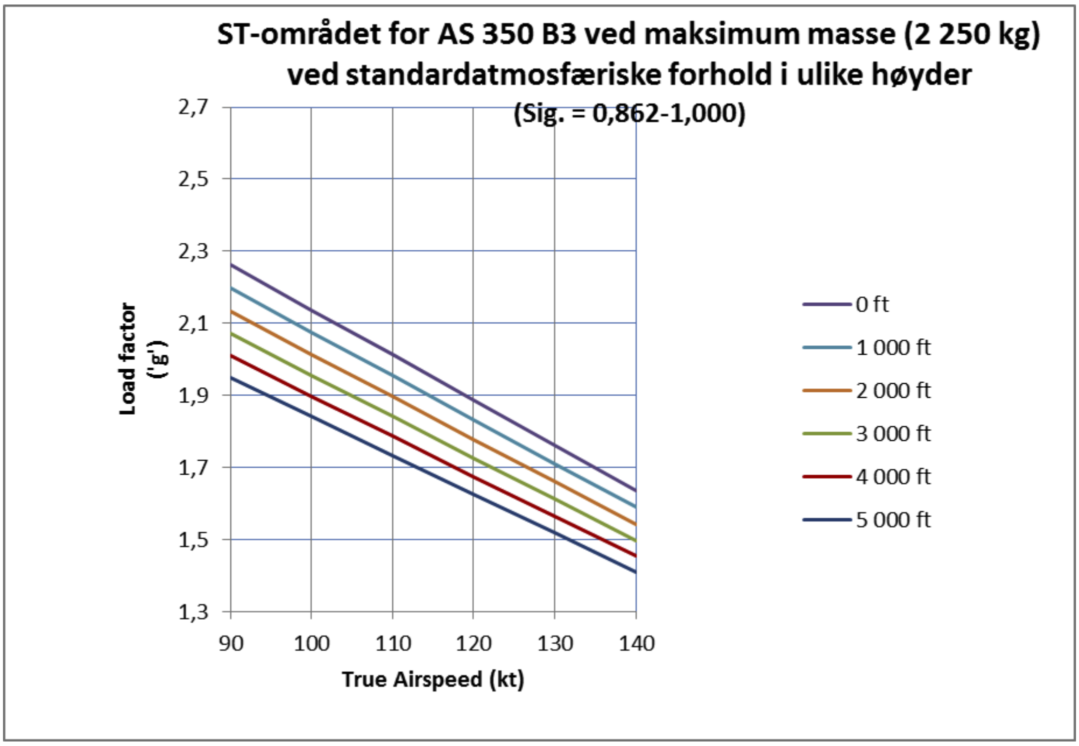

Figure 18 d): Theoretical situation where the mass is equal to 2 250 kg at standard atmospheric conditions. The lines show the effect of altitude.

Figure 18: Various diagrams which predict at which g-load servo transparency is encountered under different conditions. The servo transparency area lies above the line. (MCP assumed).

1.18.5 Servo transparency training

1.18.5.1 In connection with this and previous investigations, the AIBN received a clear impression that there are different opinions whether the servo transparency phenomenon should be or can be demonstrated/practiced on board helicopters or not. Most companies in Norway seem to have a practice where the theory is reviewed verbally, but perform no demonstration during flight. Some instructors have, however, insisted that a pilot should have experienced the phenomenon, and have demonstrated it. The lack of clarity seems to be due to an interpretation by some that the prohibition against continuing servo transparency is absolute. Some claim that servo transparency entails operating the helicopter outside of its limitations, which is not permitted. Several have referred to the fact that for a period at least, servo transparency was not demonstrated to pilots that received type training under the auspices of Eurocopter. The AAIB UK also expressed skepticism with respect to training in the helicopter. AAIB recommended thorough theoretical ground study as part of the type rating (cf. 1.18.7.2).

1.18.5.2 Airlift has stated that one of their experienced instructors has demonstrated servo transparency in type ratings/skills tests. His method was based on the Manufacturer’s method from the mid-eighties, when he got his type rating. Theoretical training consisted of reviewing the text in the flight manual with the candidate before flight. Practical training was that the instructor first demonstrated the phenomenon and its effect while the candidate followed through on the controls. The exercise was then repeated by the candidate with the instructor monitoring, ready to take over. The procedure was performed by accelerating straight ahead in a shallow dive until the speed reached approximately 135 kt, followed by a firm pull-up. The exercise had also been demonstrated in a descending spiral to the right.

1.18.5.3 Airlift has explained that apart from this, no other training has been held as regards the phenomenon. They have explained that for a long time, it was difficult to get a clear statement from Eurocopter on whether you could train for servo transparency or not. In October 2011, Airlift at last received clarification from Eurocopter that servo transparency could be practiced regularly, on one and the same helicopter without risk of damage, providing it was demonstrated by a qualified instructor and in accordance with the procedures.

1.18.5.4 The French team that visited the AIBN in connection with the investigation included representatives from Eurocopter. They asserted that it was a misunderstanding that one should not demonstrate and train for servo transparency, and that the same misunderstanding had prevailed in the US for a period. The representative presented Eurocopter's training programme for Single Pilot VFR Type Rating dated 05/2006. The programme briefly stated that servo transparency must be demonstrated, and that the candidate must be made familiar with the procedure and phenomenon (Training Services' Single Pilot VFR Type Rating program F025 T-AS350B3-C).

1.18.5.5 More detailed guidelines for how flight instructors should carry out the demonstration of servo transparency on board Eurocopter AS 350 helicopters were published in 2010. EASAs *Certification Flight Standards Operational Evaluation Board Report* contains the following description[18]:

> *"8.9.2 Demonstration methodology for Flight Instructors and Type Rating Instructors:*
>
> *Servo-transparency (called also servo-reversibility):*
>
> *Except for EC 130 B4 and AS 350 B3 Arriel 2B1 & AS 350 B3e when fitted with dual Hydraulic system.*
>
> *The servo-transparency training could be performed in the following way:*
>
> *- Complete procedure should be performed above 1000 ft (AGL),*
>
> *- Achieve airspeed between 130 and VNE (with a rate of descend),*
>
> *- Perform a 30° left turn,*
>
> *- Slowly increase the load factor by a backwards cyclic action,*
>
> *- When the servo-transparency is achieved, the tendency of the aircraft is to pitch up and turn to the right,*
>
> *- As soon as the load decreases, servo-transparency disappears*
>
> *Pay attention to the following:*
>
> *- Due to control loads linked to servo-transparency, the collective pitch tendency is to decrease. The collective pitch decrease and the pitch up may lead to rpm increase.*
>
> *- The procedure should not be done too aggressively*
>
> *- The exercise is easier when high All Up Weight and/or high density altitude."*

1.18.6 Use of simulators

1.18.6.1 Using of simulators for helicopter training is not required by the authority, and use of simulators for light helicopters generally is not common. However, the Regulations relating to

[18] *cf. http://easa.europa.eu/certification/experts/docs/oeb-reports/eurocopter/EASA-OEB-Final-Report-Eurocopter_AS350_Family_(B3e)-03-08022012.pdf*

certification of pilots and requirements for flying training organisations for helicopters (BSL JAR-FCL), state that a simulator must be used if available, cf. Appendix 1 to BSL JAR-FCL 2.240/2.295 Item 2:

> *"Flight simulators, if available and other training devices as approved shall be used."*

1.18.6.2 In a circular issued in 2005, the Civil Aviation Authority of Norway gave their interpretation of 'available' (AIC-N 39/05):

> *"Available simulator is defined as a simulator within and outside of Norway, that has either been approved in accordance with JAR-STD or in accordance with the requirements of the Federal Aviation Administration (FAA) in the US."*

1.18.6.3 As far as the AIBN is aware, there is only one Level B simulator for Eurocopter AS 350 in the world, located at American Eurocopter in Texas, USA[19].

1.18.6.4 Two representatives from Airlift (both experienced pilots) visited American Eurocopter in February 2012 and performed flights in the AS 350 simulator. In addition to general demonstration of capacity and testing its suitability for realistic emergency training in other areas, servo transparency was also induced. Their impression was that it was very realistic compared with what you would experience in a helicopter. In a right turn, you experience an uncontrolled further roll to the right, the controls 'jammed' while the collective pitch decreased. The effect was less in a left turn, where the helicopter largely self-corrected. The setup was conditions that were somewhat similar to the situation of LN-OXC, a right turn from 300 ft with a nose down attitude. The experienced instructor concluded that even if one was aware of what could happen, it was not a given that they managed to regain control in time.

1.18.6.5 The manoeuvre was also made by lowering the collective just before starting a right turn:

> *"That resulted in only a hint of feedback in the controls, which is also the case in reality".*

1.18.6.6 Eurocopter has shown interest in the simulator experiences during the draft consultation on this report, and asked for more detailed parameters. Airlift provided the following information on request:

> *"Initially 80 % torque. 500 ft density altitude, 100 kts, gross weight 2200 kg, right and left turn, approx. 45 degrees bank, 20-30 degrees nose down."*

1.18.7 <u>Previous accidents</u>

1.18.7.1 *Eurocopter AS 350 accidents involving servo transparency*

After an accident, it is not possible to determine whether servo transparency occurred from any technical findings. Servo transparency has anyhow been discussed as a possible or likely contributing factor in several accidents and incidents with this helicopter type around the world. AIBN refers to the following reports available on the internet:

- Incident at Hunderfossen, Oppland County, Norway on 15 January 2001, Eurocopter AS 350 B3, registration LN-OAK, Report <u>SL2001/42</u> from the AIBN.

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[19] *http://www.eurocopterusa.com/images/training/as350_sim_Brochure_2011.pdf*

- Accident 11 October 1994, Eurocopter AS 350 B3, registration ZK-HZP. Report 94-022 from the Transport Accident Investigation Commission of New Zealand.
- Accident 10 august 2001, Eurocopter AS 350 B2, registration N169PA. Report NTSB/AAB-04/02 (pp. 33-35) from National Transportation Safety Board, USA.
- Accident 19 October 2001, Eurocopter AS 350 B2, registration N111DT. Report FTW02FA017 from the National Transportation Safety Board, USA.
- Accident 11 May 2005, Kolsås in Bærum. Eurocopter AS 350 B2, LN-OPY. Report SL2010/01 from the AIBN.
- Accident 23 July 2007, Eurocopter AS 350 BA, registration C-FHLF. Report A07W0138 from the Transportation Safety Board of Canada.
- Accident, 15 September 2007, Eurocopter AS 350 B2, registration G-CBHL. Report EW/C2007/09/06 from Air Accidents Investigation Branch, the UK.

1.18.7.2 *Eurocopter AS 350 accident in Scotland on 15 September 2007*

The last accident on the list took place in Scotland on 15 September 2007. The helicopter collided with trees and crashed while executing a right turn at high speed and low height. There were indications that the pilot had started a recovery but, with insufficient height to succeed. All four persons on board were killed. The UK Air Accidents Investigation Branch believed that technical failure could not be entirely ruled out, but that it was more likely that the helicopter deviated from the intended flight path due to other causes; for example handling difficulties, misjudgement, spatial disorientation, distraction or a combination of such factors.

The report is comprehensive, and the AAIB concludes, like the AIBN, that it seems to be necessary to distinguish between right and left turns when discussing the importance of the servo transparency phenomenon. In a right turn, the bank will increase, as will the rate of turn. Thus, instead of creating a favorable speed reduction that will contribute to the phenomenon correcting itself, the risk of deviating from the intended flight path increases. The AAIB believes that the helicopter's bank can quickly exceed 90°, and that the pilot will not have time to recognise what is happening. The stick forces can also make an unprepared pilot believe that a technical problem has jammed the controls. The following quote is from the AAIB's report:

> *"According to Eurocopter, servo transparency is a transitory phenomenon which, because of the helicopter's natural response, tends to be self-correcting. However, this may not be so for a helicopter in a turn to the right. In this case, the helicopter's natural reaction will cause the angle of bank to increase which, together with a possible pitch-up, will cause an increased rate of turn. The effect, if any, on airspeed would be much less.*
>
> *Although the helicopter will recover from the servo transparency of its own accord, the potential exists for a significant flight path deviation. The onset of this could be rapid and could conceivably lead to a helicopter in a right turn exceeding 90º of bank before the pilot was able to recognise what was happening and react accordingly. The associated transition from light and responsive controls to heavy controls that require considerable force to counter the uncommanded manoeuvre, could cause an*

unsuspecting pilot to believe that he was experiencing a malfunction, rather than a known characteristic of the helicopter when manoeuvred at the published limits. As Eurocopter have advised, a servo transparency encounter 'may give a pilot who is not aware of this phenomenon an impression that the controls are jammed'."

