Accident Investigation Board Norway

Issued January 2010

REPORT SL 2010/01

REPORT ON AIR ACCIDENT ON 11 MAY 2005 AT KOLSÅS IN BÆRUM, AKERSHUS, NORWAY INVOLVING EUROCOPTER AS 350 B3 ECUREUIL, LN-OPY, OPERATED BY AIRLIFT AS

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Photos: AIBN and Trond Isaksen/OSL

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AIR ACCIDENT REPORT

Type of aircraft:	Eurocopter AS 350 B3 Ecureuil
Nationality and registration:	Norwegian, LN-OPY
Owner:	Aviation Management ApS, Denmark
Operator:	Airlift AS, Norway
Crew:	Male, 26 years of age, minor injuries
Passengers:	6 passengers – 1 fatality, 1 seriously injured, 4 with minor injuries
Accident site:	Kolsås, municipality of Bærum, Akershus, Norway (59º55’59’’ N, 010º30’51’’ E)
Date and time:	Wednesday 11 May 2005, at time 2046

All times given in this report is local time (UTC + 2), if not otherwise stated.

NOTIFICATION

On 11 May, at time 2100, the AIBN was notified of the accident by Airlift’s Flight Operations Manager, who reported that one of the operator’s AS 350 helicopters had crashed at Kolsås with 7 persons onboard, one of whom was severely injured. The helicopter was a total loss. A similar message was received at time 2115 from the Joint Rescue Coordination Center for South Norway. The AIBN arrived at the accident site approx. 1 hour after the accident and began its investigations immediately.

In accordance with ICAO Annex 13 “Aircraft Accident and Incident Investigation”, the AIBN notified the incident to the accident investigation board in the country of manufacture (France). The French accident investigation board, Bureau d’Enquêtes et d’Analyses (BEA), appointed an accredited representative who assisted during the investigation.

SUMMARY

The commander was tasked by his employer Airlift to do an event flight[1] over the Oslo fjord for the company PS-Arrangements. As he was given little other information, he decided to try to find out by himself what the assignment would involve by spending the evening before the flight watching a video of how Airlift had conducted a similar assignment previously. The commander and a load master had carried out several assignments from leaving the base in Kinsarvik in the morning until arriving in Fornebu, Oslo at time 1345 on the date of the accident. After a long break, the manager of PS-arrangements arrived and the helicopter was prepared by the removing the doors and mounting a climbing rope, carabiners and climbing harnesses for fastening in the passengers. The manager of PS-arrangements took active control of how the flight should proceed and the

[1] Event flight is not a defined expression in an aviation context. However, it could be described as a flight designed to give passenger a thrilling experience.

commander decided that the helicopter operator's authority-approved procedures for dropping of parachute jumpers could be used. The helicopter took off at time 2015 and four persons in survival suits jumped into the sea from low altitude. Thereafter, one person climbed a rope from a rubber inflatable boat and up into the helicopter. The assignment over the Oslo fjord lasted approx. 20 minutes.

The manager of PS-arrangements wanted to reward some of his assistants and it was decided to fly a short trip to Kolsås. Four of the passengers were fastened in by rope, and were seated on the floor with their legs outside the cabin. The manager was secured in the helicopter with a somewhat longer rope and placed himself on the floor in the centre of the cabin. The commander considered this flight to be less demanding than the previous one, but still wished to bring the load master along to keep an eye on the passengers. There were therefore seven persons onboard when the helicopter took off after eight minutes on the ground. The first part of the flight proceeded uneventful. They passed south west of Store Kolsås and then Lille Kolsås. Making a right turn towards rising terrain, the commander misjudged the turn in relation to the helicopter's performance limitations and altitude over the terrain. Following an unexpected loss of altitude during the turn, the helicopter hit some treetops resulting in heavy vibrations. In the subsequent emergency landing, the helicopter rolled over onto its side and the manager of PS-arrangements fell out and was trapped under the helicopter. He later died of his injuries.

The investigation has revealed that, over time, a market has developed for event flights for passengers, which has not been particularly regulated by the Norwegian Civil Aviation Authority. In addition, Airlift did not have approved procedures covering this type of operation.

The AIBN has issued one safety recommendation in connection with this investigation.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 <u>Flight planning</u>

1.1.1.1 The commander was at the operator's base in Kinsarvik. On the day before the accident, he was given an assignment for a flight from Fornebu on the following day. It emerged that he would need to contact the events company PS-arrangements for more detailed information. There was little other information about what the assignment involved.

1.1.1.2 PS-arrangements had previously organized event flights in aircraft on several occasions. Airlift was one of several helicopter companies used by the events company.

1.1.1.3 The commander had not previously flown for PS-arrangements. However, he was aware that Airlift had a video available with a recording of a previous flight carried out for the company. He decided to study the video, and see whether it contained information which could be useful for the upcoming assignment. From the base office in Kinsarvik, he logged on to the operator's server and studied the video on the evening before the assignment.

1.1.1.4 Early next morning, Wednesday, 11 May, the commander called the events company and was told that PS-arrangements had been asked to organize a special event assignment over the Oslo fjord. The sailing vessel Christian Radich had been chartered by Helly

Hansen, and Airlift had been given an assignment to fly four persons in survival suits out to the vessel. From a height of a few metres above the water, the four would jump out of the helicopter and be picked up by a rubber inflatable boat (RIB). One person would climb out of the RIB and into the helicopter.

1.1.1.5 The commander has stated that he considered the operator's authority-approved procedures for dropping of parachute jumpers could be used for the assignment over the Oslo fjord.

1.1.2 <u>Flight program on the day of the accident</u>

1.1.2.1 The commander and one of the operator's load masters took off from the operator's base in Kinsarvik and commenced with the following program:

- Kinsarvik – Jukla, positioning flight, departure at time 0825
- Jukla – Jukla, dam inspection
- Jukla – Sandefjord airport Torp (ENTO), positioning flight and fueling
- Torp – Sarpsborg, positioning flight
- Sarpsborg – Sarpsborg, underslung load flight (2 loads)
- Sarpsborg – Drøbak, positioning flight
- Drøbak – Drøbak, underslung load flight (1 load)
- Drøbak – Fornebu, positioning flight, arrival at time 1345

1.1.2.2 When they arrived at Fornebu, the commander and load master relaxed in the helicopter for a few hours. They then went into the centre of Oslo where they had a light meal and enjoyed the nice weather. They were back at the helicopter at around 1800, a couple hours before the next flight.

1.1.3 <u>Assignment over the Oslo fjord</u>

1.1.3.1 Prior to the assignment over the Oslo fjord, the manager of PS-arrangements (hereafter also called passenger "1") came to Fornebu to make some preparations. Although he did not have any flying experience, he had several years' experience in training officers and crew in connection with helicopter flying in the Norwegian armed forces. This meant he had extensive experience in "tactical" low flying and picking up personnel.

1.1.3.2 The commander has stated that passenger "1" took active control of how the assignment would be carried out. In order to obtain maximum space on the floor, the row of seats at the back of the cabin was folded up and fixed to the back wall. In addition, all four doors on the helicopter were removed.[2] Passenger "1" had brought a climbing rope, carabiners and climbing harnesses, which he attached to the cabin floor on LN-OPY. The passengers in the cabin could therefore attach themselves securely in the helicopter during the flight

[2] AS 350 B3 is approved by Eurocopter, CAA-N and Airlift for flying with the cabin doors removed and/or open, with certain restriction, in conditions which include reduced speed.

and disengage themselves before jumping into the sea (see Figure 10: How the passengers were fastened in. The blue rope, which was attached to passenger “1”, was originally approx. 40 cm longer, but was cut during the rescue operation.

1.1.3.3 The load master has told the AIBN that the passengers were given a very detailed safety briefing. They were, for example, shown how to attach and free themselves from their position in the helicopter.

1.1.3.4 The commander decided to bring the load master on the flight so that he could look for high masts etc when flying over the Oslo fjord. In addition to the commander, load master and passenger “1”, there were four other persons on the flight from Fornebu. The load master has stated that the flight was conducted in a “*very calm*” way.

1.1.3.5 The assignment over Oslo fjord lasted 20 minutes from departure from Fornebu at time 2015 until landing at the same location.

1.1.4 <u>The flight to Kolsås</u>

1.1.4.1 Three students from Markedsinstituttet (MI), two women and a man, had helped PS-arrangements organize the assignment over the Oslo fjord. The events company wanted to reward them by way of a short sightseeing trip from Fornebu. The manager of PS-arrangements (passenger "1") wanted to give the students a feeling of freedom and an “adrenalin” experience. A PS-arrangements employee would also join them on the sightseeing trip. Passenger “1” suggested that they fly to the Kolsås hill. The commander agreed, as this is not a populated area and the flying time from Fornebu is short.

1.1.4.2 Between the assignment over Oslo fjord and the departure to Kolsås, LN-OPY remained on the ground for 8 minutes with the rotors turning. During this time, passenger “1” showed the other passengers how to put on their climbing harnesses and sit on the floor with their legs outside the cabin. Passenger “1” then made sure they were securely attached to the climbing rope which was fixed to the centre of the cabin. Finally, passenger “1” attached himself with a somewhat longer rope and knelt in the centre of the cabin. The load master assisted while they where on the ground.

1.1.4.3 The commander has told the AIBN that he considered the sightseeing flight to Kolsås less demanding than the assignment over the Oslo fjord. However, the commander wanted to bring along the load master to keep an eye on the passengers. There were therefore a total of seven persons onboard as they took off towards Kolsås. The commander and load master [3] were seated at the front in the standard aircraft crew seats. The three students (passengers “2”, “3” and “4”), the PS-arrangements employee (passenger “5”) and the manager of PS-arrangements (passenger “1”) sat on the floor in the cabin (see Figure 9 and 10).

1.1.4.4 At time 20:43:43[4] LN-OPY took off from Fornebu and set a course for Kolsås (ref. Figure 1). The commander was quite well acquainted with the municipality of Bærum. The load master and commander followed the map and commented that there was a

[3] AS 350 B3 is certified for flying with only one pilot (single pilot). The load master did not have a formal role as crew member during the flight and has been considered as a passenger.
[4] Times, positions, speeds and the course flown have been taken from the GPS track log. The helicopter’s GPS stores times and positions in the case of significant changes to the route flown. Minor course changes are not registered and the values for the route flown are therefore not exact values. Altitudes were not registered.

power line between Fornebu and Kolsås. The commander has stated that he decided to climb relatively high out of Fornebu because he wanted to reduce noise impacts over the populated area. Passenger "1" used a headset with a microphone and was constantly active in conveying to the commander his wishes as to how the flight should be carried out.

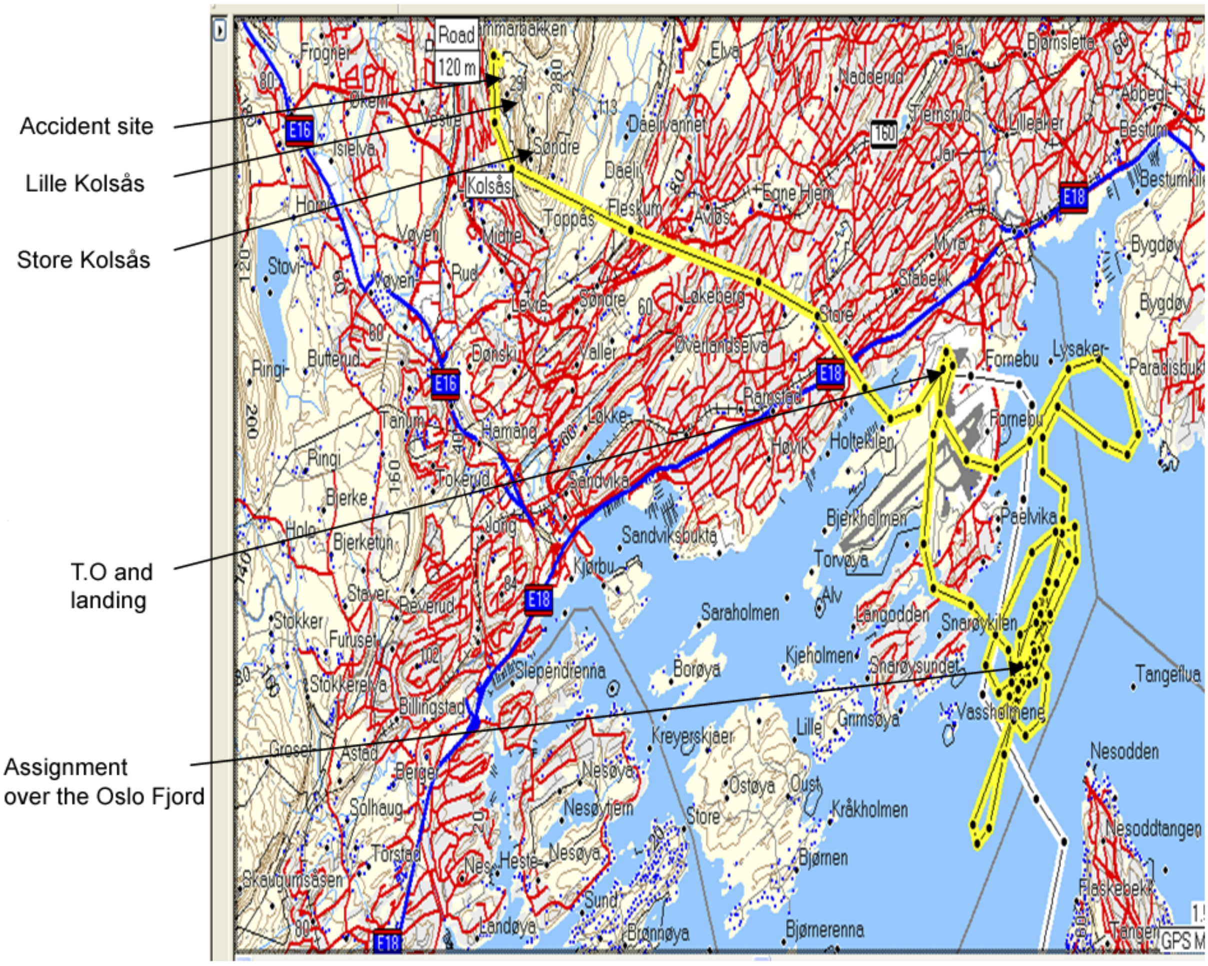


Figure 1: Track log from GPS showing route from time 2015 until the accident at time 2046.