The report from the AAIB had three safety recommendations related to servo transparency, of which two were adopted. One of the recommendations was that the UK CAA should publish the content of Eurocopter's circular (cf. 1.18.1.7). The other, No. 2008-069, was about strengthening the theoretical training with respect to servo transparency as part of the type rating training. EASA supported the UK CAA's view that this was already covered by a requirement in the applicable regulations:

"2008-069: It is recommended that the Civil Aviation Authority, in conjunction with the European Aviation Safety Agency, require an awareness of the causes, symptoms, hazards and recovery actions relating to 'servo transparency' or 'jack stall' encounters to be covered as a ground study item as part of the mandatory training for aircraft type ratings for those helicopter types likely to be affected."

The third safety recommendation was to include a warning in the flight manual of hazards related to encountering servo transparency in low level right turns. It was especially emphasised that there was a risk of significant deviation from the planned flight path:

"2008-067: It is recommended that Eurocopter review current operational information and advice about the servo transparency phenomenon. This should be with a view to including a warning in applicable Flight Manuals that the associated uncommanded right roll and possible pitch-up, if encountered by an aircraft manoeuvring in a right turn, have the potential to cause a significant deviation from the intended flight path which, if encountered in close proximity to terrain or obstacles, could be hazardous. "

This recommendation, 2008-067, was rejected by Eurocopter on 10 May 2010. The reason for this is stated in a letter to the AAIB in which Eurocopter claims that such a warning may have a detrimental effect on safety:

"Eurocopter considers that a warning in the Flight Manual about the hazardous consequences of the onset of servo transparency in close proximity to terrain could have a negative effect on safety. Indeed, should pilots operate at high speed and close to the ground and not encounter servo transparency, then this minimizes the importance of both the transparency phenomenon and the risky maneuver."

The letter ends with Eurocopter concluding that the presentation of the phenomenon in the flight manual is sufficiently precise in their view, and that they cannot agree with the proposal made in the safety recommendation:

"In closing, Eurocopter considers that the Flight Manual is sufficiently explicit in its presentation of the servo transparency phenomenon and cannot agree with your warning proposal in the Safety Recommendation 2008-067."

The AAIB has stated to the AIBN that they believe that Eurocopter's response does not fully address the safety problem described in the report. The AAIB therefore considers this response to be unsatisfactory.

Eurocopter has elaborated on its opinion in this regard during the investigation of the accident with LN-OXC. It is claimed that describing all conditions and situations where a helicopter may experience servo transparency in a comprehensive manner in the flight manual, runs the risk of introducing too much theory that would be difficult to understand. Eurocopter states that for pilots' needs, the recommendation to decrease collective pitch slightly before initiating a turn in maximum power configuration is adequate (cf. 1.18.1.6).

1.18.7.3 *Previous fatal accident in Airlift – the Kolsås accident*

Airlift encountered a fatal accident with a Eurocopter AS 350 B2 helicopter at Kolsås in Bærum on 11 May 2005 (Cf. report SL 2010/01). The helicopter with registration LN-OPY was engaged in event flying with the doors removed. In a right turn towards rising terrain, the helicopter lost altitude and hit treetops, resulting in severe vibrations. In the subsequent emergency landing, the helicopter rolled over and one of the people on board fell out of the cabin and was fatally injured. The Accident Investigation Board concluded that the commander of LN-OPY misjudged the turn in relation to the helicopter's performance limitations and height. Due to inadequate visual references during the turn, he did not notice the high rate of descent until it was too late to avoid hitting the trees.

Servo transparency as a factor in the accident at Kolsås was discussed. AIBN considered it unlikely, as the speed was far below V_{NE} and as the commander did not describe unexpected forces in the controls while manoeuvring. AIBN was however critical of the manufacturer not distinguishing between the effect of servo transparency in right and left turns, and stated the following about the manufacturer's description in the flight manual:

> *"The description of the phenomenon does not contain any warning that the situation can become critical if it occurs at low altitude. It can be rightly claimed that the phenomenon cannot occur if the helicopter is flown within the limitations. However, a pilot does not have clear guidelines for assessing when the limits have been reached. The only sure indication is that the controls stiffen. It may then be too late to avoid problems associated with servo transparency. The rules of good airmanship say that the combination of high speed, high load and low altitude represents an increased safety risk. Nevertheless, the AIBN still believes that Eurocopter did not provide sufficiently clear warnings of the dangers that might arise from servo transparency."*

In the Kolsås report, the Accident Investigation Board made a recommendation to the Civil Aviation Authority to assess the regulations in connection with event flying:

> *"Event flying is not defined or regulated, and has been allowed to develop over time. The flying contains elements from both passenger flights and aerial work, combined in a manner that can result in a major safety risk. The Accident Investigation Board therefore recommends that the Civil Aviation Authority ensures a practical regulation of this form of flying."*

While the investigation process was on-going, the Civil Aviation Authority stated that *«event flying must be defined and then stopped or brought under control»*. When the recommendation was processed after the publication of the report, however, the Civil Aviation Authority decided not to amend any regulations. The reasoning was as follows:

> *"To the Civil Aviation Authority, event flying is not an approved form of operation, and it will therefore not be defined or regulated. The Civil Aviation Authority believes that defining and regulating such flying would pave the way for breaches of the*

current regulations for sight-seeing flights and possibly contribute to legitimise high-risk passenger flights.

It is correct that some operators seem to take assignments from event companies and fly outside the regulations to create excitement and thrill. The Civil Aviation Authority will come down on this when uncovered.

The Civil Aviation Authority maintains that the activities must be within the framework of the regulations relating to sightseeing flights and within the flight manual limitations, and that the operator is responsible for not accepting assignments which will result in breaches of the regulations."

The report from the Accident Investigation Board contained no recommendation to Airlift.

Airlift has stated to the AIBN that the Kolsås accident did not result in any procedural changes or new limitations in their manuals. However, all event flying was stopped and focus directed towards attitudes and the commander's responsibility to operate in accordance with the described procedures for sight-seeing flights/minimum altitudes. The technical briefing seminars were then used to repeat this, also with focus on servo transparency. Relevant information of a temporary nature was issued to the pilots (OPS Info). However, all this happened before the commander of LN-OXC was hired by Airlift.

1.18.8 Measures in Airlift after the accident with LN-OXC

1.18.8.1 Airlift established its own internal investigation team after the accident with LN-OXC. As part of the investigation, a reconstruction of the approach part of the flight was held at a safe altitude, while manoeuvring as observed by the witnesses. The pilots that participated in the reconstruction described that they experienced servo transparency every time if they did not reduce collective before initiating the turn. This resulted in the heading change to the right becoming larger than intended, and they lost an estimated 200-300 ft before fully recovering.

1.18.8.2 The investigation team prepared a comprehensive internal investigation report after the accident. The report had no definite conclusions, but discussed several scenarios that may have arisen. Several recommendations were made to the company, including the use of simulators and flight recorder (for example Appareo Vision), introducing manoeuvring limitations during normal operations with passengers, and that systematic servo transparency training should be introduced. In addition, the report called on the company to put further emphasis on safety culture issues, with closer follow-up and more frequent monitoring of the work performed by recently hired pilots, as well as appointing stand-ins for key personnel during prolonged absences. The team also expressed a desire to modify the helicopters to give an advance warning in the form of lights, etc., allowing the pilot to reduce the severity of the manoeuver if there is a risk of servo transparency.

1.18.8.3 On 12 March 2012, Airlift implemented changes to their procedures for passenger flights. The following limitations were introduced:

"1.1.3 Roll and pitch angle during passenger flights

Maximum roll and pitch angle during operations with passengers on board below 500' AGL is set to 30 degrees roll and 15 degrees pitch.

1.1.4 Initiating a right descending turn at low level

Initiation of a right descending turn at altitudes below 500' AGL with passengers on board without first lowering the collective is prohibited."

1.18.8.4 The company's management has stated that they are considering using lightweight recorders to further reinforce the preventive safety work. The company is also a self-declared proponent of simulator training requirements.

1.18.8.5 After the accident with LN-OXC, Airlift has changed the working schedule for the base chief pilot, so that the base chief pilot sees all pilots on the base regularly, giving the company a closer operational follow-up of the individual pilot.

1.18.8.6 Regarding flight following, Airlift has informed that several years ago it was decided to replace the manual mobile phone scheme by Iridium, a satellite based system with global coverage. Its fleet in the Arctic areas was given first priority. As per September 2012, 10 out of 17 helicopters were equipped with the satellite based system.

1.18.9 National and international measures for improvement of helicopter safety

1.18.9.1 *The Committee for Helicopter Safety – Inland Operations*

In 2007, Airlift arranged a safety forum for onshore helicopter operators (also called *inland operators*). The idea was to establish an annual seminar, hosted in turn by the different operators. The Civil Aviation Authority also participated, and it took responsibility when the initiative was not continued by the operators. Onshore helicopter safety has been a designated focus area for the Civil Aviation Authority for several years. In order to focus on this work and ensure continuity, the Committee for Helicopter Safety – Inland Operations (hereafter named the Committee) was established in May 2009. The Committee has its own website (www.helikoptersikkerhet.no). The website states that the Committee will be a driving force vis-à-vis the authorities, customer groups and operators in issues that can promote safety for onshore helicopters. The Committee is chaired by the Civil Aviation Authority. Its mandate is as follows:

> *"The Committee shall work to significantly improve safety for inland helicopters, with a zero accident vision.*
>
> *The Committee shall be a driving force towards responsible authorities and players. It shall raise issues of importance for helicopter safety and follow up with specific measure proposals.*
>
> *The Committee shall, in addition to its work on the national level, cooperate with international organisations dealing with helicopter safety."*

In 2011, funds were allocated to a specific safety study of onshore helicopter operations. The study is financed by the Ministry of Transport and Communications, but the Committee is responsible regarding technical issues. According to the Committee's website, the purpose is to look into risk areas and make recommendations to improve safety based on the results of the study. The study should estimate the future safety level and analyse the effect of the measures. The assignment was awarded to Safetec Nordic following a tender process. The study will be completed by the end of January 2013.

1.18.9.2 *International initiatives for improvement of helicopter safety*

European Helicopter Safety Team (EHEST) was established in November 2006 on the basis of the International Helicopter Safety Team (IHST), established in the US earlier that same year. The common objective is to reduce the number of accidents with helicopters in the world by 80% within 2016. EHEST consists of representatives from the authorities, helicopter manufacturers and helicopter operators all over Europe.

EHEST has analysed European helicopter accidents in the period 2000-2005 and has identified contributing factors in the categories *'Pilot judgement and actions' and 'Safety Culture and Management'* as the most frequent, closely followed by *'Ground Duties'* (cf. Final Report 2010). A ranked list of the main challenges facing transport of passengers with helicopters is set out in the report:

- *Pilot decision making*
- *Pilot-in-Command self-induced pressure*
- *Inadequate oversight by the Authority*
- *Failed to follow procedures*
- *Selection of inappropriate landing site*
- *Reduced visibility – whiteout, brownout*
- *Pilot's flight profile unsafe for conditions*
- *Inadequate government/industry standards and regulations*
- *Disregarded cues that should have led to termination of current course of action or manoeuvre*
- *Aircraft position and hazards*
- *Pilot inexperienced with area and/or mission*
- *Mission involves operations at high density altitudes*
- *Management disregard of known safety risk*
- *Inadequate consideration of obstacles*

Furthermore, the EHEST report contains a number of proposals for initiatives to prevent recurrences of the most common accident types. The aspects mentioned include preparation of procedures for all types of tasks, improved safety culture measures, use of risk assessments, increased use of flight recorders, etc. Improved authority oversight and the need for sanctions against those who do not comply with regulations are also emphasised.

1.18.9.3 *Technological development*

In addition to the proposed operational measures, EHEST has started to look systematically at safety problems that can be solved using technology. A lecture by EHEST at the 2011 European Rotorcraft Forum (ERF) was titled *«Mapping Safety Issues with Technological Solutions»*. Flight Data Monitoring (FDM) adapted to light helicopters was emphasised as promising. Systems can be programmed to record when exceeding certain parameters, and will for example be useful tools for monitoring compliance with standard operational procedures and for prioritisation of training and for raising awareness of potential risk factors. Such equipment can also be of assistance during accident investigations.

Eurocopter has stated to the AIBN that authority approval has been issued for installation of lightweight recorders (LWR) of the type Appareo Systems Alert Vision 1000 in Eurocopter AS 350 helicopters. The manufacturer has also stated that lightweight recorders will be standard in new helicopters, which means that customers must pay if they do not want the equipment on board. There are multiple suppliers in the market, and there are indications that we are facing a tremendous future development in this field[20].