1.1.4.5 The commander has stated that he used engine power of approx. 90% First Limit (9 FLI) during the flight, which gave an indicated air speed of 90 kt (KIAS).

1.1.4.6 At time 20:46:18, after flying for approx. 2.5 minutes, LN-OPY passed southwest of Store Kolsås with the radio mast on its right[5]. According to the commander, the helicopter was then at the same altitude or slightly higher then the radio mast on the top of Kolsås. After passing the radio mast, the commander turned northwest (approx. 330º), followed by a turn to the north at time 20:46:27 (approx. 358º). The helicopter then followed a boundary area between a populated area on the left and forests and Kolsås on the right. The speed at this time was approx. 95 kt. The commander maintained more or less the same altitude from passing the antenna mast until beginning a right turn. The plan was to turn around and fly along the ridge of Kolsås to Store Kolsås for the return to Fornebu.

[5] The radio mast is 116 ft high according to Aeronautical Chart Norway 1:250 000.

1.1.4.7 GPS shows that the turn was commenced at time 20:46:40. Those on board have told the AIBN that the helicopter started the turn with 40 – 45º of bank. During the turn, the bank angle increased to 60 – 70º, according to the commander. There helicopter then flew over rising terrain. When asked whether it had been necessary to make such a steep turn, the commander replied as follows: *"No, that was not necessary to make the turn. It was more a case of adding a thrill factor."*

1.1.4.8 The commander stated that he did not experience any particular g-load, but that the helicopter lost speed during the turn. Towards the end of the turn a "*very high rate of descent*" developed. He further explained that he rolled out of the turn, raised the collective lever[6] and pulled the cyclic back hard. At this point the commander reckons he used all available power from the engine. The helicopter's nose lifted a little, but the helicopter continued to sink. To the commander, it felt as if the helicopter was pushing the air in front of it. The airspeed had become low and he realized that the helicopter needed higher speed to be able to climb. However, there was now insufficient altitude over the rising terrain to allow him to lower the nose and accelerate. He explained that the helicopter was not reacting normally and that positive climb was not achieved. The helicopter continued with a moderate rate of descent and the commander realized that it was going to hit some trees. When asked by the AIBN whether "servo transparency[7]" could have been a contributory factor, the commander replied: *"I can't say for certain, as I was pre-occupied with the rate of descent at the time."* However, he was aware that the controls would become "very stiff" if this phenomenon occurred.

1.1.4.9 After few meters, the helicopter hit some treetops and the main rotor suffered damage. The place is indicated on Figure 2. The commander has stated that the damage to the main rotor resulted in heavy vibrations in the helicopter. The flight controls were imprecise, although the helicopter was still controllable to a certain extent. He said he remembered hearing abnormal whistling or howling noises in the helicopter, but was unable to determine whether they were coming from the warning system, the emergency locator transmitter (ELT) or something else. He feared the vibrations might cause the helicopter to break up, and his assessment of the situation was that an emergency landing was needed as soon as possible.

[6] Handle which regulates the power output from the main rotor. The engine automatically regulates the delivered power in order to try and maintain a virtually constant rotor speed.
[7] See section 1.6 for an explanation of the expression servo transparency.

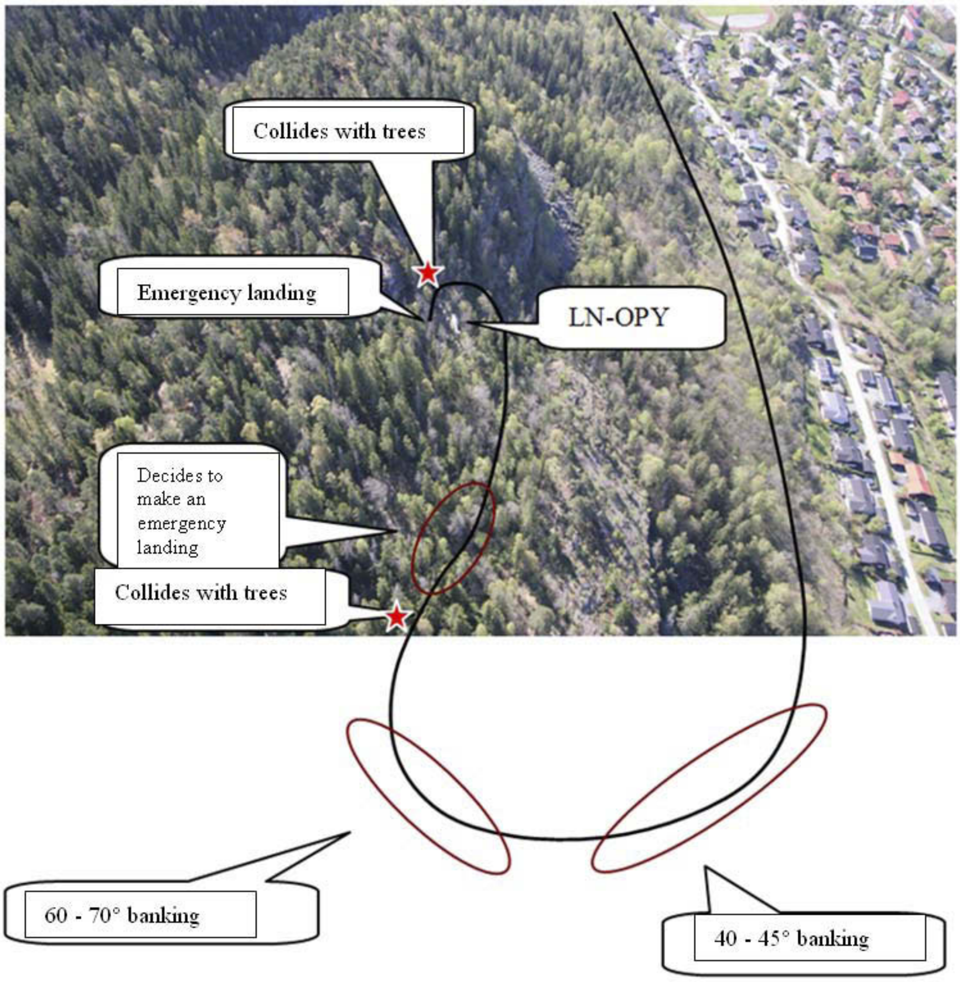


Figure 2: The accident site looking towards the south. Estimated flight path and bank angles are shown. A sports field is visible in the top right corner. (photo: the police)

Figure 3: Kolsås looking towards the northwest. The accident site is indicated by a red arrow (photo: the police).

1.1.4.10 In the first interview with the AIBN shortly after the accident, the commander said "*We had good height over the trees and a good distance to the top*". He also said he had never been in any doubt that there was sufficient horizontal terrain clearance to make a turn to the right. The commander expanded on this by saying: "*There was plenty of clearance, loads of it*".

1.1.4.11 The load master and one of the passengers have given the AIBN supplementary information which on all relevant subjects supports the pilot's statements. The passengers who had been sitting with their legs outside the helicopter said that they tried to pull their legs in and held tight as the helicopter approached the trees. Passenger "3" was hit in the leg by a tree and suffered a broken leg.

1.1.4.12 The commander thought that a landing in the residential area on the right would endanger people on the ground. However, he discovered an open plateau in the steep forest terrain ahead to the left and made an immediate decision to prepare for an emergency landing there. According to his own statement, he entered autorotation[8].

1.1.4.13 The helicopter quickly approached the emergency landing site and continued a few meters beyond the plateau the commander had identified. He was therefore forced to make a steep 180º turn to the left. This was carried out mainly by turning the tail. He

[8] During normal flight, the rotor is driven by the engine. In the case of autorotation, the pilot changes the rotor blades' angle of attack so that the rotor is driven by the airflows (like a windmill). The rotor speed can then be maintained at the expense of altitude.

flared out over the edge, hit some trees on the approach and got the helicopter gently down. The trees are indicated in Figure 2.

1.1.4.14 The flat part of the plateau was scarcely larger than the helicopter's landing gear (see Figure 5). For a moment the commander was elated that had been successful in mastering the autorotation and making an emergency landing in particularly demanding circumstances. However, the vibrations in the helicopter caused it to slide off this ledge and roll over onto its left side. When the main rotor hit the ground, the helicopter turned from a northwesterly to a southeasterly heading. The helicopter came to rest lying on its right side (see Figure 6).

1.1.4.15 When LN-OPY rolled down the plateau and turned round, passenger "1" was flung out through the open side. He landed partly under the helicopter. The other passengers in the back of the cabin were hanging in a heap inside the cabin. The commander and load master had five-point seat belts and were still strapped in their seats.

1.1.4.16 As soon as the helicopter had come to rest, the commander shut down the systems onboard. The load master released his seat belt; the commander followed suit, and they escaped through the broken front windshield on the right side.

1.1.4.17 There was a little smoke coming from the engine, and the load master brought the fire extinguisher from the cockpit and sprayed it onto the engine. As there were no flames, he moved away from the engine, but left the extinguisher there just in case.

1.1.4.18 The commander was in pain and was strongly affected by what had happened. He called the alarm centre (tel. no. 113) to inform them of the accident, but was otherwise not able to help anyone for a short period due to his own pains.

1.1.4.19 One of the passengers that had managed to free him self, the load master and the commander managed to free the other passengers. However, passenger "1" was pinned under the helicopter and it was obvious that his condition was serious. The rope with which the passenger was attached was cut, but he was so firmly wedged that it was still not possible to release him without help. The load master and commander have said they gave the best care they could while awaiting the rescue personnel and doctor.

1.1.4.20 The first police patrol arrived at the wreckage at time 2100, 14 minutes after the accident. They were shortly followed by an air ambulance doctor who immediately began to examine the injured.

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Other
Fatal		1	
Serious		1	
Minor/none	1	4	

1.3 Damage to aircraft

The helicopter was a total loss. See section 1.12 for details.

1.4 Other damage

Damage to a number of trees.

1.5 Personnel information

1.5.1 <u>Commander</u>

1.5.1.1 Male, aged 26

License:	Norwegian CPL (H) valid until September 12, 2010.
Ratings:	AS 350
Limitations:	None.
Medical certificate:	Class 1, valid until November 10, 2005. No limitations.

Table 2: Flying experience Commander

Flying experience	All types	On type
Last 24 hours	6	6
Last 3 days	10	10
Last 30 days	47	47
Last 90 days	96	96
Total	1 768	1 625

1.5.1.2 The commander held a valid commercial pilot license (CPL (H)), and had gained his AS 350 type rating from the European Flight Center, Sandefjord, in March 2000. He subsequently spent a year working as a load master and two years as a pilot at Helitrans on the helicopter type AS 350.

1.5.1.3 In February 2004, he joined Airlift. The operator has said that one of the factors in their decision to appoint the commander was his experience in cargo flights with the AS 350. Both the commander and the operator have stated that he underwent a reduced training program and that the program was adapted to his relatively high level of experience on the helicopter type.

1.5.1.4 His first operator proficiency check (OPC) at Airlift was carried out on February 17, 2004 in an AS 350 B3. Airlift has stated that the OPC went very well, both in terms of the theoretical and the practical disciplines. The next OPC was carried out on August 22, 2004, and the last one on February 13, 2005 (valid until August 31, 2005). A theoretical refresher course on the helicopter type was held on September 5, 2004. A crew resource management (CRM) course was held on February 13, 2005.

1.5.1.5 Airlift carries out many types of operations with its helicopters, and the operator keeps track of the operations individual pilots are authorised to perform. The commander had the following authorisations: company (ferry), air taxi, dropping of parachute jumpers, general cargo flights, transporting of concrete (long line), mast assembly, thermography/power line inspection, forest fire operations and flights to light houses.

1.5.1.6 The commander had a civilian education and had therefore never had formal instruction or training in what in a military context is called tactical low flying[9], i.e. maneuvering the helicopter close to terrain at speed.

1.5.1.7 The commander told the AIBN that while obtaining his AS 350 type rating, he had been made aware of the phenomenon known as servo transparency (see subparagraph 1.6.4). However, he had not practiced for handling the phenomenon. During the commander's induction at Airlift, servo transparency was not re-introduced, as he already had a valid type rating on the AS 350.

1.5.1.8 The commander has been given the highest recommendations by the operator and many colleagues. He has been described as quiet and pleasant to work with. Airlift has told the AIBN that the commander was a proficient pilot and was safety-conscious, reliable and responsible.