The AIBN has earlier made a recommendation to the Civil Aviation Authority to facilitate the use of such new technology as soon as possible. This is one of several measures to achieve the objective of significantly improved safety in onshore helicopter operations. The recommendation was made in connection with a fatal accident involving flight in degraded visual conditions (Report SL2011/08) and it is still under consideration.

The AIBN knows that the accident investigation authorities in France, the UK and Hungary have made recommendations to EASA to consider requirements for recorders also in lighter aircraft. EASA has listed this as a measure in their «Inventory Rulemaking Programme» for 2012-2015 (RMT.0272). This means that it is in the long-term plan, but that it is not binding. The plan is renewed annually[21]. AIBN is also aware that ICAO has received safety recommendations to make provision in the area of Airborne image recording systems, and that ICAO Safety Information Protection Task Force is currently considering protection of such data on a general basis. The results are expected in 2013.

1.19 Useful or effective investigation techniques

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

2. ANALYSIS

2.1 Introduction, delimitations and specifications

2.1.1 The analysis primarily discusses the chain of events leading up to the accident. Furthermore, the analysis touches upon human factors, technology and organisational issues relevant to how and why the accident happened. In parallel, the need to make safety recommendations to prevent future accidents and improve flight safety in general is discussed.

2.1.2 The AIBN believes excessive maneuvering may have led to servo transparency, and that this may have contributed to the accident. It is important that helicopter pilots flying helicopter types that are equipped with a single hydraulic system are familiar with the limitations and are aware that the margins in some cases are reduced faster than expected. The AIBN has noticed that more knowledge and understanding of the phenomenon is needed. A desire to highlight important aspects of servo transparency and to make the material more easily understandable to the operational helicopter community is one reason for discussing the phenomenon to such an extent in this report.

2.1.3 It was unfortunate that the Civil Aviation Authority of Norway did not follow up the recommendation made following the specialist medical examination of the pilot in question in 2005 (cf. 1.13.6). However, the pilot had no history of illness, and the relevant requirement relating to EEG examination was later removed from the regulations. As described in Item 2.5.2.6, the AIBN believes that it was unlikely that the medical finding was in any way

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[20] Rev. 7 of European Technical Standard Order includes ETSO-2C197 on "Information Collection and Monitoring Systems", a concept for lightweight recorders (http://www.easa.europa.eu/agency-measures/certification-specifications.php). It refers to industry standard for lightweight recorders (EUROCAE Document ED-155).
[21] A description of the process for EASA's four-year plan for the Rulemaking Programme is available at http://www.easa.europa.eu/rulemaking/docs/programme/2012-2015/2012-2015%20Rulemaking%20Programme.pdf

relevant to the course of events in the accident. The AIBN has chosen not to allocate more resources to investigating whether the lacking follow-up was an isolated incident or a systematic failure.

2.2 The course of events

2.2.1 The AIBN has analysed the course of events, with the purpose of finding out what happened. The most important sources of information were the witness statements and the GPS recordings. The information concerning the height and the speed has error margins, but it seems that the flight was executed in a normal, safe manner until the descent for landing was initiated. When the altitude on the approach is reduced for landing, the minimum height requirements no longer apply. The general requirements concerning safe manoeuvring apply, of course, throughout. In the Accident Investigation Board's assessment, a dangerous situation only arose when the helicopter started the tight turn.

2.2.2 Although sporadic, the GPS receiver's recorded positions, calculated ground speeds and altitudes were useful in the investigation. It must be taken into account that the GPS shows ground speed, unlike the helicopter's airspeed indicator. The general, corrected maximum airspeed V_{NE} at the relevant altitudes would be about 143-146 KIAS (cf. 1.6.1). An average ground speed of 125 kt with a headwind component of less than 10 kt, also indicates that the maximum speed with externally fitted cargo basket of 124 KIAS seems to have been complied with[22].

2.2.3 The very last GPS position definitely showed incorrect altitude in relation to its position, and witness statements and expert statements have cast doubts on the accuracy of the preceding two-three positions. The witnesses' description of the helicopter following a route roughly 150 metres further south correlated better with the expert's calculations than the last GPS points. The Accident Investigation Board believes that reception during the last seconds preceding the impact could have been poor, and that the points may have been based on prediction. Considerable bank may have caused the fuselage to block signals to the internal antenna while the helicopter was in a steep turn towards rising terrain. (Corresponding to what car drivers can sometimes experience in tunnels, with GPS positions becoming incorrect/ displaced for a period).

2.2.4 The GPS receiver provides no information about the helicopter's attitude, and it is not possible to calculate g-forces based on a track log alone. Eurocopter was able to help with making dynamic calculations based on GPS data combined with others parameters (cf. 1.16.2), but it was not possible to describe the flight path in further detail on the basis of the available information. There is no indication or reason to believe that main rotor rpm deviated significantly from normal. Based on the distance between the impact marks of the main rotor blades and a rotor rpm of 370 – 390, the forward speed of the helicopter at the moment of impact was calculated to 102 – 107 kt[23].

2.2.5 The witness statements diverge somewhat with respect to how much the helicopter was banking, from an estimated 60 degrees to almost 90 degrees (cf. 1.1.8). The described visual impression of an almost vertical main rotor and statements that the belly of the helicopter was clearly visible from where the witnesses stood, make the AIBN believe that there is no doubt that the helicopter had an unusual flight attitude in the turn.

[22] *True air speed (TAS) is about 8% higher than the indicated air speed (IAS) at a density altitude of 5000 ft.*
[23] *Eurocopter calculated a lower value, 92 kt, based on 2.4 m spacing between the rotor impact marks.*

2.2.6 Witnesses have also described that the helicopter seemed to get out of control, with excessive bank and a steep descent rate. This description gives the impression that control was completely or partially lost. The witnesses have further described how the turn continued, banking steeply, just beyond where they expected it to roll out. This is supported by the statement that they saw the underside of the helicopter when it banked steeply, which would not have been possible if the helicopter was heading straight for them.

2.2.7 AIBN considers it most likely that abrupt manoeuvring initiated a sequence that caused control of the helicopter to be lost for a short period. Potential scenarios and factors that could have caused abrupt manoeuvring are discussed in detail in Chapters 2.5 and 2.6.

2.2.8 Information that the bank was reduced before impact indicates that the commander was in the process of levelling out the helicopter. The witnesses' description of the helicopter banking 45° to the right as it hit the ground correlates with findings at the accident site and the calculations made. Overall, the information indicates that control of the helicopter was partly or completely lost for a period, and that there was not sufficient height for the commander to roll out and stop the descent in time.

2.3 Survival aspects, fire and rescue

2.3.1 In this accident, it is evident that neither cabin structure nor personal protection equipment beyond the helmet and seatbelts worn, could have prevented a fatal outcome. The magnitude of the impact forces inflicted fatal injuries on everyone on board. Improved fire protection, quicker fire extinguishing, activation of the ELT or immediate notification would therefore not have changed the outcome.

2.3.2 Effectiveness of emergency beacons is a known challenge, especially for helicopters. The location of the beacon is a problem as the transmitter and antenna cannot be placed in the tail, where they can be destroyed by the main rotor. It is a general problem that the antenna wire can be torn off, and/or the antenna broken. The transmitters are also vulnerable if installed further forward, as they can easily be damaged by impact forces or fire, as the case was with LN-OXC. Such factors are difficult to guard against. In this case, there is nothing to indicate that the lack of signal was due to an ELT malfunction or irregular installation.

2.3.3 The presence of a piece of the fuel tank close to the point of impact indicates that the tank broke up in the violent collision with the ground. It is not surprising that parts of the wreckage were sprayed with fuel. The AIBN believes that the turbine blades that were shed from the engine might have been one of several possible ignition sources for the fire (cf. Figure 10).

2.3.4 There were several helicopters in action in the area after the accident. Although there are no reports of serious airprox incidents, JRCC-S expressed concerns about flight safety (cf. Item 1.15.4). The AIBN has also noted that Professor dr. med. Inggard Lerheim, who chaired the Directorate of Health's evaluation following the terrorist attack at Utøya on 22 July 2011, believed that deficient management of the helicopters was a major problem and that there is a clear potential for improvement in this area. The report «*Learning for better emergency preparedness*» points out areas for improvement and contains relevant recommendations. The Accident Investigation Board believes that the involved parties would have a common interest in improving their systems to prevent dangerous situations and optimise the use resources in connection with major mobilisations, and will refrain from making further comments.

2.4 The probability of technical defect or malfunction

2.4.1 Findings and witness statements indicate that the helicopter was intact prior to impact. Nor were there other indications of any defect or malfunction in the helicopter that could have contributed to the accident. The AIBN believes the complaints that the helicopter "ran a bit rough" and was "sluggish", and the recently made adjustments were not relevant to the accident (cf. 1.6.5.2).

2.4.2 In spite of the helicopter wreckage being almost completely destroyed by fire, it was possible to verify that the engine was delivering power to the rotors when the accident happened. It has also been possible to verify that key parts of the flight controls were intact prior to the impact.

2.4.3 Although technical failures cannot be completely ruled out, it is considered unlikely that it should have been a factor in the accident. The Accident Investigation Board decided not to look further into the theoretical possibility of a technical failure. The positions of the servos were probably affected by the impact, as was the cyclic stick, and they do not necessarily correlate with the positions of the flight controls prior to the crash.

2.4.4 The external cargo basket is assumed to have had a minimal negative influence in the form of generally reduced performance of the helicopter. The lid was undamaged, and there is no information to indicate that it opened before the collision had happened.

2.5 Factors that could have caused abrupt manoeuvring

2.5.1 Introduction

Unlike some of the advanced aerial work performed with helicopters, transport of passengers is a type of flying that does not require operating near the limits of normal manoeuvring. Without survivors and without flight recorders, the considerations when trying to assess why the helicopter ended up with quite an abnormal flight attitude and flight path must include aspects of speculations. The AIBN believes that meteorological visibility factors, wind and turbulence can be precluded. The controls on the left side were removed, and any influence from the passenger in the front seat seems unlikely. Unknown technical failure is also considered improbable. The relevant factors for consideration in this case are therefore thought to be human factors and organisational, underlying factors in the company as well as in the industry in general.

2.5.2 Human factors

2.5.2.1 The commander on LN-OXC had accumulated 860 flying hours and was medium experienced in the context of Airlift. He had been through the regulatory required training scheme, including demonstration of servo transparency. The Accident Investigation Board has no reason to believe that any misjudgement can be attributed to lack of knowledge or skill, but believes to have uncovered insufficient general knowledge in the helicopter community of the dangers associated with servo transparency. This is discussed in more detail in the next chapter.

2.5.2.2 The AIBN believes that the commander may have fallen for the temptation of giving the passengers an extraordinary experience at the end of the ride. Eurocopter AS 350 B3 is an aircraft with high performance and good manoeuvring characteristics. Just as all the other pilots who have replied that they have been involved in low flying or aggressive manoeuvring with passengers on board (cf. 1.17.3.10), the commander of LN-OXC most likely felt that he was in full control, and that the manoeuvre he started did not entail any mentionable risk. Flying conditions were good, and he was familiar with the area.

2.5.2.3 With a relatively steep bank to start with, it may be difficult to discover if the bank angle increases further when flying at low height surrounded by higher terrain. This description fits with the situation for LN-OXC. The AIBN thus believes that it cannot be entirely ruled out that the roll angle in the turn increased and the flight path changed without the onset of servo transparency.

2.5.2.4 The Accident Investigation Board believes that most people would experience a helicopter flight as spectacular enough in itself, and supports the statement from one of the respondents in the anonymous questionnaire survey that it is not necessary to manoeuver aggressively or low to give the passengers a thrill. One example illustrating the risk of low flying and aggressive manoeuvring, took place in a different Norwegian helicopter company in 2004 during a sightseeing flight. The main rotor touched a rock as the helicopter passed low over a mountain ridge when the pilot wanted to give the passengers the feel of being sucked into the chasm behind the ridge[24].

2.5.2.5 The autopsy of the commander showed no signs of illness or intoxicants or sedatives, and the Accident Investigation Board believes that the available information provides no reason to assume that his alertness or judgment was significantly impaired due to lack of sleep. Trials have shown that a full night without sleep has little effect on the quality of work on the next day, assuming that you are not already exhausted from lack of sleep before the sleepless night[25]. Although he slept little on the last night, he slept well the night before. He probably also slept for a while in bed before noon, which would have been beneficial. The witness statements also indicate that the commander was awake, alert and in a good mood.

2.5.2.6 As regards whether the commander suffered an epileptic seizure during the flight, the Accident Investigation Board builds on the assessment from the medical experts, who state that this would be speculation (cf. 1.13). The abnormal findings were more than five years old, and the commander had passed routine medical examinations repeatedly after this. His immediate family had no knowledge of any seizures or loss of consciousness. Witness statements to the effect that the helicopter was about to level out just before it hit the ground also indicate that the commander was not incapacitated.

2.5.3 Underlying conditions

2.5.3.1 The commander is responsible for exercising sound pilot judgment and keeping within sufficient safety margins, but there may be underlying factors. Risk acceptance will in practice be influenced by the norms in the company in question, and the industry in general. The probability of an accident occurring as a result of judgment errors will therefore increase if risk behaviour is common in the organisation. This indicates that the safety culture of the organisation can have a large influence on individuals' attitudes.

2.5.3.2 In the anonymous questionnaire survey conducted by the AIBN, only 12% of the pilots in Airlift stated that they had never flown extra low and/or manoeuvred aggressively to give passengers a thrill (cf. 1.17.3.10). 68% of the pilots said that they had rarely taken part in such behaviour. The survey did not specify any time perspective, and we therefore do not know

[24] *No one was injured in this accident. The pilot immediately entered autorotation and completed a successful emergency landing, cf. report SL2005/13.*
[25] *Myhre, G. (2000). Flypsykologi, Oslo: Gyldendal norsk forlag*

when this happened and whether the frequency has changed over time. (More potential sources of error are discussed in Item 2.9). It is, however, worth noting that everyone with a low number of flying hours (less than 500 hours) had taken part in such manoeuvring, indicating that this is not something that only happened in the past.

2.5.3.3 Although the replies to the questionnaire survey give the impression that reckless manoeuvring happened rarely in Airlift, the AIBN believes that it is necessary to acknowledge that all behaviour that reduces safety margins lead to increased risk. The margins are reduced, regardless of how the individual perceives the situation as it happens. It becomes more vulnerable to errors and upsets, and such passenger transport will not be as robust as it must be to achieve and maintain a safety level comparable to other air transport. In spite of the AIBN not having any databases to compare the results of the questionnaire survey with, a certain impression has formed after investigating a number of helicopter accidents in similar operations in the last decades. The Accident Investigation Board has no reason to believe that risk behaviour is rarer in other companies than in Airlift.

2.5.3.4 After the accident with LN-OXC, Airlift has introduced specific company limitations to prevent similar accidents in the future (cf. 1.18.8.3). Less is now left to the pilot's judgment at low height with passengers on board, as specific limits have been set for extreme flight attitudes and starting a descending right turn without first lowering collective is not allowed. By distinguishing between manoeuvring in right and left turns, the company has implicitly taken into account special hazards associated with servo transparency. The AIBN sees a possible additional favourable effect in that the mentioned measures can make it easier to say no if a passenger encourages aggressive manoeuvring.

2.5.3.5 It can be asked whether the measures are too narrowly focused and specifically aimed at what may have been causal to this accident. It is timely to point out that servo transparency is not limited to passenger flights, and the AIBN believes that the company should evaluate more risk behaviour aspects. Other measures implemented or considered by the company are discussed in Ch. 2.9.

2.5.3.6 Whether introducing the specific company limitations earlier could have prevented the accident is hard to say for certain. This depends on compliance, and the options to monitor this are currently very limited. One sign of a successful safety culture is that individuals choose to do things right, even when no one is watching.

2.5.3.7 The limitations introduced by Airlift after the accident can be claimed to have been implemented with the benefit of hindsight. Ideally, a well-functioning safety management system will uncover any risk behaviour and other safety issues without there having to be an accident first. The persons responsible will uncover and acknowledge that there is a problem and implement the necessary preventive measures and monitor their effect. The AIBN doubts that traditional noncompliance reporting systems would uncover any inclination towards unauthorised manoeuvring with passengers on board, flights at low height or "pressing on" in reduced visibility. This is due to the fact that the persons involved do not consider the situation to be a noncompliance as long as everything goes well. This is exactly why more tools such as recorders and "creative distrust" are necessary to identify risk areas. If an inclination towards unauthorised manoeuvring really was a major problem in Airlift, the AIBN believes that it would have been expressed more clearly in the anonymous questionnaire survey performed after the accident.

2.5.3.8 Minimising risk is what makes a system robust enough over time to achieve and maintain a stable high safety level. In order to achieve absence of risk to the extent expected in passenger transport, it is necessary to combat even a low prevalence of unacceptable risk behaviour. The AIBN believes Airlift should be commended for introducing measures that may be unpopular, but which reduce the risk in passenger transport.

2.5.3.9 How to identify and manage threats in own operations is a key issue in safety management. This is discussed in the President's message in the May 2012 issue of the monthly journal Aero Safety World. President and CEO William R. Voss, launches the following simple test:

1. *What is most likely to be the cause of your next accident or serious incident?*
2. *How do you know that?*
3. *What are you doing about it?*
4. *Is it working?*

2.5.3.10 The Accident Investigation Board agrees that unless you can provide honest answers, based on documented risk assessments, to these four questions, you do not have an effective Safety Management System.

2.6 The probability that servo transparency was encountered

2.6.1 Introduction

There are no technical findings that can prove whether servo transparency occurred in retrospect. Available information for evaluating the probability of onset of the phenomenon was in this case witness descriptions, GPS positions, tracks on the ground, wreckage examination, helicopter mass and atmospheric conditions. Even when considering these sources together, there is not enough "evidence" to conclude. A flight recorder would have provided opportunities for establishing what happened with more certainty. This is discussed in more detail in Item 2.11. The following sections discuss the probability of servo transparency occurring in the turn and at the end of the sequence, just before ground impact.

2.6.2 Probability of servo transparency occurring in the turn

2.6.2.1 The witnesses' description of the helicopter starting a tight turn while flying at a relatively high speed in a shallow descent indicates a markedly increasing g-load. The question is whether the load on the main rotor exceeded the forces where servo transparency is encountered under the prevailing conditions. Tests and simulator flights performed by the operator after the accident indicate that LN-OXC may have experienced servo transparency resulting in partial loss of control, assuming that the collective was not reduced sufficiently before starting the turn (cf. 1.18.6 and 1.18.8).

2.6.2.2 As part of this investigation, the AIBN has prepared charts that do not exist in the manufacturer's manual or training programme, but which specify and quantify relevant relationships in this case (cf. Item 1.18.4). Table 4 and Figure 18 indicate where the onset threshold load for servo transparency was at different speeds. The fact that the threshold for LN-OXC was 130 kt at approx. 1.6 G, while it would have been approx. 1.85 G in standard atmosphere conditions at sea level, shows that the margins are narrower at higher altitudes. The background for the differences is that high mass and low air density require a larger angle of attack for the rotor blades to create lift. Thus, the hydraulic system reaches its limitation earlier, causing servo transparency to occur during less abrupt manoeuvring (cf. 1.18.1). With passengers on board, manoeuvring that results in loads of 1.5-1.6 G can be termed as unnecessarily abrupt, but not evidently hazardous[26]. The AIBN believes that the manoeuvring in the turn at the altitude in question may have been abrupt enough to encounter servo transparency.

2.6.2.3 It is possible to estimate a probable flight path where the load does not exceed the onset threshold for servo transparency, as Eurocopter did. The AIBN believes these calculations were useful to attempt to explain the course of events, but that this does not provide a clear and unambiguous explanation. There are major or minor sources of error associated with variables such as speed, bank, descent rate, torque and turn radius. The AIBN believes that by changing one or more variables it is possible to make calculations showing that LN-OXC was exposed to loads higher than the onset threshold. For example, if a steeper turn was used in the calculation, as claimed by the witnesses. The speed LN-OXC had upon impact also seems to have been higher than Eurocopter expected on the basis of calculations (cf. 2.2.4). In this connection, the AIBN also refers to the AAIB's comments regarding increasing turn rate and less speed reduction than expected if servo transparency occurs in a right turn (cf. 1.18.7.2).

2.6.2.4 In its report, the AAIB has described how there is a risk of the bank angle increasing to more than 90° in a right turn, without the pilot having time to react if servo transparency occurs. During the demonstration flight at Gardermoen, the bank also became significantly greater in a right turn than in a left turn (cf. 1.18.3.4). Although it could not be directly measured when the phenomenon occurred and how much of the bank angle was a result of servo transparency during this demonstration, these experiences support the theory of a significant difference between the effect of servo transparency in right and left turns. The AIBN finds basis for making a recommendation in this connection. The need is discussed in more detail in Item 2.8.5.

2.6.3 <u>The probability of servo transparency occurring at the end of the sequence</u>

2.6.3.1 The speed when the helicopter impacted the ground has been calculated at approx. 105 kt, higher than the minimum speed for inducing servo transparency. When the ground approaches, you instinctively raise the collective and pull the cyclic back. The AIBN believes that the load on the main rotor quite certainly caused servo transparency to either occur or persist until right at the end of the sequence, when the commander became aware that LN-OXC was too low with a too high angle of bank and sink rate and it was necessary to correct this quickly. In such a case, servo transparency will directly resist the pilot's attempts at levelling out the helicopter, but the forces on the controls are not greater than what the pilot can overcome in an emergency (cf. 1.18.2).

2.6.3.2 Whether servo transparency occurred earlier in the sequence or not is of no importance for the observations related to the last few seconds before impact. As the situation developed for LN-OXC, with a high descent rate, the margins in any case became insufficient. Instead of the helicopter levelling out at low height over the valley floor, it was still banking and descending when it hit the ground.

2.7 Summary of considerations related to handling and servo transparency

2.7.1.1 The AIBN believes abrupt maneuvering initiated a sequence where the helicopter came partly out of control for a while. The cause of the loss of control cannot be determined with

[26] For purposes of comparison, a turn with a 45-degree bank performed at a constant altitude and constant speed would result in forces equalling 1.41 times acceleration of gravity (G), while corresponding conditions at 60 degree bank gives 2 G.

certainty. Experience has shown that in sharp turns at low height, with poor references to the horizon in certain situations can result in pilots discovering deviations from the planned flight path too late, as the AIBN believes happened in the Kolsås accident (see 1.18.7.3). Another and more likely possibility in the accident with LN-OXC in AIBN's view is that the margins became insufficient as a result of servo transparency.

2.7.1.2 It is a fact that servo transparency occurs earlier when maneuvering at altitude than close to sea level and earlier the higher the mass. Conditions that favored servo transparency were present in combination at the accident with LN-OXC. If servo transparency was encountered in the turn, the cyclic and collective controls would appear to have "jammed" and move respectively to the right and down. The AIBN believes the commander may have been caught by surprise. The flight path was probably affected before he could identify what was happening and intervene. With approximately 90 ° bank a helicopter will rapidly lose altitude before a normal flight attitude is regained.

2.7.1.3 Regardless of what affected the flight path, the height was too low to correct in time to avoid the accident.

2.8 Measures to reduce risk associated with servo transparency

2.8.1 Introduction

2.8.1.1 If Servo transparency is encountered during manoeuvring, it can contribute to a considerable worsening of an already marginal situation and result in it being impossible to recover in time. It is therefore clear that the phenomenon is a safety issue that ideally should be eliminated.

2.8.1.2 As in other cases, it is not possible to provide undisputable evidence to show that servo transparency indeed occurred as part of the accident sequence of LN-OXC. It is, however, a fact that servo transparency will occur on this helicopter type when certain conditions are met. The AIBN believes that this investigation has substantiated that such conditions were most likely present in the LN-OXC accident. Lack of evidence that could prove that it actually occurred must not preclude a proactive approach to this identified safety issue. The listed accidents where Servo transparency is mentioned as a possible or likely contributing factor (cf. 1.18.7), indicates that there is a need for strengthening the safety barriers in this area.

2.8.2 Safety barriers in general

2.8.2.1 The recognised priority regime of manufacturers' safety measures is that barriers built into the design which reduce or eliminate the risk, are most important (Risk reduction by design). Then, if it is not possible to eliminate exposure through design-related measures, the risk must be controlled (Safe-guarding). Technical/physical barriers that protect are preferred over soft barriers such as training, information and warnings (Information for user). The need for additional precautions must also be considered (Source: CEN, 1991. EN 292).

2.8.2.2 In practice, optimal safety solutions will at times entail cost or weight increase that would be unrealistic to implement on an existing helicopter type. If the uncovered problems are not considered to be sufficiently critical to safety to justify retroactive modifications, the knowledge could provide a basis for improvements that are incorporated into the development of new helicopter types or models. The residual risk in existing products must in such instances be managed using simpler and cheaper measures, such as knowledge, training and procedures.

2.8.3 Design safety barriers

2.8.3.1 The users seem to understand that the servos on Eurocopter AS 350 have been designed with limitations to prevent overload, and the principle seems to work as intended. However, it appears to be hard for many to accept that a warning light cannot simply be retrofitted, to give the pilot a warning before reaching the limit. Airlift's internal investigation team called for a warning light following this accident, and the AIBN made a recommendation to consider the possibility of such a light in connection with an investigation in 2001. With the knowledge now possessed by the AIBN, we have an understanding for Eurocopter's rejection of the recommendation to introduce warning lights in the AS 350. As described in Item. 1.6.6.6, the twin-engine version has a completely different type of (double) servos, where a load sensor that triggers the light is integrated. As a result, this cannot simply be installed retroactively on the (single) servos on the AS 350, and it seems impossible to introduce this without completely redesigning the servos.