1.5.1.9 The commander has stated that he had slept normally during the night before the accident and that he felt rested when his working day started at approx. 0800. In his opinion, there was a normal workload on the day in question. The commander ate a light meal about four hours before the accident.

1.5.2 Load master

1.5.2.1 Male, aged 28.

1.5.2.2 The load master held a valid commercial pilot license (helicopter) (CPL (H)) with an AS 350 type rating. As he did not have any formal role onboard, he is considered as a passenger.

1.5.2.3 It is normal practice in most helicopter companies for a pilot with limited flying experience to start as load master before being offered a position as a commander.

1.6 Aircraft information

1.6.1 General information

Manufacturer:	Eurocopter
Model:	AS 350 B3
Serial number:	3446
Year of construction:	2001
Nationality and registration:	Norwegian, LN-OPY
Certified minimum crew:	1 pilot. Airlift operates the helicopter type with one pilot.
Airworthiness certificate:	Valid until August 31, 2005

[9] Tactical low flying is a wide expression which also includes a number of other elements such as formation flying, delivery of weapons etc.

Accumulated flying time:	2,947 hours
Daily inspection:	Carried out and signed for May 11, 2005, at time 0740
Flying time since last inspection:	Approx. 22 hours since 100-hour inspection
Engine:	1. Turbomeca Arriel 2B
Engine performance:	847 hp (maximum take-off power) 728 hp (maximum continuous power)
Maximum speed (VNE):	155 kt[10]
Fuel:	Jet A1

LN-OPY was equipped and approved for VFR flights, day and night

LN-OPY was certified for maximum 6 persons on board. Eurocopter supplement (SUP.21) for the AS 350 B3 allows the helicopter type to be fitted with a double seat on the front left side in the cockpit. The European Aviation Safety Agency (EASA) has certified that if such a seat is fitted the helicopter type can carry up to 7 persons. As LN-OPY was not fitted with a double seat in the front, it was therefore restricted to carrying a maximum of 6 passengers (ref. "Authorisation Page - Flight Manual" approved by CAA-N on August 9, 2001).

LN-OPY was not equipped with pop out floats for landing on water.

1.6.2 Mass and center of gravity

The calculations below are based on information provided by the commander.

		LONGITUDINAL		LATERAL	
	WEIGHT (kg)	ARM (m)	MOMENT	ARM (m)	MOMENT
EMPTY WEIGHT	1228.80	3.67	4390.52	0.00	2.88
ENGINE OIL	4.70	3.40	15.98		0
Pilot	90.00	1.55	139.50	0.36	32.40
HANG IN EQUIPMENT	23.19	2.29	53.18		0
CoPilot	75.00	1.55	118.25	-0.38	-27.00
Passengers LH (3 and 4)	130.00	2.25	292.50	-0.70	-91.00
Passengers RH (2 and 3)	160.00	2.25	360.00	0.70	112.00
Passenger Middle (1)	80.00	1.95	156.00		0
Fuel	210.00	3.48	729.75		0
Fuel pump	19.00	3.20	60.80	0.80	15.20
Load equipment	46.80	4.60	215.28		0
Door removed LH	-14.00	1.94	-27.16	-0.70	9.80
Door removed RH	-7.80	1.45	-11.31	0.70	-5.46
OPERATING WEIGHT	**2045.69**	**3.17**	6493.29	**0.02**	48.82

The table shows that the mass at the time of the accident was 2,046 kg. The maximum permissible take-off mass is 2,250 kg. In addition, the longitudinal center of gravity was at 3.17 m. With the stated mass, the centre of gravity must lie within the range of 3.18 m

[10] Applies to sea level. VNE is reduced by 3 kt for each 1,000 ft increase in altitude.

– 3.45 m. Based on the assumption that passenger “1” sat at station 1.95 right behind the pilot, this gives a centre of gravity forward of the forward limit. The lateral centre of gravity was at 0.02 m. The limits are - 0.18 m to + 0.14 m.

1.6.3 Hydraulic system and servos for the main rotor on Eurocopter AS 350

Eurocopter AS 350 B3 is fitted with a hydraulic pump which provides 40 bar pressure for the helicopter’s hydraulic systems via a regulator. If the pressure drops below 32 ±1 bar, a red HYD light and a warning horn are activated in the cockpit. To control the pitch angles of the blades on the main rotor and tail rotor, the helicopter is equipped with three main rotor servos and one tail rotor servo. The three main rotor servos are attached to the upper part of the gear box and the swash plate (see Figure 4). The forward servo on the left controls pitch. The left and right lateral servos control the helicopter’s roll movements. All three servos control collective pitch changes. The three main rotor servos are identical and each has its own accumulator (see also appendix F).

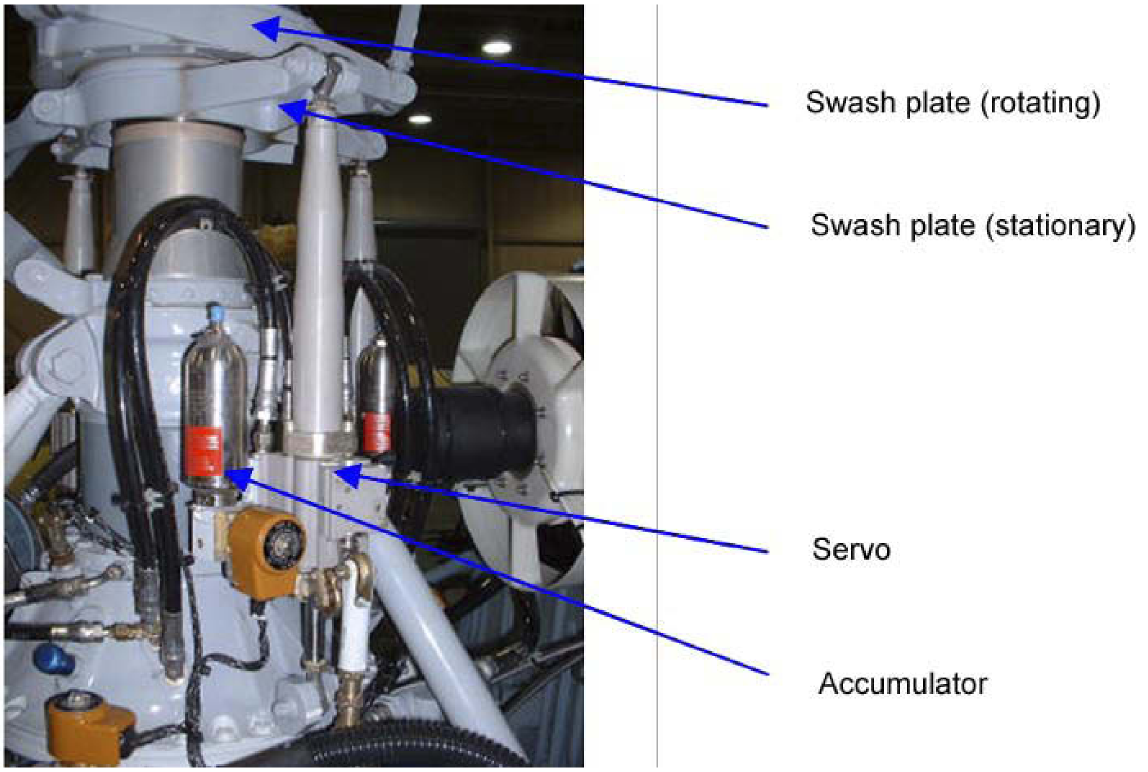


Figure 4: Rotor mast with hydraulic servos, accumulator and swash plates.

The servos on LN-OPY were of the SAMM type with part numbers SC5083 and SC5084 respectively.

1.6.4 Servo transparency (jack stall[11])

1.6.4.1 The hydraulic system on the AS 350 can become overloaded in certain conditions. Below is an extract from the Eurocopter Flight Manual AS 350 B3, Normal operations, Maneuvers-Loads-Servo transparency, section 8.2[12]:

[11] Eurocopter uses the expression servo transparency. “Jack stall” and “Hydraulic lock” are two other terms that have been used for the phenomenon.

"- Maximum load factor is determined by the servo-controls transparency limit.

-Maximum load factor is a combination of TAS, Density Altitude, Gross Weight. Avoid such combination at high values associated with high collective pitch. The transparency may be reached during maneuvers such as 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. The transparency feedback forces are fully controllable, however immediate action is required to relieve the feedback 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…."

The text above is the result of Service Letter SL 1648-29-03, which was issued in 2003, and which gave more detailed information about the phenomenon known as servo transparency.

1.6.4.2 Another extract from the Eurocopter Flight Manual AS 350 B3, Limitations, Approved flight envelope, section 7.3: "Maneuvering limitations":

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

1.6.5 Incidents involving the Eurocopter AS 350 where servo transparency has been a factor

1.6.5.1 The AIBN has investigated an aircraft incident at Hunderfossen in Oppland on January 15, 2001, in which a Eurocopter AS 350 B3, LN-OAK, experienced control problems. A possible explanation for these control problems could have been servo transparency. This is described in report RAP SL 42/2001 (issued in October 2001).

1.6.5.2 The AIBN also refers to the following online reports:

- Accident, October 1994, Eurocopter AS 350 B3, registration ZK-HZP. Report 94-022 from Transport Accident Investigation Commission of New Zealand.

- Accident, October 2001, Eurocopter AS 350 B2, registration N111DT. Report FTW02FA017 from National Transportation Safety Board, USA.

- Accident, February 2005, Eurocopter AS 350 B2, registration C-GNMJ. Report A05F0025 (see sections 1.13.6 and 2.2) from Transportation Safety Board of Canada.

- Accident, September 2007, Eurocopter AS 350 B2, registration G-CBHL. Report EW/C2007/09/06 (see pages 90-) from Air Accident Investigation Branch, UK.

[12] The information about servo transparency for the AS 350 B3 has later been moved to Section 2, Limitations in the Flight Manual.

1.6.6 Type training and maintaining proficiency on the AS 350

1.6.6.1 Eurocopter have stated that they provide thorough training in servo transparency theory at their training center, but there is no practical training in the phenomenon. They justified this by saying it is not advisable to practice maneuvering which falls outside the helicopter's approved flight envelope. In addition, there is no simulator for the AS 350 which would have allowed such training to be conducted safely. Type training and maintenance of proficiency must therefore take place in a helicopter.

1.6.6.2 In Airlift's training manual, both theory and practical training are described for the different emergency situations which can arise with the flight controls. The practice regarding servo transparency training has varied somewhat. Servo transparency training was previously achieved by flying the helicopter in such a way as to make the phenomenon occur. After some discussion at Airlift around the year 2000, it was decided to refrain from demonstrating the phenomenon in practice because in reality this meant the helicopter was flown outside its limitations.

1.6.7 Other information

1.6.7.1 According to the helicopter's Flight Manual, it can be flown with all the doors removed. In this case, the maximum permitted airspeed (VNE) is 110 kt.

1.6.7.2 At the time of the accident there were approx. 45 helicopters of the AS 350 series registered in the Norwegian Civil Aircraft Register.

1.7 Meteorological information

1.7.1 The Meteorological Institute has analyzed the weather conditions in the Kolsås area at the time in question and has provided the following information: Surface wind: SWW 5 – 15 kt. Wind at 2,000 ft: SWW 10 – 20 kt. Precipitation: None. Cloud: 0 – 3/8. Cloud base: Above 5,000 ft. Visibility: Over 10 km. Air temperature: 10 – 12ºC.

1.7.2 An official weather observer who lived to the south of Kolsås contacted the AIBN on the day after the accident. At the time of the accident he heard a loud roar of an engine and ran to a window which faced Kolsås. Through the window he saw a cloud of smoke rising up at Lille Kolsås. He made a note of the time, which was 2047, and made the following weather observation from his home (approx. 2.5 km south of the accident site): Calm. Temperature: 13.4 ºC. Humidity: 35%. Atmospheric pressure (QNH): 1015.7 hPa

1.7.3 The weather observer told the AIBN that the cloud of smoke was slowly drifting towards the southeast. He estimated the wind at the accident site to be from 310º with a speed of 1 kt.

1.8 Aids to navigation

1.8.1 LN-OPY was equipped in accordance with standard regulatory requirements for VFR flights. The flight was based on the use of maps and visual references to terrain, and was not dependent on other navigational aids.

1.8.2 In addition to the standard equipment, the helicopter was fitted with a Garmin 195 GPS and a radar altimeter.

1.9 Communications

1.9.1 As the flight took place in non-controlled class G airspace outside the air traffic services' area of responsibility, the commander of LN-OPY was not required to establish two-way radio communication with air traffic services.

In accordance with AIC N 16/01, which was in force at the time of the accident, pilots flying over the Oslo area (below the controlled airspace) were required to transmit their position blind and to monitor on frequency 122,000 MHz. The commander of LN-OPY transmitted several messages on the helicopter's position on the given frequency. The last message was as follows[13]: *"Oslo, helicopter LPY operating over Kolsås"*

1.10 Aerodrome information

1.10.1 An asphalted area at Fornebu was used for taking off and landing for flights over Oslo fjord and Kolsås. The nearby abandoned airport did not have any aviation aids.

1.10.2 The transponder onboard the helicopter was not in use. The AIBN has received confirmation from Avinor that LN-OPY was not registered on air traffic control's radar for the flight concerned.

1.11 Flight recorders

1.11.1 Flight recorders are not mandatory on this type of helicopter, and LN-OPY was not equipped with a flight data recorder or a cockpit voice recorder.

1.11.2 The helicopter was equipped with GPS, which allowed a track log to be obtained. The track log contained automatic registrations of the helicopter's positions at each major course changes (see Figure 1). Altitudes were not registered.

1.11.3 The helicopter type AS 350 B3 is fitted with a VEMD (Vehicle Engine Management Display). The VEMD replaces a number of traditional analog instruments and includes an instrument which indicates the available power reserves (First Limit Indicator – FLI). In addition, the following engine and aircraft parameters are monitored:

- A rectangular cross-hatched flag: bleed valve open.
- "NG and delta NG": NG and delta NG (gas generator power, difference between Ng and maximum take-off power, as a percentage).
- "T4": T4 (temperature at free turbine intake).
- "TRQ": Tq (engine torque).
- "FLI": first limitation indicator.
- "OAT": outside air temperature.
- "Zp": pressure altitude (Hp) (in PERFORMANCE page).
- ”P2": P2 air pick-off.
- "FUEL QTY": fuel contents.
- "ENG OIL PRESS": engine oil pressure.
- "ENG OIL TEMP": engine oil temperature.
- "BUS": BUS bar voltage.
- "GEN": generator current.
- "START": starter current.

[13] Taken from recordings at the Royal Norwegian Air Force's tower cabin at Kjeller airport.

- "FUEL F": instantaneous fuel flow rate and endurance.
- "SLING": sling load (optional).

1.11.4 VEMDs store error codes when given parameters are exceeded. The AIBN has examined the VEMD which was onboard LN-OPY. The readings showed that no error codes had been registered in the VEMD memory system on last flights. However, there were error codes registered in the memory system as a natural consequence of the accident.

1.12 Wreckage and impact information

1.12.1 The accident site

1.12.1.1 There is a marked boundary between the populated area and the unpopulated area around Kolsås (see Figure 2). In order to avoid unnecessary noise for residents in the area, the commander followed a course over the unpopulated area. The populated area contains closely positioned houses and gardens. Outside the populated area, the terrain is mainly dense forest. The plateau along the top of Kolsås is relatively flat, with a steep slope down to the populated area. There is a sports field approx. 800 meters from the site of the accident; this would have been suitable as an emergency landing site. There are a few car parks which could have been used for an emergency landing in a desperate situation and if conditions had been favourable.

1.12.1.2 The area where the helicopter first hit treetops was a dense spruce forest, approx. 10-meter high. The distance between the first impact and the accident site was approx. 130 meters. The two sites are on virtually the same contour line (approx. 260 meters above sea level).

1.12.2 The helicopter wreckage

1.12.2.1 Very close to the place where LN-OPY hit tree tops for the first time, a 2-meter thin piece of the trailing edge from one of the main rotor blades was found. Parts from the nose were also found; these included the mirror with attachments and pieces from a floor window.

1.12.2.2 Several small parts from the helicopter were found in the area where the main rotor blades hit the trees immediately before of the accident site. The aft part of the tail boom with the tail rotor lay approx. 10 meters above the wreckage on the slope. The tail rotor and fins were damaged, but relatively intact. Large and small parts of the main rotor blades were strewn over an area up to 100 meters from the wreckage. Part of the front right landing gear (skid) was found near the ledge where the emergency landing had been made (see Figure 5).

1.12.2.3 Apart from the broken off parts already mentioned, the wreckage of LN-OPY was chiefly in one piece. The right side of the cabin and the cockpit were seriously damaged (see Figure 7). In addition, the helicopter's nose and underside had been partly compressed and several access covers were broken or torn off (see Figure 8).

1.12.2.4 The engine had relatively major damages. The engine sections were deformed and displaced in relation to each other. The engine mounts were damaged, although the engine was still attached to the fuselage. The gearbox and rotor head were also still attached to the fuselage. The fuel tank showed no signs of leakage. However, a small quantity of fuel had run out of the fuel system's ventilation system. The hydraulic tank was intact, although a small quantity of hydraulic liquid had run out from several places in the hydraulic system.

1.12.2.5 The commander clearly stated that he was not aware of any technical problems with the helicopter which might have contributed to the accident. Nor were any error codes found in the VEMD from the last flight. The helicopter's technical systems were therefore only examined to a minor extent by the AIBN.

Figure 5: The ledge where LN-OPY made an emergency landing. The dotted lines show the position of the helicopter's landing gear. The arrow shows the direction of the helicopter before it tipped over.

Figure 6: Main wreckage seen facing north.

Figure 7: The damaged right side of the cabin.

Figure 8: Damage forward and under the helicopter.

1.13 Medical and pathological information

1.13.1 The commander had a slight pollen allergy, but has explained that he mainly flew in areas which did not require use of allergy medication. On the date of the accident, there was a need for medication as his eyes were swollen. However, he did not have his prescription with him. He has told the AIBN that he purchased and took one Reaktin tablet and a few Diosin eye drops, a non-prescription pollen allergy medication.

1.13.2 Extract from BSL JAR-OPS 3:

> *"JAR-OPS 3.085 (d) A crew member shall not perform duties on a helicopter:*

(1) While under the influence of any drug or psychoactive substances that may affect his faculties in a manner contrary to safety (see also JAR-FCL Part 3 (medical) – 3.035 & 3.040);"

1.13.3 Extract from BSL JAR-FCL 3.040:

"(a) Holders of medical certificates shall not exercise the privileges of their licenses, related ratings or authorisations at any time when they are aware of any decrease in their medical fitness which might render them unable to safely exercise those privileges.

(b) Holders of medical certificates shall not take any prescription or non-prescription medication or drug, or undergo any other treatment, unless they are completely sure that the medication or treatment will not have any adverse effect on their ability to perform safely their duties. If there is any doubt, advice shall be sought from the AMS, an AMC, or an AME. Further advice is given in JAR – FCL 3 (se IEM FCL 1.040)."

1.13.4 In its Operations Manual (OM Part A), Chapter 6 Crew Health Precautions, Airlift has medical references corresponding to those contained in BSL JAR-OPS 3.085.

1.13.5 AIBN has consulted an aeromedical doctor about the consumption of pollen allergy medication mentioned above, and has been advised that this medication does not normally have a negative effect on operational performance.

1.14 Fire

No fire occurred during the accident. However, when the helicopter tipped over, there was a small fuel leakage and smoke emerged from the warm engine. Consequently, there was a risk of fire. Both the commander and load master were concerned about fire, and the load master got the fire extinguisher out and used it for a short while.

1.15 Survival aspects

1.15.1 <u>Rescue work</u>

1.15.1.1 Having received a number of alarms, the alarm center requested two helicopters from Norwegian Air Ambulance's base in Lørenskog, ambulances from Bærum Hospital and fire engines from Bærum Fire Service. Asker and Bærum Police districts were also alerted.

1.15.1.2 The air ambulances arrived at Kolsås after a short time. One ambulance landed close by, and the HEMS crew member and doctor made their way on foot to the accident site where they started the work of stabilizing passenger "1". By 2112, the doctor from the air ambulance had examined everyone onboard and reported that one person was seriously injured, one had suffered a fracture and the others were uninjured. The second air ambulance also landed nearby, and started preparing for flying with the stretcher and HEMS crew member hanging on a line under it. As soon as passenger "1" had been freed from the wreckage, he was placed on the stretcher. The stretcher and HEMS crew member were lifted hanging underneath the ambulance helicopter. The patient was then placed inside the helicopter and flown to Ullevål University Hospital to receive intensive care.

1.15.1.3 Bærum Police Station were notified of the accident at time 2051[14] and sent a large proportion of their available resources to the accident site. The police helicopter was called out at time 2052. The first police patrol arrived at the helicopter wreckage at time 2100 (14 minutes after the accident).

1.15.1.4 The media were quickly informed that there had been an accident, and they arranged for two media helicopters for journalists who would be covering the incident. The first media helicopter (Helidrift 16) operated above the accident site while the ambulance helicopter was lifting up the most seriously injured passenger. In the media, it was reported that the media helicopters had interfered with the rescue operation. The pilot of the air ambulance helicopter which picked up the stretcher passenger told the AIBN that Helidrift 16 had not been a direct nuisance, but that it was an extra factor to take into consideration during an otherwise demanding lifting operation.

1.15.1.5 When the police helicopter discovered that the media helicopter was in the area, they called on radio frequency for the Oslo area (122,000 MHz) to tell them a rescue operation was in progress. They asked Helidrift 16 not to operate below 2,500 ft[15]. The commander of Helidrift 16 complied with the police request. It should be mentioned here that Oslo Control Centre had asked the ambulance helicopter to use a different frequency than 122,000 MHz, and the crew of the ambulance helicopter did therefore not hear the communication between the police helicopter and Helidrift 16.

1.15.2 <u>Passenger safety</u>

1.15.2.1 The commander and load master suffered minor injuries. They had been seated in standard front seats with five-point seat belts. The front seats and seat belts were undamaged.

1.15.2.2 Passenger “1” had been kneeling, forward-facing, on a foam rubber mat. He had been using a climbing harness secured with carabiners to a climbing rope which was attached to the floor (see Figure 10). The rope was so long that the end could reach approx. 40 cm outside the cabin. When the helicopter tipped over, he was thrown through the open door and landed partly under the helicopter. He died a few hours later from crushing injuries.

1.15.2.3 Passengers “2, 3, 4 and 5” were seated on the floor with their legs outside the helicopter, at 90 degrees to the direction of travel. They were secured with climbing harnesses and carabiners which were attached to a relatively taut climbing rope on the floor. They were all exposed to possible injury because there were no doors and because their legs and upper bodies could extend outside the fuselage.

1.15.2.4 Passenger “3” suffered a broken leg when the helicopter hit some trees shortly before the crash. The injury has taken a long time to heal. However, she managed to pull her legs in before the helicopter crashed and did not suffer any further injuries. Passengers “2, 4 and 5” all managed to pull their legs in before the helicopter crashed and they only suffered minor physical injuries.

[14] Information taken from Asker and Bærum Police district “Detailed log”.
[15] Information taken from recordings at the Royal Norwegian Air Force’s tower cabin at Kjeller airport.

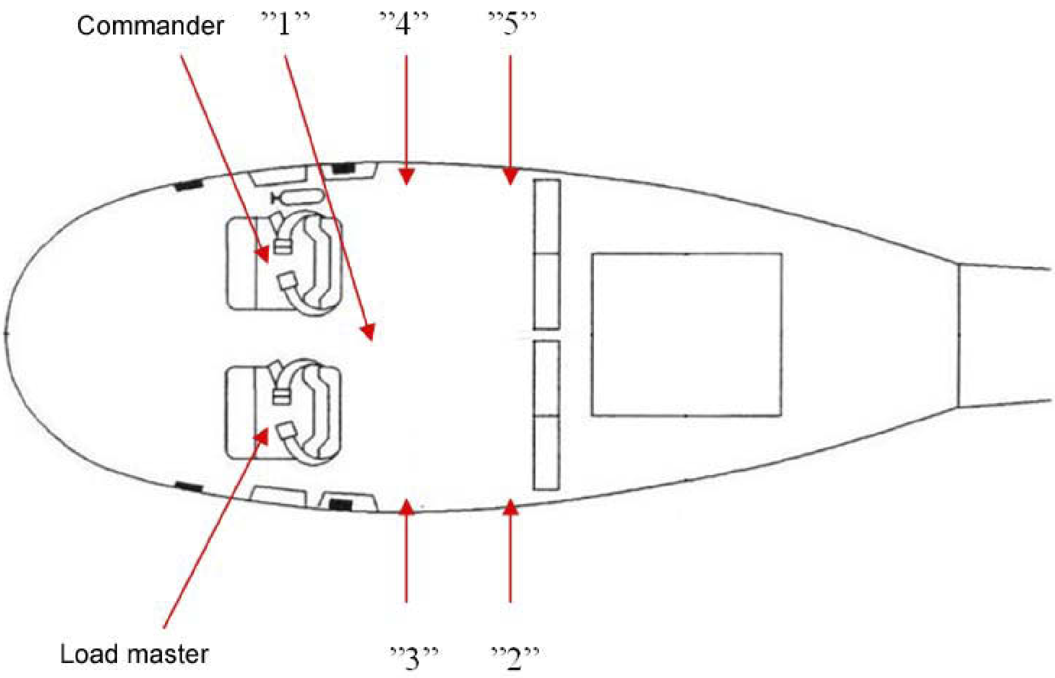


Figure 9: Diagram of the helicopter showing the position of those on board.