2.8.3.2 The comprehensive modification where the original hydraulic system on the helicopter type Eurocopter AS 350 is replaced with a dual hydraulic system as described in Item 1.6.6.5 is currently the only possibility to introduce LIMIT warning lights on the helicopter type. A dual system also eliminates the servo transparency problem, but does not prevent structural overload. However, the high costs associated with the modification appears to preclude this from being a realistic alternative for the Eurocopter AS 350, and the Accident Investigation Board believes other solutions or safety barriers must be introduced.

2.8.3.3 If retrofitting warning lights is not possible, the AIBN believes that the manufacturer should ideally find another technical solution that prevent or give advance warning of servo transparency. What solutions could be practicable has not been considered by the AIBN. The AIBN believes awareness of the Servo transparency phenomenon could strengthen safety to some extent.

2.8.4 Soft safety barriers – Training

2.8.4.1 When it is clear that the most effective measures seem to be unrealistic, it is even more important to optimise the factors you can do something about. The manufacturer has an obligation to contribute by providing accurate descriptions of a product and a basis for training of the users, which is important for the quality of the soft barriers.

2.8.4.2 Training in abnormal situations is known to be an effective safety barrier. However, training itself can cause operational risk and wear and tear on equipment. Based on the guidelines from 2010 that describe how instructors should demonstrate it on the Eurocopter AS 350 family, it is clear that the phenomenon can be demonstrated in a left turn in the helicopter (cf. 1.18.5.5). These new guidelines seem to be not too well known in the market, but the AIBN believes that any ambiguity regarding whether training on servo transparency is permitted or not has now been removed. The system is not overloaded unless you fight against the force of the controls so that the phenomenon persists. Fear of material damage should therefore not be an obstacle, assuming adherence to the described procedure.

2.8.4.3 The AIBN has understanding for the recommendation to do the training in a left turn, as servo transparency can then be induced with the lowest load factor and can be claimed to be self-correcting. However, the AIBN would warn that this approach runs the risk of playing down the hazards associated with the phenomenon. If the manufacturer believes that demonstration of the drill in a right turn causes an unacceptable risk or other undesirable effects, then the

AIBN believes that this must be specified. The risk elements, increased bank angle and significant deviation from the flight path, must at least be unequivocally stated in the theoretical review. It is important that the information in the underlying documentation is correct, to provide the pilots with the best possible understanding of what actually happens. The AIBN makes one recommendation in this area.

2.8.4.4 If all hazardous training could be carried out in a representative manner in a simulator, there would be fewer dilemmas to relate to in the form of risk and wear and tear on equipment. As long as simulator availability is poor and not easier or cheaper to use than helicopters, few would voluntarily use such a service. A regulatory requirement would be the best encouragement to speed up development in this area, but appears not to be imminent as far as the AIBN understands. However, there is a general tendency that technology is becoming cheaper, and if dedicated players consider that the use of simulators give a safety benefit great enough to also use it in single-pilot helicopter operations, then this should have a positive ripple effect. The AIBN also believes that the Civil Aviation Authority should review the interpretation of JAR-FCL and the description of «available simulator» in AIC N 39/05 in light of the fact that there is now an approved Eurocopter AS 350 simulator in the US (cf. 1.18.6). It should also be considered whether training could take place in simpler devices than a full flight simulator (FFS).

2.8.5 Soft safety barriers – Information system

2.8.5.1 The changes Eurocopter implemented in the flight manual in 2003 and the service letter that was prepared, typically concerned strengthening soft barriers. The AIBN believes that these were steps in the right direction to raise awareness of servo transparency, but maintains that the information is still deficient. In the AIBN's assessment, it is misleading to claim that the phenomenon is self-correcting without emphasising that this is at the expense of the ability to manoeuvre.

2.8.5.2 In a right turn, the bank increases, the speed reduction is less and there is a risk of a significant deviation from the planned flight path before the situation is resolved. At low height, this can result in an inability to level out the helicopter before it hits the ground. In Eurocopter's opinion the pilots' need for information is covered by the recommended lowering of the collective before commencing a turn (cf. 1.18.1.6 and 1.18.7.2 page 43). The AIBN agrees that this is important information, but is of the opinion that pilots in addition should get a specific warning about the phenomenon being more critical in right turns. This is discussed further in 2.8.5.5.

2.8.5.3 The AIBN does not agree that as the phenomenon does not occur before the helicopter manoeuvres outside applicable limitations, it is unnecessary to warn against servo transparency. As we know, the limitation for servo transparency cannot be measured or found in charts in the flight manual. The AIBN is unable to understand how such a warning could have a negative effect on flight safety, as Eurocopter argued in the reasoning to reject Recommendation 2008-067 from the AAIB (cf. 1.18.7.2).

2.8.5.4 AIBN understands the argument that the information in the flight manual must not be too comprehensive and complicated (cf. 1.18.7.2). In response, the AIBN asserts that charts similar to those prepared in connection with this investigation (cf. Figure 18:), can be useful in raising pilot understanding of the phenomenon and should be included in information material and training programmes. Although the helicopter is not equipped with a g-load indicator and the information cannot be used directly during flight planning or during flight, the charts highlight the effect of important parameters such as altitude and mass in a manner that should be relatively easy to understand.

2.8.5.5 Like the UK Air Accident Investigation Branch, the AIBN continues to believe that there is a need to warn against the risk of unintentional deviation from the planned flight path if servo transparency occurs in a right turn. The AIBN therefore makes a safety recommendation to the effect that EASA should direct Eurocopter to warn against this. To avoid that the information is of a detached, temporary nature, the AIBN believes that a permanent, specific warning in the flight manual is preferable. Any detailed information such as training programmes, information bulletins or circulars should come in addition.

2.9 The company's role and safety-promoting measures

2.9.1 During this investigation, the Accident Investigation Board has not uncovered aspects of Airlift's activities that can be claimed to be directly related to the accident. The AIBN believes that the results from the anonymous questionnaire survey are a reminder that risk behaviour can occur, even in a company where the ‘average’ values are very good. In a complex system such as in aviation, even a one-time misjudgement can turn out to be dramatic if several unfortunate factors coincide.

2.9.2 The title of the questionnaire was “Safety survey Airlift”, and the questions were related to Airlift operations unless otherwise specified. Although the form was reviewed by representative test persons beforehand, some of the questions or response alternatives may have been unclear or ambiguous. The results must accordingly be considered more as indications rather than exact descriptions of reality. A potential source of error in the survey can be that it was held in connection with an accident investigation, and that the respondents have been determined to defend – or blame – their employer to the extent that it affects the honesty of the replies.

2.9.3 In total, the replies in the questionnaire survey in Airlift gave the impression of a pilot corps that was mainly happy with the company's flight safety work in a broad sense. Many pointed out how good Airlift was in comparison with their competitors, and expressed that they "did not deserve" this accident.

2.9.4 The replies which indicated that the pilots working at the main base were more convinced that the management was actively following up that the work is carried out in a safe manner are worth noting. This contributes to demonstrate that the presence of and good access to the operative base manager at secondary bases is correct and important, as Airlift has seen the need for. The AIBN believes this can be particularly important in the follow-up of new employees.

2.9.5 Like the Civil Aviation Authority, the AIBN has got the impression that Airlift operates in a serious manner with well-functioning flight safety management activities. The internal investigation team in Airlift made a major effort, and the recommendations it made seem to have been properly considered by the company's management. In addition to the mentioned company limitations concerning manoeuvring, several measures have been implemented or initiated. The AIBN believes that these measures will further strengthen the safety work (cf. 1.18.8). If Airlift is committed to utilising lightweight recorders and simulators before this becomes a regulatory requirement, this will document their dedication to safety management to an even greater extent.

2.9.6 Another identified area with potential for improvement that the operator has addressed, is flight following. More modern systems with regular, automatic updates of position may provide some insight into how operations take place and be a supplement in search-and-rescue operations. At present satellite-based systems with global coverage, such as Airlift is implementing, are relatively expensive (cf. 1.18.8.6). Cheaper solutions depend on mobile phone coverage to be effective. In this regard, it is regrettable that parts of mainland Norway are still without coverage. The AIBN has previously issued a safety recommendation to establish a mobile telephone relay station at a suitable location in order to ensure communication during rescue missions over large parts of Hardangervidda (SL 2003/19). The recommendation was not accepted, as such decisions are left to the commercial service providers. The Ministry of Justice stated that it had taken note of the case and incorporated it into the work on the Norwegian Public Safety Radio Project.

2.9.7 Another aspect that the AIBN would like to point out is that passenger flights without knowing who and how many are on board can complicate rescue missions. The CAA has stated that Airlift's interpretation of the regulations regarding whether such operations could be considered aerial work, and thus don't require a passenger manifest, is not correct (cf. 1.17.2.2).

2.10 The role of the aviation authorities

2.10.1 One would expect that annual inspections would form part the traditional safety oversight of operators. In light of this, the Accident Investigation Board finds it surprising that it took 2 years and 4 months between inspections of an operator as large as Airlift, with complex operations and multiple bases. Inadequate authority oversight is high on the EHEST list of the main challenges facing passenger transport with helicopters. More modern, risk-based oversight allows for longer intervals between each inspection. Whether the Civil Aviation Authority has based its supervision on one or the other systems has not been looked into in this case, as the AIBN has no reason to believe that inadequate oversight of Airlift was relevant for the accident.

2.10.2 In principle, the AIBN supports all initiatives that are implemented on the national and international levels to improve helicopter safety. The Accident Investigation Board believes that meetings between authorities and operators, such as in a Committee for Helicopter Safety where experiences are shared, can be a positive supplement to traditional oversight activities. However, this contact only has effect when resulting in specific measures with the operators or other players, as assumed by the Committee's mandate (cf. 1.18.9.1). The AIBN is also concerned that a forum such as the Committee for Helicopter Safety – Inland Operations must not become an excuse for the Civil Aviation Authority to scale back on the regular safety oversight activities.

2.10.3 Which measures one can realistically expect from the activities in the Committee, is a subject of interest. It is both complicated and time-consuming to implement regulatory changes under the current international regime. While there may be some areas where there is a need for stricter regulatory requirements to enhance safety, the AIBN's impression is that the greatest challenge facing both authorities and operators is operating in compliance with the existing regulations. This impression stems from various accident investigations the AIBN has carried out over the years, and it is also supported by the findings in EHEST (cf. 1.18.9.2). Several of the items on the list concern deficiencies in safety management work in general, particularly compliance with procedures, as well as inadequate authority follow-up. These are aspects that the Accident Investigation Board believes that the national aviation authority can and should address.

2.10.4 The AIBN believes that community should expect the publicly financial safety study that will be completed in 2013 to provide information that can be translated into higher safety, assuming that the responsible authority demonstrates an ability to act. Much could probably be achieved by establishing an industry standard for Norway and possibly together with Sweden. This could, for example, cover equipment requirements and other measures that are not suited for regulations and/or that would take time to get in place, as well as elements that one believes are not adequately covered in the common European regulations. This could contribute to higher safety levels while ensuring a level playing field. Any industry standard must be complied with by all to be effective. If not, the competitive terms would not be the same for everyone. It must be expected that the hourly cost of onshore helicopter services could increase as a result of such additional equipment and training requirements that are agreed upon.

2.10.5 One example of a safety-enhancing measure that costs nothing and that is probably not realistic to set out in regulations in the short term, are limitations on manoeuvring with passengers on board, as Airlift has implemented. The AIBN believes that it would be advantageous to introduce similar limitations as an industry standard. The Accident Investigation Board believes that such an initiative would fit well with the Committee for Helicopter Safety's mandate, and therefore makes a safety recommendation in this area.

2.11 The need for flight recorders

2.11.1 In order to find the causes of accidents such as the one involving LN-OXC, it would be a major advantage for the Accident Investigation Board to have access to reliable flight recorder data. Traditional, fire and crash-protected recorders are very expensive, relatively large and heavy, and not relevant for installation in light helicopters. Alternatives in the form of lightweight recorders that can be approved for installation in various aircraft types are now on the market and we expect them to become common in the next few years (cf. Item 1.18.9.3). These shall also be protected against damage according to industry provisions.

2.11.2 Without eye witnesses and GPS data, the Accident Investigation Board would have had very little information available in this case. Accident investigation authorities all over the world have often investigated accidents where it has been impossible to establish what happened without access to flight recorder data. The AIBN believes that use of lightweight recorders will be a major step forward that would to a great extent meet the need of safety investigation authorities. The AIBN welcomes that EHEST has started an effort in the technology area, in addition to working on strategies that entail strengthening soft barriers such as standardised procedures and safety management in general (cf. 1.18.9.3).

2.11.3 To make the introduction of technology such as lightweight recorders successful, the authorities must follow up with approval of installations (Supplementary Type Certificate, STC) and regulations that provide sufficient data privacy protection[27]. Other segments of the aviation industry have established arrangements that make it possible to use recorded data in training as well as other proactive safety work, while still respecting the privacy issues. The AIBN believes that the Civil Aviation Authority should play an active role in clearing any obstacles to make Flight Data Monitoring (FDM) for light helicopter operations a reality. The

[27] Use of data from systems that record audio and images from flight recorders in investigations of accidents and incidents is strictly regulated (cf. EU OPS 1.160 (c), EU Regulation 996/2010 and the Norwegian Aviation Act § 12-10.

recommendation in the Accident Investigation Board's report SL2011/08 concerns this issue (cf. 1.18.9.3), and no new recommendation is made to the CAA in this regard.

2.11.4 In preparing this report, the AIBN has, like many other accident investigation authorities in Europe, made a recommendation to EASA to introduce requirements regarding flight recorders on more aircraft than are currently covered by the rules. The AIBN has deliberately avoided specifying the type of recorder, type of aircraft, type of operations or mass categories that should be given priority. Any expansion of the scope of the requirement regarding flight recorders, in the opinion of an investigation authority, is positive. The AIBN expects the aviation authorities to consider a reasonable scope as part of the follow-up activities related to the relevant recommendations.

3. CONCLUSIONS

3.1 Findings

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

b) The mass and centre of gravity were within the permitted limits at the time of the accident.

c) The helicopter was structurally intact prior to impact.

d) The helicopter was destroyed by impact forces and a post-impact fire.

e) Extensive damage to parts of the system prevented meaningful examinations, but it was possible to establish that the engine was delivering power to the rotors when the accident happened.

f) It was possible to verify that key parts of the flight controls were intact prior to impact.

g) There are no indications of any defects or malfunctions in the aircraft or irregularities in its maintenance that could have contributed to the accident.

h) The external cargo basket is assumed to have had minimal negative influence in the form of generally reduced performance for the helicopter.

i) The commander had a valid licence and type rating, and had undergone practical training/demonstration of the servo transparency phenomenon on board the helicopter as part of his education.

j) The autopsy of the commander showed no signs of illness or traces of intoxicants or sedatives, and it is considered unlikely that his ability to work was noticeably reduced due to lack of sleep.

k) A recommendation from a specialist to further examine the commander for epilepsy based on findings in a routine EEG examination in 2005 was not follow up by the Civil Aviation Authority. The requirement for routine EEG examinations when issuing Commercial Pilot Licences was later removed.

l) The commander had no history of illness indicating epilepsy, and it is unlikely that the accident was caused by him being incapacitated by a seizure.

m) Wind, turbulence or meteorological visibility conditions were not factors in the accident.

n) The approach started after passing a ridge, and according to witnesses located at the planned landing site a steep turn to the right towards rising terrain was initiated.

o) During the turn the helicopter was observed with unusually steep bank, estimated at 60-90 degrees. It lost altitude rapidly and deviated from the expected track.

p) The bank angle was observed to reduce before the helicopter hit the ground.

q) A combination of parameters that advance overload of the hydraulic system was in effect, facilitating the onset of servo transparency during excessive manoeuvring.

r) At the actual mass in the ambient conditions, the threshold for servo transparency encounter would be approx. 2 G at a speed of 100 kt and approx. 1.63 G at a speed of 130kt.

s) The particular dangers associated with the helicopter deviating significantly from the intended flight path if servo transparency occurs in a right turn are not described by the manufacturer, neither in the flight manual nor in the training programme.

t) The helicopter hit the ground with an estimated forward speed of approx. 102-107 kt, with a descent rate that gave more than 15 G vertically, and with approx. 45 degrees bank to the right.

u) The impact force caused fatal injury to all persons on board, and an explosive post-impact fire started immediately.

v) The notification of the accident was delayed by the lack of signals from the ELT as well as there being no mobile phone coverage in the area, but neither this nor the extent of the rescue effort had any significance on the outcome.

w) An anonymous questionnaire survey among all onshore pilots and loadmasters based in Kinsarvik and Bringeland gave the impression that the employees were generally happy with the company's flight safety work in the broadest sense.

x) The anonymous questionnaire survey indicated that risk behaviour have taken place. The majority of the flight crew in this company responded that they have been involved in low flying and/or aggressive manoeuvring with passengers on board.

y) The lack of accurate, reliable data gave limited opportunities to establish with certainty what happened during the last part of the flight.

z) Flight recorders are not required for light aircraft such as this helicopter; however, modern lightweight recorders that are approved by aviation authorities are available.

4. SAFETY RECOMMENDATIONS

The investigation of this accident has identified several areas where the Accident Investigation Board Norway sees a need for making recommendations to improve flight safety:[28]

4.1 Safety recommendation SL 2012/08T

Excessive manoeuvring at low height reduces safety margins. Airlift has, following the accident, set a limit for 30 degrees roll and 15 degrees pitch at heights below 500 ft when transporting passengers. As such manoeuvring limitations are not necessarily suited for regulations, one possible measure may be to establish an industry standard.

The Accident Investigation Board Norway (AIBN) recommends that the Civil Aviation Authority, through its role as chair of the Committee for Helicopter Safety – Inland Operations, ensures that an industry standard for manoeuvring limitations is established for passenger transport.

4.2 Safety recommendation SL 2012/09T

If servo transparency is encountered in a right turn, the associated uncommanded right roll and possible pitch-up have the potential to cause a significant deviation from the intended flight path which, if encountered in close proximity to terrain or obstacles, could be hazardous.

The Accident Investigation Board Norway (AIBN) recommends that EASA requires the type certificate holder Eurocopter to issue a warning of the particular hazard when encountering servo transparency in a right turn, preferably as a permanent note in the Flight Manual of the helicopter models in question.

4.3 Safety recommendation SL 2012/10T

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

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

The Accident Investigation Board Norway

Lillestrøm, 1 November 2012

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

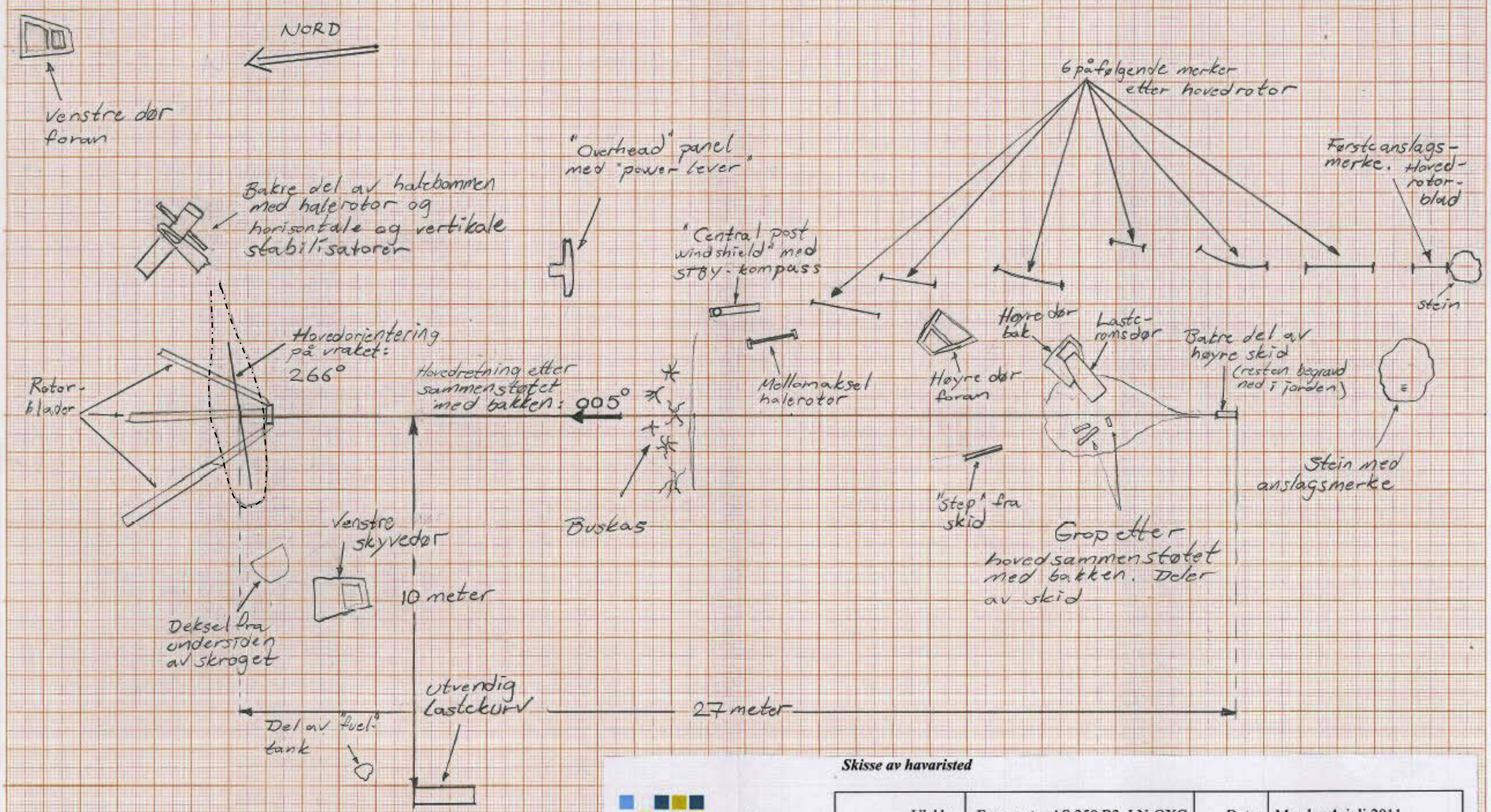
APPENDICES

Appendix A:	Relevant abbreviations
Appendix B:	Mapping of accident site
Appendix C:	Hydraulic system Eurocopter AS 350
Appendix D:	Eurocopter Lettre-Service No. 1648-29-03
Appendix E:	FAA Special Airworthiness Information Bulletin
Appendix F:	UK CAA AIC Helicopter Hydraulic-powered Flying Controls “Servo Transparency”
Appendix G:	The servo transparency phenomenon as presented by Eurocopter's training department

ABBREVIATIONS

AAIB	Air Accidents Investigation Branch
AOC	Air Operator Certificate
AUM	All Up Mass
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
BSL	Bestemmelser for sivil luftfart
CAT	Commercial Air Transportation
CPL	Commercial Pilot’s Licence
CPL(H)	Commercial Pilot Licence Helicopter
daN	DekaNewton
E	East
EASA	European Aviation Safety Agency (EASA)
EHEST	European Helicopter Safety Team
ELT	Emergency Locator Transmitter
GPS	Global Positioning System
hPa	Hektopascal
Hσ	Density altitude
IHST	International Helicopter Safety Team
JAR	Joint Aviation Requirements
KIAS	Knots Indicated Air Speed
Kt/KT	Knots, i.e. Nautical miles per hour
LWR	Light Weight Recorder

m.a.s.l.	Meters above sea level
MCP	Max Continuous Power
MGB	Main Gear Box
MTOM	Maximum Take Off Mass
N	North
OM	Operations Manual
OPS	Operations
PC	Proficiency Check
QNH	Code for atmospheric pressure
RCC-S	Joint Rescue Coordination Centre for Southern Norway
rpm	Revolutions per minute
SOP	Standard Operating Procedure
STC	Supplementary Type Certificate
UK	United Kingdom
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions