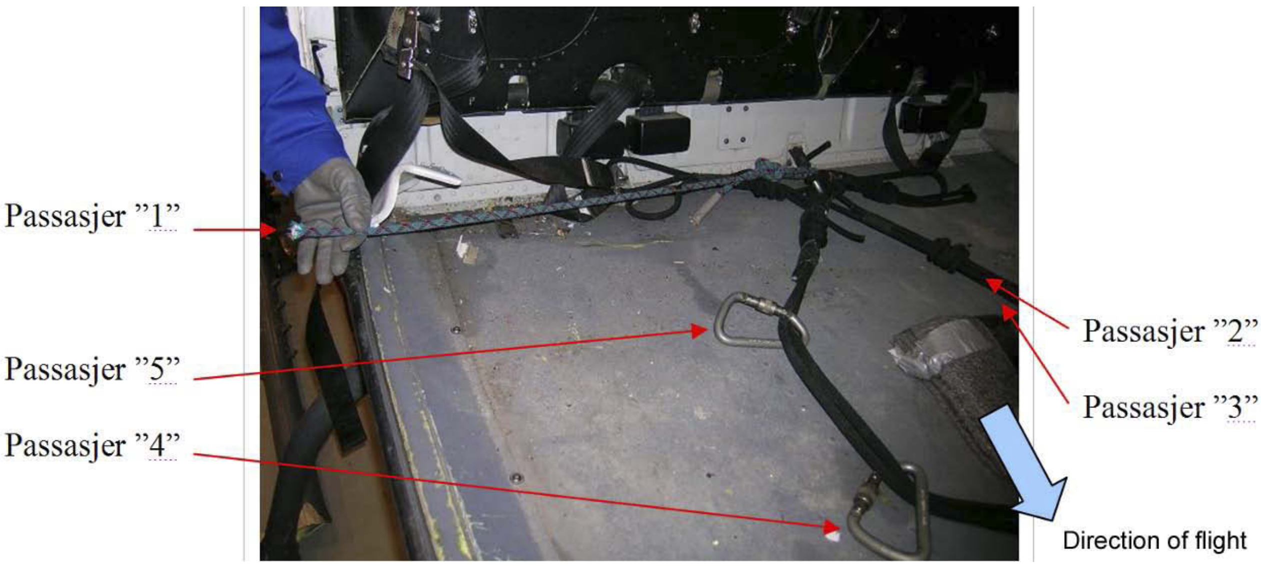


Figure 10: How the passengers were fastened in. The blue rope, which was attached to passenger "1", was originally approx. 40 cm longer, but was cut during the rescue operation.

1.15.2.5 BSL JAR-OPS 3.320 (b) states that before takeoff and landing and whenever deemed necessary in the interest of safety, the commander shall ensure that each passenger on board occupies a seat or berth with the safety belt, or seat harnesses where provided, properly secured. BSL JAR-OPS 3.730 also states that:

> *"An operator shall not operate a helicopter unless it is equipped with: (1) A seat or berth for each person who is aged two years or more; (2) A safety belt, with or without a diagonal shoulder strap, or a safety harness for use in each passenger seat for each passenger aged two years or more;"*

Corresponding provisions are found in BSL D 1-6 § 5 for other transportation of passengers.

1.15.2.6 Airlift's Operating manual (OM A) states that all passengers must occupy a seat and use a seat belt.

1.15.2.7 The AIBN asked CAA-N whether it is acceptable for passengers not to occupy a standard seat or berth. The CAA-N gave the following reply (extract):

> *It is not acceptable, with the exception of parachutists, where special arrangements have been approved. The design and construction regulations are quite clear about this. Each person on board must have a seat which meets defined requirements. Flying with the seats removed or allowing passengers to sit on the floor with some form of restraint other than a seat belt or to use non-approved seats means the aircraft no longer conforms to its type certificate and is therefore not airworthy."*

1.15.2.8 When asked whether it is acceptable for passengers not to use seat belts, but to use some other form of restraint, the CAA-N gave the following reply (extract):

> *"No. With the exception of aircraft approved for parachute jumping, it is not acceptable (and in this case the equipment may only be used by parachutists when a parachute jump is definitely going to take place)."*

1.15.2.9 The AIBN refers to the report on an accident involving C-206, LN-VYN at Huseby airport on June 22, 2007 (RAP SL 2007/34) in which use of alternative seats and seat belts was an issue.

1.15.2.10 None on board was using a helmet. The AIBN does not have any information which indicates that non-use of helmets had any bearing on injuries to those on board in connection with this accident. Use of helmets is not a regulatory requirement. In Part A § 8.1.13.4 of the operator's Operations Manual there is no requirement regarding use of helmets for the type of flying in question.

1.15.3 Emergency Locator Transmitter

The helicopter was equipped with an automatic ELT which activated during the accident.

1.16 Tests and research

None.

1.17 Organizational and management information

1.17.1 CAA-N oversight practices regarding onshore helicopter operations

1.17.1.1 On May 1, 2005,[16] the CAA-N sent a letter to all Norwegian helicopter operators informing them it had decided to increase ad-hoc inspections of aerial work in view of the particular exposure to risk in these types of operations.

1.17.1.2 On May 26, 2005,[17] the CAA-N sent another letter to all Norwegian helicopter operators regarding approval for sightseeing flights. The letter was entitled *"Sightseeing flights – manoeuvring of aircraft and maintaining minimum altitudes"*. In the letter, reference was made to the air accident report SL RAP 13/2005 on an accident during a sightseeing

[16] 11 days before the LN-OPY accident.
[17] 15 days after the LN-OPY accident and 4 days before the meeting with AIBN (see 1.17.1.3).

flight where the commander flew so close to the terrain that the main rotor made contact with the ground. Reference was made to AIBN recommendation no. 17/2005:

”The AIBN recommends that the operator consider whether the procedure for sightseeing flights should be expanded and more closely observed with regard to maintaining minimum altitudes.”

The CAA-N found it appropriate to request all operators to consider the recommendation and if necessary implement measures to prevent flights being carried out in contravention of the regulations. Reference was made to the rules of the air on reckless manoeuvring and minimum altitudes. The CAA-N asked all operators to make their pilots aware of the reminder.

1.17.1.3 The AIBN has kept CAA-N updated on its findings and preliminary analysis in the course of the investigation into the accident involving LN-OPY (cf. Norwegian Aviation Act § 12-20). On May 30, 2005 a meeting was held, in which central CAA-N representatives participated. The AIBN gave a presentation which covered event flights[18], seating and securing of passengers, number of persons on board, limitations regarding the helicopter type AS 350, minimum altitudes and previous accidents. The presentation was aimed at giving the regulatory authority sufficient information to enable them to come up with relevant measures to prevent similar accidents.

1.17.1.4 Shortly after the accident, CAA-N made it known through the media that they were concerned about the ever-increasing “creative” ways of using helicopters.

1.17.1.5 In the CAA-N 2005 annual report, it was announced that oversight of onshore helicopter safety was to be intensified due to the high accident rate. The report also contained details of measures to increase safety (see appendix B). Extract from CAA-N’s annual report for 2005:

“It is an unfortunate fact that risk has become a new industry. CAA-N works actively to get these products regulated.”

“Event flights must be conducted in controlled form, safety training at schools must be strengthened and Scandinavian cooperation must be developed.”

1.17.1.6 However, during the consultation process for the draft report, the CAA-N gave the following comment regarding event flights:

“The CAA-N will not define such a type of flying. Our point of view is that such activities are flights from A-to-A, a type of flight which is sufficiently regulated in existing regulations. The CAA-N can not accept activities which breaches regulations in BSLs or the Flight Manual.”

1.17.1.7 This focus was continued. Extract from CAA-N’s annual report for 2007:

“Measures to promote helicopter safety

[18] “Event flight” is not a defined expression in an aviation context. However, it could be described as a flight designed to give passenger a thrilling experience.

Safety for onshore helicopter flights is one of CAA-N's priority areas. In 2007, CAA-N held safety meetings with several Norwegian companies which operate onshore.

As a member of European Helicopter Safety Team (EHEST) and European Helicopter Safety Analysis Team (EHSAT), CAA-N has a large number of assignments, which include heading the Nordic input in EHSAT."

1.17.2 Airlift AS

1.17.2.1 Airlift was established in 1986, and has a main base at Førde airport Bringeland (ENBL) and other bases in Kinsarvik and on Svalbard. On the date of the accident, the operator had 14 helicopters at its disposal.

1.17.2.2 The operator has a license with an Air Operators Certificate (AOC) no. N-006 based on BSL JAR-OPS 3. The rights cover carriage of passengers and transportation of cargo/goods by helicopter (VFR and IFR). The operator also has an operating permit which includes approval for sightseeing flights, aerial drop, aerial photography and aerial advertising.

1.17.2.3 At the time of the accident, Airlift had its own maintenance organisation with a JAR 145 approval.

1.17.2.4 The most recent CAA-N inspection of Airlift prior to the accident was an inspection of the technical department at the main base in Førde on 3 December, 2004. The most recent inspection of the flight operations department was in Førde on 5 May, 2004.

1.17.2.5 At the time of the accident, the operator's flight operations department was organised as follows:

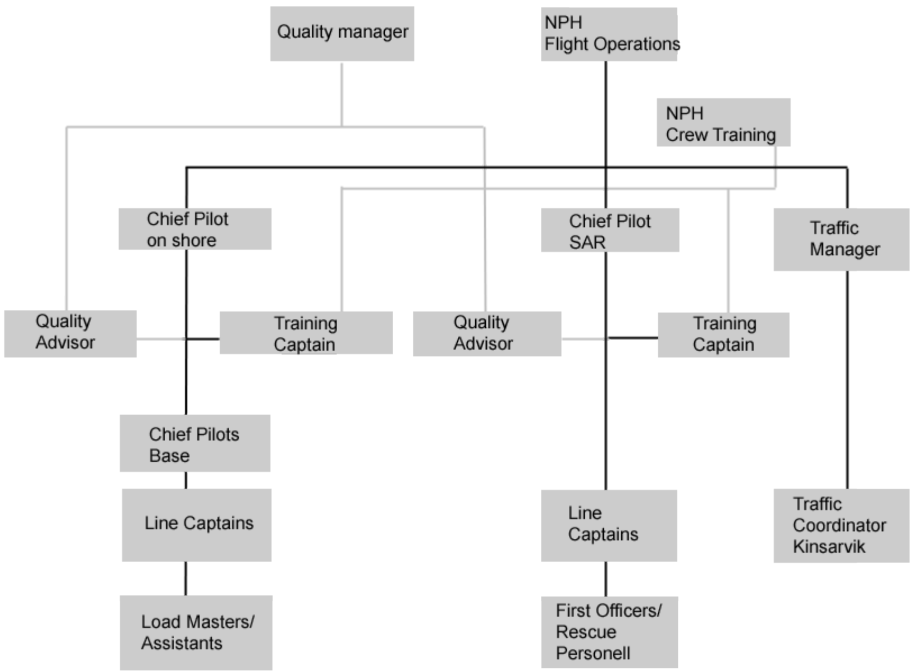


Figure 11: Organisational chart for operations department in Airlift.

1.17.2.6 The day after the accident, CAA-N suspended Airlift's license and operating permit for onshore flights. The accountable manager, quality manager and flight operations manager were summoned to a meeting at the CAA-N head quarters on the same day. As a result of the meeting, Airlift's approval documents were reinstated on condition that all pilots and crew members undergo a personal interview with the operator flight operations manager before resuming flying duties. Immediately after the accident, the operator informed the AIBN that they would not engage in any further event flights.

1.17.2.7 As part of the investigation, AIBN investigators visited Airlift's head office in Førde on 21 June 2005 to obtain information on the operator's organisation and operating routines and on the internal measures implemented as a result of the aircraft accident.

1.17.2.8 Airlift provided information about its flight safety work and submitted the operator's internal report on the Kolsås accident. This report showed that the operator was in the process of implementing three immediate measures and 12 long-term measures as a result of the accident involving LN-OPY.

1.17.2.9 Airlift was informed about circumstances brought to light in the course of the investigation and some of the AIBN reflections on the Kolsås accident. Central topics included event flights, seating and securing of passengers, number of persons on board, limitations with the helicopter type AS 350, minimum altitudes and previous accidents. Information was provided to enable Airlift to quickly implement relevant measures in order to prevent similar accidents.

1.17.2.10 Airlift informed AIBN that in the period following the accident, the knowledge gained from the Kolsås accident was used for further development of the operator's flight safety program and the transfer of experience to its pilots.

1.17.3 <u>Authorisation of Airlift's flights</u>

1.17.3.1 The operator's Operating Manual (OM A) states that all flights must be authorised by a senior pilot or on-duty manager in the flight operations department. It was delegated to the traffic coordinator and commander to authorise charter flights, passenger flights and normal aerial work as described in the operations manual, and for which commanders are qualified in accordance with a list. The authorisation system is part of the operator's operational monitoring and control system and is approved by the CAA-N.

1.17.3.2 The assignment over Oslo fjord was authorised as a standard assignment and was not subject to any separate risk assessment by the operator. The operator did not know about the flight over Kolsås and subsequently it could not have been subject to the operator's evaluation.

1.17.3.3 Authorisation of special flights is described in chapter 2.4.8 of the OM A.

> *"Operations Manager or respective Chief Pilot shall authorise special flights. Special Flights are defined as:*
>
> *a) Flights not described in Operations Manuals or flight of such a nature that they require special preparations, such as: Special permit from authorities (closing of streets, landing in populated area, night flights VFR with single engine helicopters, sling operations over populated areas etc.), special equipment, flights to vessels, not including large barges and semi-*

submergible installations with a slow rate of pitch and roll, are considered as special flights."

1.17.4 Airlift's routines for flights with parachutists

1.17.4.1 As mentioned in section 1.1.1.5, it was the commander's opinion that he could use the operator's authority-approved procedures for dropping of parachutists for the mission over Oslo fjord and the flight to Kolsås. The commander was one of the operator's qualified pilots for parachute flights. Airlift had obtained approval for use of AS 350s for parachute flights based on approval for aerial drop flights. Flights with the doors removed or open are allowed, provided restrictions in the helicopter's Flight Manual are followed.

1.17.4.2 Routines for parachute flights include a requirement for the commander to check seat belts/attachments and remove cushions and other loose objects from the cabin before the flight. Parachutists must use seat belts or other approved restraint devices during the flight. BSL D 4-2 §9(2) e) states that the restraint method is part of the approval of the parachute flight routine. An 'approved restraint device' refers to a specific restraint device used to fasten in parachutists. This was not the equipment used on the date of the accident.

1.17.4.3 The routine for parachute flights describes the minimum drop altitude as 3,000 ft and maximum drop altitude as 10,000 ft unless otherwise approved by the flight operations manager. The rest of the procedure text in the operations manual is of little relevance to the flight on the date of the accident.

1.18 Additional information

1.18.1 Regulatory requirements for parachute flights

1.18.1.1 BSL D 4-2 describes the requirements regarding dropping of parachutists:

"§ 3. Definitions:

In this regulation the following definitions apply:

Parachute jump: All forms of planned jumping from an aircraft for the purpose of using a parachute during all or parts of the descent.

(b) Parachutist: A person making or about to make a parachute jump.

…..

§ 9. Aircraft requirements

An aircraft which is used for parachute jumps must have procedures approved by CAA-N for dropping parachutists.

(2) Applications for approval of routines for aircraft which will be used for dropping parachutists must include the following documentation:

a) flight manual;

b) information on the aircraft's empty weight and centre of gravity in the configuration that will be used for dropping parachutists;

c) a diagram showing the position of the parachutists in the aircraft with given moment arms;

d) information on the take-off weight and centre of gravity at the critical combination of fuel, number on board and their position in the aircraft;

e) technical data for restraining of parachutists in cases where the aircraft will not be used in a standard configuration; and

f) reference to any supplements to the manufacturer's flight manual and an overview of the manufacturer's standard modifications for flying with open doors.

(3) Modifications to aircraft are subject to special approval. Flying with open doors is not considered to be a modification if the aircraft is approved for this type of flight.

(4) The approval must be shown in the aircraft's flight manual. The flight manual must also contain operational limitations for this type of flight."

The definition in § 3 shows that the regulation and associated approved procedures only apply to jumps using a parachute.

1.18.2 <u>Minimum flight altitudes</u>

1.18.2.1 Extract from BSL F 1-1 "Rules of the air":

"§ 3-5. Minimum flight altitudes

(1) An aircraft making a VFR flight shall not descend below 300 m (1,000 ft) over the highest obstacle within a radius of 600 m from the aircraft over a populated area or a group of people outdoors or below 150 m (500 ft) over the ground or water elsewhere.

(2) Descent below the minimum altitude is allowed when necessary for take-off, landing, or during a helicopter flight which is carried out in accordance with the regulations for commercial air transportation (helicopters) or for which a special permit has been granted by CAA-N.

1.18.2.2 Extract from BSL D 2-2 Commercial air transportation (Helicopters)":

"10. Flying at altitudes below the minimum altitude defined in rules of the air BSL F

10.1 The flight operations manager may authorise VFR flights at a lower altitude than that defined in BSL F Visual flight rules - Minimum altitude when the following conditions are fulfilled:

10.1.1 Flight at low altitudes is an absolute necessity for performing a specific mission or is part of the education or training of pilots in this type of operation.

10.1.2 The operator's operations manual contains specific procedures for carrying out a particular mission and specifies minimum requirements regarding the commander's experience and proficiency.

10.1.3 The flight is carried out away from populated areas or open-air assemblies of persons and does not expose people or property on the ground or water to any danger or inconvenience."

1.18.2.3 Extract from BSL JAR-OPS 3 which applies to passenger flights:

JAR-OPS 3.365 Minimum flight altitudes (See IEM OPS 3.250) The pilot flying shall not descend below specified minimum altitudes except when necessary for take-off or landing, or when descending in accordance with procedures approved by the Authority."

1.18.2.4 Airlift's operating manual (OM A) refers to BSL JAR-OPS 3 and states that flights shall be conducted in accordance with the national rules contained in BSL F.

1.18.3 Marketing event flights

1.18.3.1 The AIBN has examined the extent to which Norwegian air operators actively market flights which may be described as event flights. This involved obtaining information from the operators' websites. The CAA-N website shows that in June 2008, 35 Norwegian companies had a license and/or operating permit. 21 of these companies conducted helicopter operations. 8 of these helicopter companies marketed services using expressions such as *"Events"*, *"kick-off"*, *"unusual presents"*, *"special experience"*, *"memory for life"*, *"high speed"*, *"adrenalin experience"*, *"experience/adventure trips" and "bachelor parties"*.

1.18.4 Video of one of Airlift's event flights

1.18.4.1 The previously mentioned video was made to promote PS-arrangements. It was stored on the operator's network server and shows approximately 3 minutes of an event flight conducted by Airlift. The video shows two of the operator's AS 350 helicopters, one of them are LN-OPY. The helicopters with removed doors are manoeuvring at very low altitude, both over forest terrain and water. They fly in formation at times. The passengers were seated on the floor at the back of the cabin. The images show passengers wearing survival suits jumping into the water and then being picked up by a fast rubber inflatable boat. A large group of people can be seen on the shore following the flight. One helicopter performs a short demonstration flight which includes making a sudden climb. Participants and spectators alike appear to be having a great experience. The film does not contain any commentary, although Motorhead's "Ace of Spades" playing in the background produces suggestive effects.

1.18.4.2 When asked directly by the AIBN, the operator's management denied knowledge of the existence of the film.

1.19 Useful or effective investigation techniques

During this investigation, no methods have been used which require special mention.

2. ANALYSIS

2.1 Introduction

Flying can be a complicated and often unforgiving activity. In addition to good corporate and safety culture, knowledge and skills, a good attitude and airmanship are also required. Flights at low altitude always involve higher risk, and the margins for error are small. It is the AIBN's opinion that this accident did not happen because of one particular error, but that the manoeuvring just before the accident was the last crucial factor in a number of missing barriers, omissions, unfavourable circumstances and judgments of which the consequences were not understood. These factors must be seen in the context of developed industry practice generally and by the operator specially, shortcomings in the regulatory oversight, the operator's procedures, training and practice and the customer expectations. Only when these conditions have been illuminated is it possible to consider the commander's judgments and actions. The accident happened during a flight which took place after the main mission was completed. This subsequent flight and the previous flight over the Oslo fjord have so much in common that it is natural to see them as one. Below follows an initial analysis of the framework factors.

2.2 Event flights

2.2.1 There is no definition of the expression event flight. The expression does not exist in laws, regulations or the operator's procedures. AIBN understand this expression as a flight aimed at providing the passengers with an exciting experience. In many ways the expression has much in common with a sightseeing flight. Sightseeing flight is an expression with its origin in an age before flying was common for people in general and a flight was an experience in itself. AIBN believes that event flights may be seen as an extension of sightseeing flights, but with expectations of more spectacular experiences associated with the actual flight. For example, bungee jumping from helicopters is known to have taken place in other countries. In general, it can be said that event flights like those marketed in the previously mentioned video and the one carried out on the date of the accident have much in common with the armed forces' tactical helicopter operations. Because of the lack of definition and safety regulation of event flights, it has been left to the individual operator to decide how to carry out the activity within the existing regulatory framework.

2.2.2 Regulations are different for flights with and without passengers. Regulations for Commercial Air Transportation (Helicopters), BSL JAR-OPS 3, are designed to give a larger safety margin than the rules for other commercial flights, often referred to as aerial work and regulated under BSL D 2-2. The main differences are in the requirements regarding minimum altitude, engine performance, forced landing capabilities and some equipment requirements. It seems like the flights in question took place in the boundary area between passenger flights and aerial work.

2.2.3 Many helicopter companies are competing for market share and are receptive to new uses for helicopters. A large number of events companies have emerged in recent years, without any direct connection to the aviation industry, and which arrange experiences for customers. The experiences are often closely connected with marketing, team-building and kick-offs. AIBN believes there has been a gradual development of a market in which helicopter companies carry out events flights. In response to this need, helicopter companies have creatively developed products which combine speed, excitement and adrenalin kicks. Some of these operations appear to have required commanders to have the power to authorise flying below minimum altitudes (see subparagraph 1.18.2.2). They also appear to have required the operator in question to have approval for dropping parachutists by helicopter. This may lead to the interpretation that this type of flying is not to be considered as a passenger flight. This is factors which independently reduces safety margins and gives cause for concern when combined with carriage of passengers. It is particularly worrying if a flight is carried out as an individual pilot finds it appropriate from case to case, without there being any procedures, risk assessment and associated training in place with the operator. This means there is room for things being left to chance, and it places a massive responsibility on the individual pilot and his experience and proficiency.

2.2.4 As long as event flights is actually taking place, it is the AIBN opinion that the lack of a definition for event flight represents a safety problem because there seems to be a lack of clarity as to which rules it should be based on. The AIBN is aware that a new European regulatory framework in this area will be established over the next few years. AIBN believes a study should be made into whether this will provide satisfactory clarification. If not, efforts should be made to have a say in the rules by means of comments to the draft documents, as there will be little scope for having different national requirements when these rules come into force. Based on CAA-N's comments to the draft report it seems the CAA-N do not want to define the term "event flight" (se subparagraph 1.17.1.6). Regardless of the CAA-N decision, it is important to keep focus on regulatory activity regarding event flights. AIBN has issued a safety recommendation regarding the lack of regulation of these types of flights.

2.3 Operator oversight by the CAA-N

2.3.1 Even before the accident, the CAA-N had expressed its dissatisfaction with the safety standards of helicopter operators working in the Norwegian onshore market. It was decided to expand the ad-hoc oversight system, particularly for aerial work operations. These operations involve helicopters being operated at low altitude over long periods in areas with little infrastructure in place.

2.3.2 There are strong indications that at the time of the accident CAA-N was aware that many of the Norwegian helicopter operators had gradually started to carry out event flights, including passenger flights below the minimum altitudes defined in the aviation regulations. Based on CAA-N's reactions after the accident on May 11, 2005, it can be concluded that the flights for PS-arrangements would not have been allowed. Questions could probably be asked as to what extent CAA-N inspectors could be expected to keep track of what is being marketed by helicopter operators and event companies. However, in general, AIBN believes the inspectors should be sufficiently familiar with their oversight objects to know what type of flights is being marketed and carried out by the operators.

2.3.3 AIBN is aware that different types of event flights are not unique to Norway. The challenge of regulating different forms of event flights should therefore be conducted in close cooperation with other European countries. Until a common European legislation is in place, the CAA-N should state what is allowed when providing passengers with a memorable experience and what is not permissible on grounds of safety. They should also consider whether the activity can be regulated by clarifying or adjusting existing rules.

2.4 The operator's qualification for undertaking the flight over the Oslo fjord

2.4.1 A prerequisite for an air operator to perform a task is that it possesses a permit for the type of flight in question. A permit is obtained from the CAA-N following an application, and indicates that the operator has suitable equipment, standard operating procedures (SOP), training and crew to allow the type of assignment to be carried out safely and within the existing regulatory framework. Operators normally have many such permits covering the types of operation they carry out on a daily basis. The operator is also required to ensure the pilot who will be carrying out an assignment is qualified. This means he is familiar with the procedures for the assignment, has undergone and understood appropriate training and has maintained his proficiency. This is ensured by means of the operator's flight authorisation system. Authorisation is the responsibility of the flight operations manager, but in practice is often delegated to a traffic/market employee or the commander when performing normal described types of operations.

2.4.2 The point of an SOP is that the steps in the task, necessary equipment, crew, skills and limitations are described on the basis of a risk assessment. The SOP shows how the dangers which may be associated with the type of operation can be reduced and acts as the pilot's plan when he is about to carry out the task. The SOP also forms the basis of the training the pilot must undergo in order to become qualified for the type of operation.

2.4.3 It is clear that Airlift did not have an SOP to cover operations in which passengers sit on the floor attached with a climbing harness and jump into the water from low altitude. The operator did not therefore have a permit to undertake such operations. It has been claimed that it made sense to use the operator's approved procedures for dropping parachutists. At first glance, these two operations appear to have much in common. However, several of the procedures and associated hazards involved in this type of operation are not described and assessed in the SOP for parachute jumping. These include flying at low altitude, flying at low altitude over water, drop altitude, climbing on board again during flight and securing and releasing the passenger in the event of an emergency landing (se also subparagraph 1.18.1.1).

2.5 The operator's qualification for undertaking the flight over Kolsås

2.5.1 There can be no doubt that the flight over Kolsås was to be considered a flight with paying passengers; in other words a passenger flight. As the departure and arrival was to take place at the same location it can also be described as an A-to-A flight. As a main rule, this type of flight requires an approval certificate for commercial air transportation (AOC) and a license, and the flight must be carried out in compliance with BSL JAR-OPS 3. In Norway, the regulations still allow this type of flight to be carried out as a commercial flight based on an operating permit for sightseeing flights, and regulated by national requirements (BSL-D). This is described in Appendix 1 to the operating permit issued to operators. As an operator, Airlift had decided not to use this option, and this decision was described in its operating manual. Instead, all passenger flights were to be carried out in accordance with the requirements contained in BSL JAR-OPS 3. The operator had also developed a separate SOP for this type of flight, taking advantage of the option to make exceptions and simplifications to the requirements when taking off from and landing at the same location (A to A flights). These simplifications are in accordance with Appendix 1 to BSL JAR-OPS 3.005(f) and (g).

2.5.2 Passenger flights are normally routine assignments carried out in accordance with the requirements contained in BSL JAR-OPS 3. Unlike the provisions in BSL D 2-2 regarding aerial work, these do not allow flying below minimum altitudes and they require each passenger to have a seat with a seat belt. Consequently the operator had no SOP covering the flight over Kolsås the way it was carried out.