Skisse av havaristed

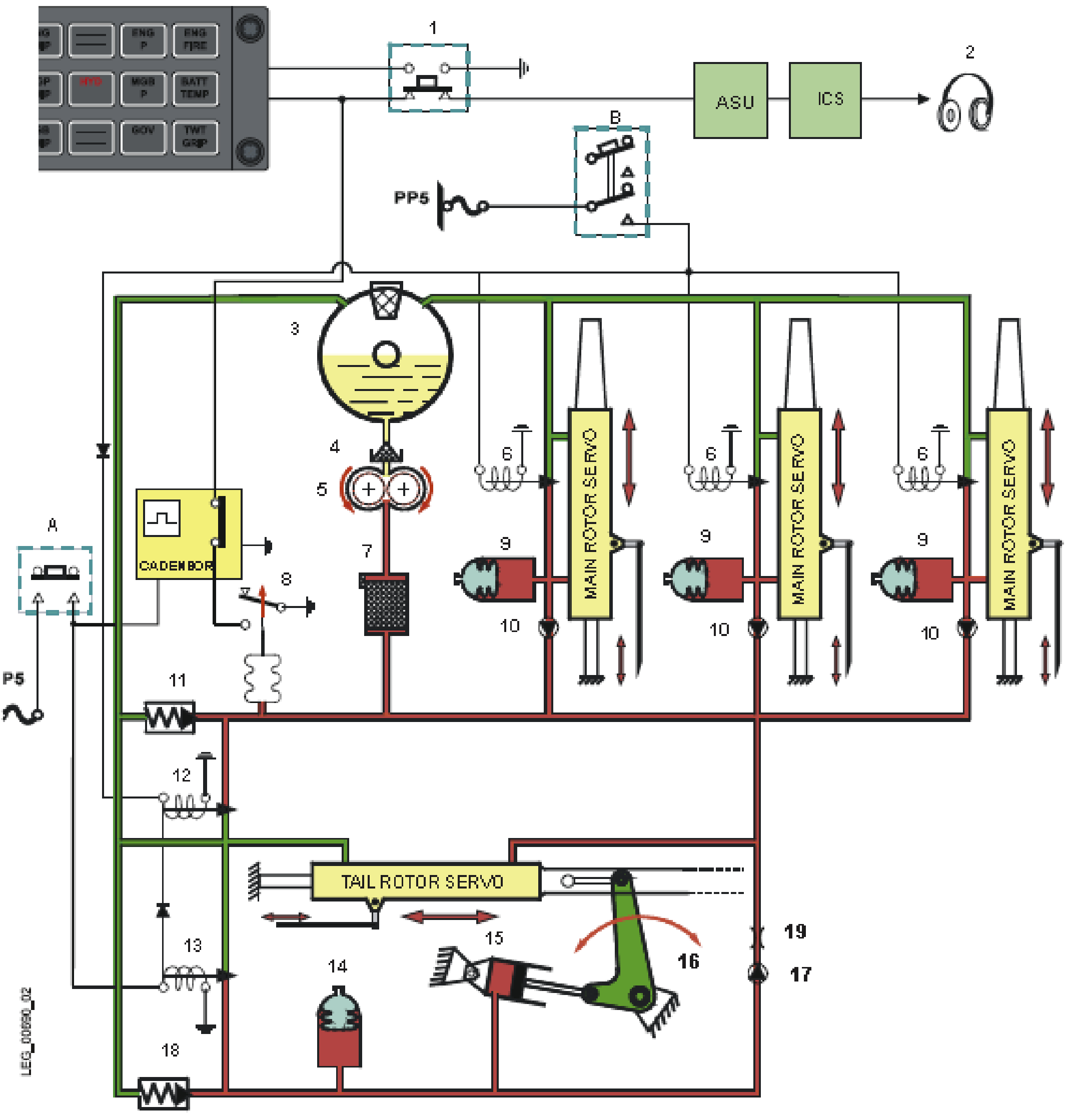
Statens Havarikommisjon for Transport

Ulykke:	Eurocopter AS 350 B3, LN-OXC	*Dato:*	Mandag 4. juli 2011
Sted:	Dalamot i Hardanger	*Posisjon:*	N60°24,442' Ø006°58,311' WGS-84
Høyde over havet:	ca. 950 m	*Skala:*	1:100

Vrak og deler er ikke gjengitt i korrekt skala

10.1.2 HYDRAULIC SYSTEM COMPONENTS AND THEIR FUNCTIONS

Post Mod 073317



1 -HORN pushbutton
2 -Alarme casque
3 -Hydraulic fluid reservoir
4 -Strainer
5 -Gear pump
6 -Main rotor servo actuator solenoid valves
7 -Filter unit
8 -Pressure switch "Low pressure"
9 -Backup accumulators
10 -Main rotor servos non-return valves

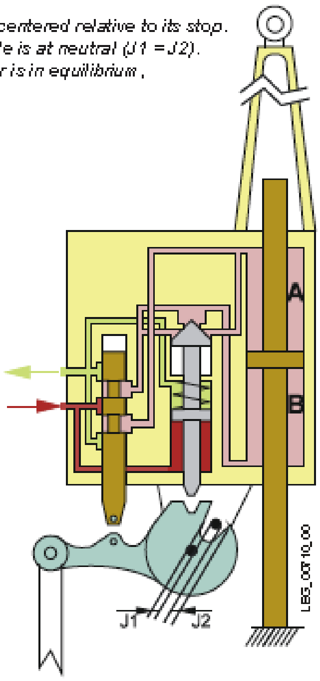
11 Regulator valve
12 -Solenoid valve (Main)
13 -Solenoid valve for discharging accumulator
14 -Accumulator
15 -Hydraulic actuator
16 -Multiplying lever
17 -Non-return valve
18 -Pressure relief valve
19 -Restrictor
A-"HYDRAULIC TEST" pushbutton
B -"Hydraulic cutoff" pushbutton

10.2.1 "SAMM" SERVO ACTUATORS (Cont'd)

(2) Operation

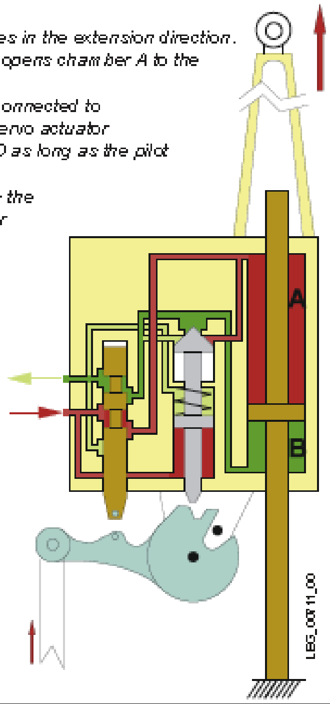
PILOT'S CONTROL STATIONARY

- *The input lever is centered relative to its stop.*
- *The distributor slide is at neutral (J1 = J2).*
- *The servo actuator is in equilibrium, i.e. stationary.*



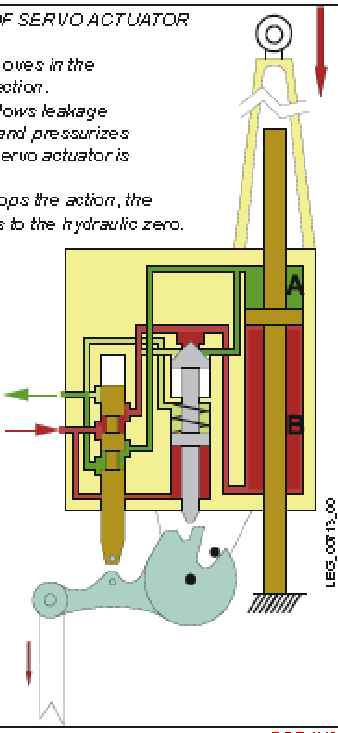
EXTENSION OF SERVO ACTUATOR

The input lever moves in the extension direction. The distributor slide opens chamber A to the pressure flow.
Chamber B is then connected to the return line: the servo actuator remains EXTENDED as long as the pilot maintains his action.
When the pilot stops the action, the distributor returns to the hydraulic zero.



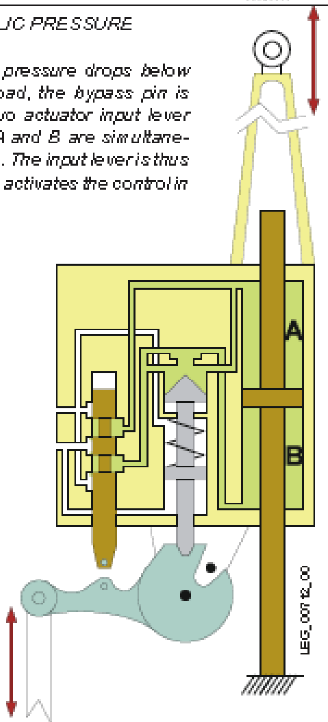
RETRACTION OF SERVO ACTUATOR

The input lever moves in the compression direction.
The distributor allows leakage from chamber A and pressurizes chamber B: the servo actuator is COMPRESSED.
When the pilot stops the action, the distributor returns to the hydraulic zero.



LOSS OF HYDRAULIC PRESSURE

When the hydraulic pressure drops below the bypass spring load, the bypass pin is pushed into the servo actuator input lever slot and chambers A and B are simultaneously interconnected. The input lever is thus blocked and the pilot activates the control in mechanical mode.



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Lettre-Service
No. 1648-29-03

Marignane 04.12.2003

SUBJECT:

350	D	B	B1	B2	B3	BA	BB	L1
550	U2	C2	C3	A2				
355	E	~~F~~	~~F1~~	~~F2~~	~~N~~			
555	~~MN~~	~~UN~~	~~SN~~	~~UP~~	~~AP~~	~~AN~~		
EC 130	~~B4~~							

HYDRAULIC POWER SYSTEM: Servo Transparency

Dear Customer,

This message is being issued as a reminder about the Servo Transparency phenomenon that can be encountered during excessive maneuvering of any single hydraulic system equipped helicopter, if operated beyond its approved flight envelope. This phenomenon is known variously as Servo Transparency or Servo Reversibility, but is referred to here as Servo Transparency. This aircraft phenomenon occurs smoothly and is not dangerous, if properly anticipated by a pilot during an abrupt or excessive high load maneuver such as a high positive g-turn or pull-up. The factors that affect Servo Transparency are airspeed, collective pitch input, gross weight, "G"-loads and density altitude.

<u>What Happens ?</u>

Hydraulic control boost is accomplished by irreversible hydraulic systems, which isolate the pilot from the aerodynamic forces of the main rotor by the use of servos. The loads are transmitted from the blades through the pitch rods to the swash plate assembly. The hydraulic power system counter-acts these forces through the servos. Since this results in zero control forces, artificial pilot control forces are then created by frictions, springs or force-trims. The maximum force the servo actuators can produce is constant and is a function of hydraulic pressure and of the servo characteristics. The system is designed to exceed the requirements of the approved helicopter flight envelope. However, the maximum available hydraulic power must be limited by design to protect the airframe against overstress, if the approved flight envelope is exceeded. With excessive maneuvering and under a combination of the above listed factors, the aerodynamic forces can increase beyond the opposing servos forces and Servo Transparency occurs. The aerodynamic forces in excess of the hydraulic forces are then transmitted back through the control links to the pilot's cyclic and collective controls.

On clockwise turning rotors as on the AS-350 and EC 120, the right servo is the highest loaded when maneuvering (retreating blade), so servo-transparency results in gradually increasing left cyclic control loads required to avoid uncommanded right cyclic motion accompanied by down collective movement due to the general overload on the swash plate assembly. The cyclic and collective control inputs required to counter these control motions may give a pilot who is not aware of this phenomenon an impression that the controls are jammed. If the severity of the maneuver is not reduced, the aircraft will roll right and may pitch-up. The amplitude of the induced control feedback loads is proportional to the severity of the maneuver, but the phenomenon normally lasts less than 2 seconds since the resultant aircraft reaction helps to reduce the factors that contribute to the severity of the maneuver and of the Servo Transparency.

The Pilot's Reaction.

The pilot's reaction to the first indication of control forces feedback should be to IMMEDIATELY reduce the severity of the maneuver. Once developed, Servo Transparency will reduce the helicopter' speed due to some pitch-up, and reduce control loads by induced down collective movement, so the servo transparency phenomenon is self-correcting. The pilot reaction is to follow the control movement and allow the collective pitch to decrease (of course, monitor main rotor rpm speed at very low pitch) to reduce the overall load on the rotor system, and smoothly counteract the right cyclic tendency to prevent an abrupt left cyclic movement as hydraulic assistance is restored.

Pilots should understand that Servo Transparency is a natural phenomenon for a perfectly flyable helicopter. Basic airmanship should prevent encountering this phenomenon by avoiding combinations of high speed, high gross weight, high density altitude and aggressive maneuvers which exceed the aircraft's approved flight envelope. It is a basic rule tells you that it is particularly inappropriate to perform maneuvers which reach and exceed several aircraft limitations simultaneously.

Yours sincerely,

M. SOULHIARD

Technical Support Operations
Customer Service

SPECIAL AIRWORTHINESS INFORMATION BULLETIN

Aircraft Certification Service
Washington, DC

U.S. Department of Transportation
Federal Aviation Administration

No. SW-04-35
December 19, 2003

www.faa.gov - Search "SAIBs"

This is information only. Recommendations aren't mandatory.

Introduction

This Special Airworthiness Information Bulletin alerts owners and operators of **Eurocopter France AS350B, BA, B1, B2, B3, D, AS355E, and EC120B model helicopters**, that the pilot can encounter a phenomenon known as *Servo Transparency, Servo Reversibility, or Jack Stall*. To clarify this concept, we will refer to the phenomenon as **Servo Transparency**.