2.6 Authorisation and planning of tasks

2.6.1 In its operating manual, Airlift has described how tasks are received and authorised. In the case in question, the operator gave the commander a task which was not described in the operator's SOP. This may indicate that the neither the operations department nor the traffic coordinator did grasp the problem when PS-arrangements placed the order. Or it may indicate that Airlift had decided to disregard this discrepancy so that an event flight was authorised as a standard assignment. The fact that the commander did not receive additional information indicates that the operator for one reason or another considered the assignment to be a standard assignment. As a result the task did not become subject to any specific risk assessment or other forms of follow up. This despite the fact that the assignment was not described in the operators procedures and the elements of high risk and uncertainty connected with it.

2.6.2 Helicopter pilots' independence in the planning and implementation of assignments varies according to the type of operation the operator is carrying out. Airlift has a large variation in its types of operations and the commander in question was authorised to carry out most of them. Consequently, if the commander was authorised for a particular type of operation, he did not need any further training or special approval for each individual trip. If a commander was given a task by the operator, he was expected to plan and perform the flight on the basis of regulations, the operator's procedures and his experience, without further detailed input from the operator's flight operations manager. In practice, he also needed to make contact with the client to obtain details on the actual tasks.

2.6.3 When Airlift assigned the commander to the PS-arrangements task, it was reasonable for him to assume this to be a task for which he as commander was authorised by the operator. To obtain a better understanding of what might be expected, he watched the afore-mentioned video. The video showed elements of previous flights, which would also be relevant for his flight on the following day. The video showed flights carried out without doors, flights with passenger sitting in the door openings, jumps out of a helicopter and low altitude flying with passengers on board. It is the AIBN opinion that the video would have given the commander a good picture of what a flight for PS-arrangements might be expected to include. He also received confirmation of what the operator's pilots had previously flown. Based on this the commander decided he could do something similar. The AIBN finds the decision understandable.

2.6.4 The video which the commander watched before flight is filled with effects which suggest speed, excitement, freedom and joy. This is emphasized by rapid cuts between repeated scenes full of action mixed with broad smiles on the faces of participants, and music. The video repeatedly lingers on scenes which could have come straight out of a "James Bond movie". The majority of the flights on the video are at altitudes significantly below the minimum altitude of 500 ft. It is the AIBN opinion that it would be easy to be influenced by this video, particularly as the commander at the time did not have any other references as to what the PS-arrangements assignment might involve.

2.6.5 The commander received further information about the flight when he contacted PS-arrangements on the morning of the accident. The commander has stated that it was his opinion that the flight could be carried out if Airlift's authority-approved procedure for dropping of parachutists was used.

2.6.6 Questions could be raised as to whether the flight could be carried out under the provisions of BSL D 2-2, which allow flying below the minimum altitudes laid down in BSL F. A considerable part of the assignment over the Oslo fjord involved jumping out of the helicopter and subsequent climbing out of the water into the helicopter. As the task obviously could not have been carried out from the minimum altitude of 500 ft, the commander had to assume having been given the job, that he was also authorised to disregard the minimum altitudes. The procedure for parachute jumps which he used as a basis for performing the task did not contain the authorisation to fly below the minimum altitude. It is possible that the commander thought that, as he was allowed to fly below the minimum altitudes in connection with many other tasks he carried out on a daily basis, it would also be acceptable in this case. Regardless of the commander's assessment about using the parachute drop procedure, he did not have a procedure for dropping passengers without parachutes.

2.6.7 In retrospect, it can be seen that both the operator and commander may have used a generous measure of goodwill in accommodating regulations, assignment and approvals/authorisations. It could be argued that the commander should have seen the gap between the approvals and the actual flight. If this had been the case, it would have been natural for him to contact the flight operations manager to check how the task should be carried out. However, it is not unreasonable to assume that the commander, consciously or unconsciously, was under a certain pressure, and that asking questions about carrying out the assignment would require particular decisiveness. The threshold for asking questions about the assignment was particularly high because the video showed that the operator had previously carried out similar flights. The commander's failure to ask questions about the task may also have been influenced by his relatively young age and short period of employment with the operator.

2.7 The planned flight over the Oslo fjord

2.7.1 The commander told the AIBN that he was well rested and comfortable with the assignments which lay ahead of him on the day in question. He had plenty of time in which to carry out the tasks and did not expect any special challenges. The commander and load master arrived in Fornebu at 1345 and had plenty time to rest, eat and plan the flight in detail.

2.7.2 As described in 1.13.1, the commander took a tablet and applied some eye drops (non-prescription pollen allergy medication) a few hours before the flight. The regulations state that holders of medical certificates shall not take any prescription or non-prescription medication unless they are absolutely certain that the medication or treatment will not have any adverse effect on their ability to safely perform their duties. Based on the opinion of an aeromedical doctor, AIBN believes that the commander's use of the above-mentioned non-prescription medication did not have any unwanted effect on the flight in question. This is also in accordance with the commander's own opinion.

2.7.3 The manager of PS-arrangements (passenger "1") took the initiative during the preparations for the flight from Fornebu. It was evident that the doors had to be removed so that the passengers could sit on the floor of the cabin before their jump into the sea. The commander did not have reason to doubt the specialist knowledge of passenger “1” with regard to climbing equipment. The climbing rope and carabiners which were fitted in the helicopter appeared to be of high quality. The commander perceived the manager of PS-arrangements as an experienced authority on event flights, and it is logical that he as a less experienced “eventpilot” was reluctant to challenge these decisions. The commander also noticed that the preparations appeared to be in line with what would have happened prior to what he had seen on the video. The fact that passenger “1” had so much input on how the flight was conducted must also be seen in the context of the lack of documented procedures to which the commander could refer. However, there is no doubt that the commander had formal responsibility for passenger safety and for ensuring that operations were conducted in accordance with current regulations and procedures.

2.7.4 When the commander accepted the flight, he had to take into account the following considerations:

- He was given the assignment by Airlift's management and had to assume that he was authorised to perform the flight according to current procedures and his best judgment.

- He knew that the operator had approval to drop parachutists using alternative restraint devices for passengers. He needed to consider whether jumping from a helicopter into the sea can be equated with parachute drops from a high altitude. He had been given the assignment to fly for PS-arrangements and had watched a video showing that the operator had conducted similar tasks before. The conclusion was that the assignment could be carried out.

- The helicopter’s flight manual allowed flights without doors with a speed limit of 110 kt.

- The flight operations manager could authorise flights below the minimum altitudes when this procedure was essential for the completion of the task. However, such authorisation was conditional on the operator having a documented procedure and requirements in place regarding the commander. The operator did not have a documented procedure for the task in question. The commander did not put any significance to this omission, considering the fact that the operator had assigned the flight to him and previously had carried out similar assignments for the customer.

- The passengers appeared to be professionally secured with restraint devices which were apparently of high quality and made it impossible for the passengers to fall out of the open doors during the flight.

2.7.5 In hindsight, questions could be raised as to whether the flight over the Oslo fjord was justifiable and whether the commander should have accepted the assignment. A closer consideration of the commander’s ability to make the right choice must also be seen in the context of the established practice and corporate culture at the operator. The task in question was not described in the operator's procedures. What is more, the operator did not have any approvals to carry out flights which combined unsatisfactory restraint of passengers, jumps from helicopters and flying below the minimum altitudes defined in BSL F. Based on interviews with the operator’s management, doubt remains as to what extent they were aware of how these operations were executed. This raises the question of whether the operator's management had sufficient contact with those executing the operations. If on the other hand management were aware of the way event flights was being implemented in their own operations, which they should have been, they should have initiated a process for ensuring that procedures and normal practice were in agreement. Such a process would eventually have involved obtaining approval from the CAA-N.

2.8 The extra flight over Kolsås

2.8.1 Airlift's commanders who are out on assignments have a large measure of freedom to adapt the flying to the customer's needs. It was not uncommon for them to fly additional flights after the original assignment that had been ordered. It was therefore nothing out of the ordinary for PS-arrangements to ask for an extra flight. This was based on the agreed price and additional billing. The commander had flown a similar trip over the Oslo fjord eight minutes earlier. It was possible for the flight to Kolsås to be a direct continuation of the previous flight, without rearranging the cabin or reinstalling the doors. The commander considered this to be a less demanding task than the one just completed. There was therefore no more cause for concern over the passenger's crash protection than on the previous flight.

2.8.2 The commander's task was to provide a safe event flight for the client within the regulations, the framework given by the operator and based on his own judgment. He had just flown a similar assignment. It may be asked whether the commander should have considered the next flight to be different and with a higher risk element than the first one and whether he should have altered or declined the assignment. The following factors are relevant:

- No-one would be jumping out of the helicopter. The flight would be less demanding, as the commander would not have to identify a safe area for jumping, make an assessment of a safe jumping height and coordinate with other players.

- The flight would take place over land and any safety issues connected with flights over water was irrelevant.

- An ordinary flight with passengers strapped into their seats and the doors installed would not give the passengers any experience other than a normal sightseeing flight. Were there any circumstances to indicate that the commander could not continue with the passengers seated with their legs outside the cabin as before? The main difference was that no-one would be jumping out and there was therefore no reason to fly with the doors removed. However, the passenger's impression of speed and the open air would have been significantly reduced if the doors had been in place. With exception that there was no jumping taking place, the AIBN regards there is no fundamental differences between the two flights and is of the opinion that the commander could not have been expected to have a different view.

- In addition to himself, the manager of PS-arrangements wanted to take four passengers. This meant there would have been six persons on board including the commander. However, the commander was keen to have the load master on board to keep an eye on the passengers in the cabin. Consequently, there was one person too many in the helicopter according to the limitations in the flight manual. As a basis, this did not have an effect on the accident as the helicopter's total mass was within the given limits. However, in reality, the extra passenger moved the centre of gravity forward and increased the mass, which reduced the helicopter's surplus power. The number of passengers who can be taken is determined by the Flight Manual, the take-off mass and the number of seats with seat belts. In this case, the helicopter was prepared for six passengers, with all of them sitting in the cabin inadequately restrained. The number of passengers and use of safe restraint devices are fully the commander's responsibility, although the accident shows that, consciously or unconsciously, the commander accepted to contravene a regulation rather than oppose the wishes of the manager of PS-arrangements. To keep within the limits in the flight manual, the commander could have decided not to bring along the load master. Alternatively, he could have reduced the number of passengers in the back of the cabin, leaving it to the manager of PS-arrangements to decide who would come on the flight. AIBN believes that, as an isolated case, the commander made an understandable safety decision by bringing along the load master.

- It is difficult to determine who influenced what parts of the flight. AIBN believes that the manager of PS-arrangements had significant influence on the conduct of also this flight. Flying to Kolsås appears to have been a natural choice because the area was close by and outside a populated area. An important consideration may also have been the fact that the Kolsås hill is surrounded by steep mountain sides which can give passengers an extra adrenalin surge when these are passed. The flight over the Oslo fjord had been largely carried out below the minimum altitudes defined in BSL F. This was an absolute necessity to allow the passengers to jump into the sea. Whether it was necessary to fly over Kolsås below the minimum altitude of 500 ft to satisfy the wishes of the manager of PS-arrangements may be difficult to ascertain after the event. It is AIBN's experience that helicopters often operate below 500 ft and that the need to do so may be called into question in some cases. Consequently, the commander was following a long tradition if he planned to, or actually on purpose flew parts of the trip below 500 ft over the terrain.

2.8.3 In many ways the commander's acceptance of the Kolsås flight may be seen as a natural consequence of his initial acceptance of the Oslo fjord assignment. AIBN finds it difficult to identify a clear point in the sequence of events where the commander should clearly have put his foot down and declined the assignment. Looking at the result with hindsight, it is easy to point to factors such as the operator's lack of a procedures describing the flight in question, inadequate training, the fact that passenger "1" alone gave orders on how the passenger were to be secured, no doors and the fact that the helicopter was flying too low with passengers.

2.9 The sequence of events

2.9.1 <u>Altitude, bank angle and power</u>

2.9.1.1 The description of the last part of the flight over Kolsås is mainly based on statements from the commander, the load master and the passengers. These are subjective and influenced by the accident. Even thought these statements are largely consistent, they provide e.g. no exact values available for altitude, speed or bank angle. Following the accident the police decided to prosecute the commander, a fact that may have influenced later statements. For that reason this analysis is based on early statements from the persons involved.

2.9.1.2 When the AIBN describes the flight altitude as being low, it is intended to mean low with regards to safety margins that should be aimed for during flights with passengers. The terrain clearance the commander chose must be seen in the context of helicopter pilots' traditional approach to selecting minimum altitudes, which has often been controlled by parameters other than the general provisions in the regulations. This in turn must be seen in the general context of the helicopter's use which often involves flying below the general minimum altitudes. It is the AIBN opinion that the regulations here make a clear difference between whether the helicopter is carrying passengers or not and whether there is an SOP describing the operation. It can generally be said that there are still gray areas in the regulations and enforcement of the minimum altitude regulations for helicopter flights. This is a situation for which CAA-N, operators and helicopter pilots must each assume responsibility.

2.9.1.3 The main consideration associated with minimum altitudes is safety margins. Increased altitude normally gives increased safety margins. It appears that the commander selected an altitude which ultimately gave such narrow safety margins that an unexpected loss of altitude resulted in contact with the terrain.