Reference: Eurocopter Service Letters	
1) For Astar family	#1648-29-03
2) For Colibri family (EC120B)	#1649-29-03

Background

Pilots and operators may misunderstand this phenomenon. This aircraft phenomenon occurs smoothly, and can be managed properly if the pilot anticipates it during an abrupt or high load maneuver such as a high positive g-turn or pull-up. The factors that affect Servo Transparency are high airspeed, high collective pitch, high gross weight, high "G"-loads, and high-density altitude.

The maximum force that the servo actuators can produce is constant and is a function of hydraulic pressure and of the servo characteristics. The system is designed to exceed the requirements of the flight limitations in the approved flight manual. With excessive maneuvering and under a combination of the above listed factors, the aerodynamic forces can increase beyond the opposing hydraulic servo forces and Servo Transparency can occur. An improperly serviced/maintained hydraulic system can also effect the onset of Servo Transparency.

Servo Transparency begins when the aerodynamic forces exceed the hydraulic forces and is then transmitted back to the pilot's cyclic and collective controls. On **clockwise turning main rotor systems**, the right servo receives the highest load when maneuvering, so Servo Transparency results in uncommanded right and aft cyclic motion accompanied by down collective movement. The pilot control force to counter this aerodynamically-induced phenomena are relatively high and *could give* an unaware pilot the impression that the controls are jammed. If the pilot does not reduce the maneuver, the aircraft will roll right and pitch-up.

The amplitude of the induced control feedback loads is proportional to the severity of the maneuver, but the phenomenon normally lasts less than 2 seconds.

Recommendations

- You should review Chapter 14, Aeronautical Decision Making, Rotorcraft Flying Handbook FAA-H-8083-21.

- You should properly service the Hydraulic system before each flight.

- The pilot should follow *(not fight)* the control movement. Allow the collective pitch to decrease (monitoring Rotor RPM, especially at very low collective pitch settings) to reduce the overall load. You should be aware that as the load is reduced, hydraulic assistance will be restored and force being applied to the controls could result in undesired opposite control movement. Follow the aircraft limitations in accordance with the Aircraft Flight Manual.

- You should understand that ***Servo Transparency is a natural phenomenon*** for any flyable helicopter. **BASIC AIRMANSHIP** should prevent encountering this phenomenon by avoiding combinations of high speed, high gross weight, high-density altitude, and aggressive maneuvers, which exceed the aircraft's approved flight limitations.

For Further Information Contact

Mr. James Arnold, Aerospace Engineer, ASW-111, FAA Rotorcraft Directorate, ASW-111 Standards Staff, Fort Worth, Texas 76193-0110; phone: (817) 222-5126; fax: (817) 222-5961; email: james.r.arnold@faa.gov

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HELICOPTER HYDRAULIC-POWERED FLYING CONTROLS 'SERVO TRANSPARENCY'

1 Introduction

1.1 Following their investigation into a helicopter accident involving a UK-registered Eurocopter AS350B2 Squirrel, the Air Accidents Investigation Branch (AAIB) recommended that owners and operators of similar helicopters be reminded of the phenomenon of 'Servo Transparency' (Safety Recommendation 2008-068). There were several other notable safety recommendations made within the report which is referenced and linked below.

1.2 The purpose of this Circular is to draw to the attention of such operators the nature of this phenomenon, which may also be known as 'Servo reversibility' or 'Jack stall'. A full description of this feature is provided below through information issued by Eurocopter in their Service Letter 1648-29-03 dated 14 December 2003.

2 The Eurocopter Service Letter

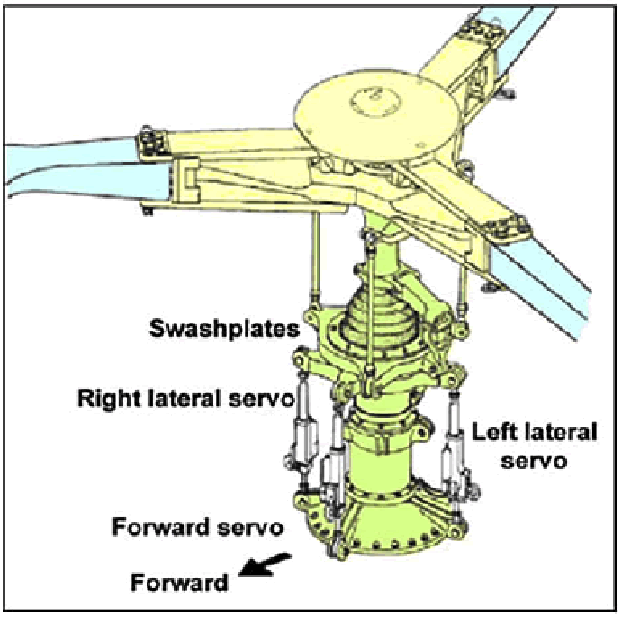
2.1 The content of the Eurocopter Service Letter is reproduced below which, although published for Eurocopter France AS350B, BA, B1, B2, B3, D, AS355E and EC120B models, provides more generic advice for similar types:

> 'This message is being issued as a reminder about the Servo Transparency phenomenon that can be encountered during excessive manoeuvring of any single hydraulic system equipped helicopter, if operated beyond its approved flight envelope. This phenomenon is known variously as Servo Transparency or Servo Reversibility, but is referred to here as Servo Transparency. This aircraft phenomenon occurs smoothly and is not dangerous, if properly anticipated by a pilot during an abrupt or excessive high load manoeuvre such as a high positive g-turn or pull-up. The factors that effect Servo Transparency are airspeed, collective pitch input, gross weight 'G' loads and density altitude'

2.2 **What Happens?**

2.3 Hydraulic control boost is accomplished by irreversible hydraulic systems which isolate the pilot from the aerodynamic forces of the main rotor by the use of servos. The loads are transmitted from the blades through the pith rods to the swash plate assembly. The hydraulic power system counter-acts these forces through the servos. Since this results in zero control forces, artificial pilot control forces are then created by frictions, springs or force trims. The maximum force the servo actuators can produce is constant and is a function of hydraulic pressure and of the servo characteristics. The system is designed to exceed the requirements of the approved helicopter flight envelope. However, the maximum available power must be limited by design to protect the airframe against overstress, if the approved flight is exceeded. With excessive manoeuvring and under a combination of the above listed factors, the aerodynamic forces can increase beyond the opposing servos forces and Servo Transparency occurs.

The aerodynamic forces in excess of the hydraulic forces are then transmitted back through the control links to the pilots cyclic and collective controls. On clockwise turning rotors, as on the AS350 and EC120, the right servo is the highest loaded when manoeuvring (retreating blade), so servo transparency results in gradually increasing left cyclic control loads required to avoid un-commanded right cyclic motion accompanied by down collective movement due to the general overload on the swash plate assembly. The cyclic and collective control inputs required to counter these control motions may give a pilot who is unaware of this phenomenon an impression that the controls are jammed. If the severity of the manoeuvre is not reduced, the aircraft will roll right and may pitch up. The amplitude of the induced control feedback loads is proportional to the severity of the manoeuvre, but the phenomenon normally lasts less than 2 seconds since the resultant aircraft reaction helps to reduce the factors that contribute to the severity of the manoeuvre and of the Servo Transparency.



2.4 **The Pilots Reaction**

2.5 The pilots reaction to the first indication of control forces feedback should be to IMMEDIATELY reduce the severity of the manoeuvre. Once, developed Servo Transparency will reduce the helicopter speed due to some pitch-up and reduce control loads by included down collective movement, so the servo transparency phenomenon is self correcting. The pilot reaction is to follow the control movement and to allow the collective pitch to decrease (of course, monitor main rotor rpm speed at very low pitch) to reduce the overall load on the rotor system and smoothly counteract the right cyclic tendency to prevent an abrupt left cyclic movement as hydraulic assistance is restored.

Pilots should understand that Servo Transparency is a natural phenomenon for a perfectly flyable helicopter. Basic airmanship should prevent encountering this phenomenon by avoiding combinations of high speed, high gross weight, high density altitude and aggressive manoeuvres which exceed the aircrafts approved flight envelope. It is a basic rule tells (sic) you that it is particularly inappropriate to perform manoeuvres which reach and exceed several aircraft limitations simultaneously.

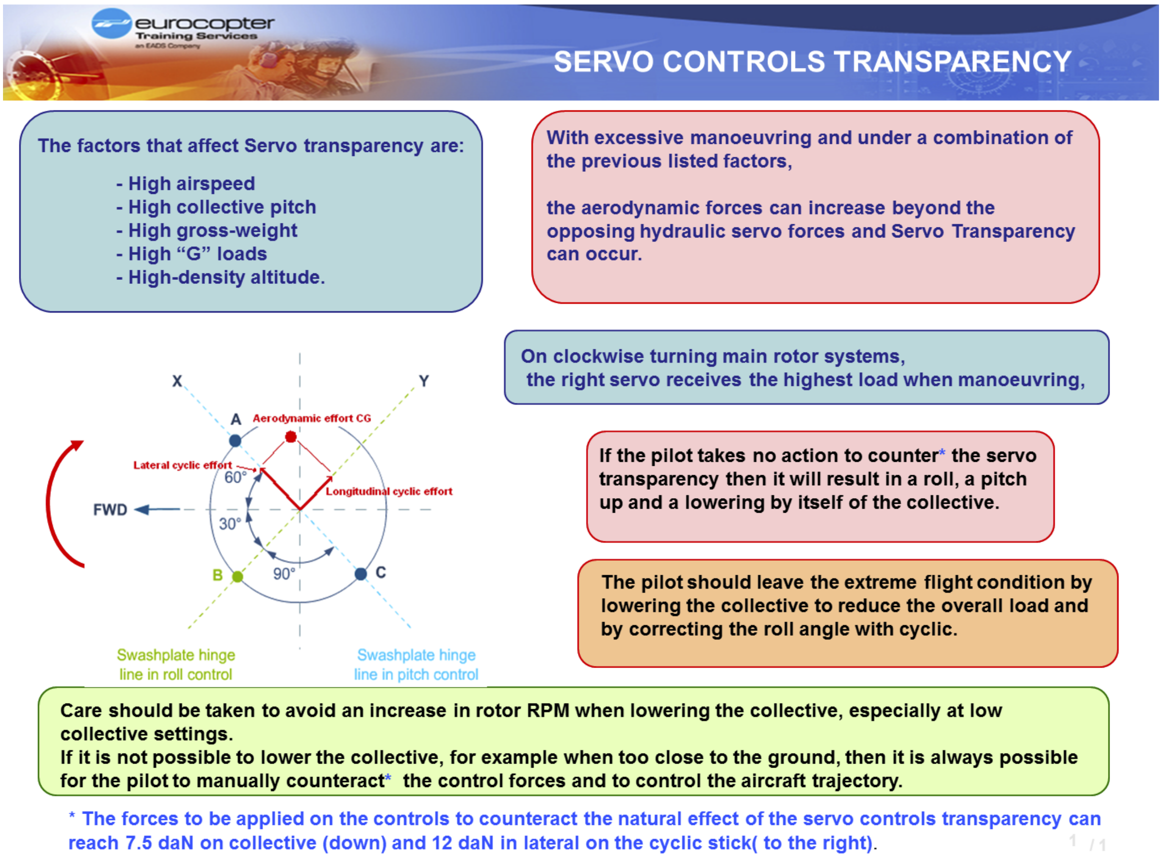
3 Comment

3.1 It can not be emphasised enough that pilots should ensure that they fly their aircraft within the limits published in the appropriate Flight Manual. If these limits are inadvertently exceeded, structural or handling problems may be experienced in any aircraft, and it is important that any recovery manoeuvre should be carried out smoothly, which may require considerable height to complete.

3.2 The Federal Aviation Administration (FAA) Special Airworthiness Bulletin SW-04-35 on the subject of Servo Transparency makes several recommendations including:

a The pilot should follow (not fight) the control movement. Allow the collective pitch to decrease (monitoring Rotor RPM, especially at very low collective pitch settings) to reduce the overall load. You should be aware that as the load is reduced, hydraulic assistance will be restored and force being applied to the controls could result in undesired opposite control movement. Follow the aircraft limitations in accordance with the Aircraft Flight Manual.

The servo transparency phenomenon as presented by Eurocopter's training department



The maximum force that the servo actuators can produce is constant and is a function of hydraulic pressure and of the servo characteristics.

Servo Transparency begins when the aerodynamic forces exceed the hydraulic forces and is then transmitted back to the pilot's cyclic and collective controls.

You should be aware that as the load is reduced, hydraulic assistance will be restored and force being applied to the controls could result in undesired opposite control movement.