2.9.1.4 AIBN has no indication that the first part of the Kolsås flight proceeded other than expected. The route flown would avoid generating noise over a populated area. The right turn would position the helicopter for flying along the ridge of Kolsås. Passing the cliff at Store Kolsås on the way south could give the passengers in the partly open cabin an adrenalin surge.

2.9.1.5 As the right turn towards the ridge of Kolsås was flown over rising terrain, the ground clearance would be reduced if the helicopter did not climb accordingly. It is not possible to ascertain after the event what altitude the helicopter had before the turn was initiated. Working from the commander's statement, the helicopter would have come in over the ridge of Kolsås at an altitude of 100 – 200 ft provided it was flown horizontally.

2.9.1.6 When LN-OPY was approx. halfway through the 180-degree turn, the terrain immediately ahead was rising. It is AIBN's opinion that the commander may have found it difficult to judge the bank angle in the latter part of the flight. Likewise it might have been difficult to judge the slope of the terrain. This was caused by him sitting on the right side towards the trees which gave little references to the horizon. The fact that the terrain sloped in several directions may have affected the perception of angles. Similarly, little importance should be placed to the passengers' assessment of the banking, as sitting in the open doors they were given sensory inputs that could easily lead to an exaggerated feeling of movement. The bank angles described in the sequence of events (see 1.1.4.7) should therefore not be considered absolute.

2.9.1.7 The helicopter's performance is limited by available engine power. A banking manoeuvre increases the power requirement. A 60º bank angle in a horizontal turn gives 2.0 g[19] and a 70º bank angle gives 2.9 g. Consequently, in a 60º turn, the load on the rotor is doubled (4,100 kg at 2 g), while with a 70º bank angle, the load increases by a factor of 2.9 to

[19] $n = 1/\cos \varphi$ (n =load factor (g-load) and φ = bank angle)

5,945 kg. Available engine power is limited to 100% (10 FLI) Although the rate of climb graph in appendix C does not cover masses over 3,400 kg, it is clear that the result will be a considerable rate of descent based on the lack of power, even if the speed is reduced in the turn.

2.9.1.8 Consequently, in a 2-g turn as an example, the helicopter did not have enough power reserves to maintain a speed of 90 KIAS. The speed would fall even with full power applied. In addition, the helicopter would have lost altitude. The only way to stop the rate of descent would have been to roll out of the turn quickly and increase power above set limits (overtorque)[20]. However, by rolling out of the turn, the helicopter would have continued straight towards raising terrain. This would have reduced the height margins even further.

2.9.1.9 During the turn, the commander noticed that the helicopter was descending. Therefore, he rolled out of the turn, increased to full power output and raised the collective lever. He considered the altitude to be too low to lower the nose in order to accelerate to a higher speed, and instead raised the nose in an attempt to fly over the trees ahead of the helicopter. When he raised the nose, the speed fell even more. Thus, the helicopter had entered a situation where it was flying over raising terrain with a high descent rate and low airspeed. The helicopter mushed further down despite the increased power output and came into contact with the trees for the first time. The AIBN believe this was what the commander interpreted as the helicopter not reacting normally.

2.9.1.10 It is the AIBN opinion that the tree contact can be explained by the fact that the commander misjudged the height margins towards the terrain in addition to the high descent rate that developed during the turn. This was discovered too late due to lack of visual references. The helicopter did not have performance to fly out of the situation. Consequently, it ended up on a southerly course approx. 3 meters too low in relation to the height of the trees. In other words, it could be said that the commander misjudged the turn in relation to the altitude margins to the terrain. This type of misjudgement must be seen in the context that he had not had, and was not expected to have, any instruction or training in manoeuvring a helicopter at low height over terrain at cruise speed. The question of whether servo transparency was a contributory factor to the unexpected loss of altitude is analysed below.

2.9.2 Servo transparency

2.9.2.1 It is difficult to establish whether servo transparency was a factor in this accident or not. The evaluations made by the AIBN is based on information received from the helicopter manufacturer, statements given by the commander, load master and passengers, and information given by other pilots with experience on AS 350. As mentioned in 1.6.4.1, servo transparency can occur if the rotor load is too high in relation to the servos' capacity. The manufacturer describes that this can occur with a combination of high speed, high altitude (pressure altitude) and high mass. In this particular case, the speed was well below the maximum permitted (VNE). The pressure altitude was low and the takeoff mass was under the given limitation. These factors would indicate that servo transparency did not occur.

[20] Exceeding the defined limit for engine temperature or torque value for the engine to gearbox shaft.

2.9.2.2 The turn was flown with a 40 - 70° bank angle. This would give a considerable increase in the rotor load, and thus g-load, provided the altitude was kept constant. This was not the case here. A load of 2 g will for instance be felt as very unpleasant for persons sitting on the helicopter floor. No-one on board has experienced any g-loads worth mentioning and this indicates that the g-load was relatively low.

2.9.2.3 If servo transparency occurs in left turns, the phenomenon will be mainly self-correcting, as Eurocopter describes in 1.6.4.1. However, as far as the AIBN understands, the phenomenon may represent a serious safety threat if it occurs in a right turn at low altitude. In such a case the helicopter will roll further to the right at the same time as collective goes down. This could to an extent possibly explain the described movements of the helicopter during the turn.

2.9.2.4 The commander has stated that he could not remember feeling any stiffness in the controls. In his statement to the AIBN, he used the phrases like *high rate of descent* and *the helicopter was pushing the air in front of it*. The AIBN believes that a pilot would immediately have recognized stiff controls. The flight controls are used to manoeuvre the helicopter, and if they had become stiff in a critical phase, this would have sent a strong feedback to the pilot, and been remembered after the accident. Consequently, the AIBN considers it unlikely that the commander experienced servo transparency. However, it cannot be ruled out that the phenomenon occurred and was therefore a causal factor in the accident.

2.9.2.5 It is the AIBN opinion that Eurocopter’s information on the servo transparency phenomenon in its helicopter flight manual is one-sided and incomplete. Expressions such as *self-correcting* and *feedback forces are fully controllable* are used. Nowhere does it say the phenomenon is not self-correcting in a right turn. 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.

2.9.3 The effect of the wind

The AIBN analysis is based on a wind direction in the Kolsås area from northwest to southeast at a speed of approx. 1 kt. Consequently, LN-OPY turned into an approx. 1 kt tailwind before the accident. However, the wind speed was too low to have had any significant negative effect.

2.9.4 Vortex ring state (Settling with power)

2.9.4.1 Vortex ring state can occur at a low airspeed in combination with a relatively high rate of descent. It is difficult to assess the airspeed in the period before the helicopter hit the trees. Two factors indicate that the helicopter was maintaining a speed of at least 30-40 kt when it hit the trees:

- One of the passengers was hit so forcefully in the leg that she suffered a fractured leg

- Parts of the helicopter nose were smashed in and the mirror was ripped off

30 – 40 kt is over the speed at which vortex ring state normally occurs. In addition, it is difficult for vortex ring state to occur while a helicopter is turning. The commander's statement indicates that the speed fell during the turn. Consequently there were wide margins to vortex ring state in the turn when the biggest loss of altitude occurred.

2.9.4.2 It is difficult to assess the rate of descent for the last part of the flight after the turn was completed. Working on the basis that the helicopter flew the last critical 300 m at an average speed of 30 m/s (58 kt), this phase lasted 10 seconds. Assuming the helicopter lost 150 ft in this phase, it had an average rate of descent of 900 ft/min. This is a high figure, which at a low speed might result in vortex ring state. However, there is reason to believe that the airspeed was too high for this phenomenon to occur.

2.9.4.3 No-one on board noticed any vibrations before the helicopter hit the trees the first time. Even though this does not rule out vortex ring state, it is supporting evidence that the phenomenon did not occur. Based on the values of the helicopter's mass, pressure altitude, air temperature, likely airspeed and rate of descent, and actual engine power output, the commander's statement and the absence of vibrations, the AIBN finds it unlikely that LN-OPY experienced vortex ring state.

2.9.5 The centre of gravity

The centre of gravity was close to, or just forward of the prescribed limitation dependent on the exact location of passenger "1". It is likely that the centre of gravity came outside operational limitations given by the helicopter manufacturer if passenger "1" leaned forward. In theory, performances are unknown when the helicopter is operated outside the limitations. However, the helicopter does not change from being fully operational to uncontrollable by a 1 – 2 cm movement of the centre of gravity. A forward movement of the centre of gravity will reduce the cyclic controls total authority in keeping the nose up. However, at the actual mass there are no additional operational limitations to manoeuvring dependent on the centre of gravity as long as it is kept within limits. It is the AIBN opinion that a one cm movement of the centre of gravity forward of the limit will have no noteworthy impact on the manoeuvrability and the subsequent sequence of events.

2.10 The emergency landing

2.10.1 The commander considered the vibrations after the first contact with the trees so serious that the helicopter had to make an immediate emergency landing. He then had to decide between putting the helicopter down in the forest, trying to find a suitable site among the houses ahead of him to the right or flying to the sports field just under a kilometre away to the south. Based on what was found at the first impact point, it is likely that the damage to the rotor system was so minor that it would have been possible to fly down to the sports field. The commander's decision to make an emergency landing in the trees in sharply sloping terrain indicates that he perceived the situation as very critical and considered it urgent to get the helicopter on the ground as quickly as possible.

2.10.2 It is the AIBN opinion that when the decision was made to land immediately in the forest, the commander found the only landing area where a total loss could be avoided. The commander showed skill in successfully bringing the helicopter down in the clearing. The fact that the helicopter slid sideways and tipped over may have been due to the vibrations, and the steep sides and narrowness of the ledge.

2.10.3 The AIBN has not been able to determine what caused the whistling and howling noises described by the commander in 1.1.4.7. However, according to the commander it cannot be ruled out that the noises came from the radar altimeter.

2.11 Instruction and training

2.11.1 It is the AIBN opinion that the commander made a genuine attempt to satisfy his employer and the client. He found himself carrying out two tasks which had not been defined, described or regulated by either Airlift or CAA-N. Consequently, he had not received the necessary training to carry out the assignments. Low altitude flying is a natural part of onshore helicopter operations in Norway. Many of the operations involve flights with an external load carried out at tree-top height. Other operations include power line inspections, reindeer-herding etc. What all these flights have in common is that they are performed at low altitude and at a relatively low speed or in a hover. Not counting possible unauthorised flights or event flights, civilian helicopter pilots would not be expected to have sufficient training or experience to manoeuvre at high speed and low altitude over the terrain.

2.11.2 Consequently, AIBN believes the commander did not have sufficient training or other experience to manoeuvre low over the terrain at high speed. Although he is not expected to have received such training, he was still lacking an important prerequisite to be able to judge in a safe way the flight as it evolved over Kolsås. He did not have the training or experience necessary to assess the risks involved in the task. This is particularly true with respect to helicopter performance in steep turns, assessment of heights in hilly terrain, lack of reliable external horizon and servo transparency. AIBN does not necessarily believe such training should be introduced. On the contrary, any form of flying involving elements of unregulated “tactical” low flying should be discouraged. If this type of flying is to be carried out, a risk assessment must be conducted, regulations and procedures must be put in place and sufficient training must be provided. This is an area which should be addressed primarily by the CAA-N.

2.12 Survival aspects

2.12.1 <u>Search and rescue</u>

As there were no major impact forces involved in the accident, the emergency locator transmitter was not triggered. However, the accident was close to a populated area and there were several witnesses. In addition, the commander was in a condition to report the accident. The failure of the ELT to send signals did not have any consequences for the search and rescue efforts. Due to the location of the accident site, resources were quick to arrive on the scene. It is the AIBN opinion that the subsequent rescue operation proceeded in a fast and efficient way.

2.12.2 Passenger restraint

2.12.2.1 As previously mentioned, there were no major impact forces. The helicopter was stationary on the ground with the engine and rotor running before sliding sideways and rolling over. If a helicopter rolls over with the main rotor running, a number of potentially dangerous situations can arise. For example, the main gearbox can be ripped off and enter the cabin, injuring the passengers. The main rotor blades may enter the cabin. In this particular case the cabin was virtually undamaged and everyone on board would have been safe and uninjured if they had been sitting in the helicopter seats using the installed seatbelts.

2.12.2.2 The way the passengers were secured in the cabin they were only prevented from falling out through the open doors during flight. However, it could not prevent the passengers from being thrown around during an accident. Passenger “1” who had decided to use a rope which was longer than the other passengers, ended up on the outside the fuselage and was pinned underneath the helicopter when it rolled. The AIBN has reason to believe that if he had used a short rope like the others, the likelihood of receiving life-threatening injuries would have been considerably reduced. At the same time, it must be said that passengers “2, 3, 4 and 5” were exposed to a risk of injury if the helicopter tipped over, as their upper bodies and legs could reach outside the helicopter.

2.12.2.3 The question could also be raised as to how easy it is to release oneself from a climbing harness and carabiners in the case of an emergency landing on the water or, in this case, after the passengers were left hanging in a heap in a helicopter which was lying partly on its roof and in a worst case scenario could have caught fire. AIBN believes that the restraint devices used are questionable, both in terms of protection against injury and evacuation. Additionally, the restraint devices used were not according to the operator’s procedures for fastening in parachute jumpers and consequently not approved.

2.12.3 Doors

Previous accidents involving the AS 350 have shown that the actual cabin construction does little to provide protection against injury to the occupants. Consequently, the presence of the doors generally is of little importance in the case of an accident. In this case, the passengers were so loosely restrained that they could partly reach outside the cabin. The doors would therefore have acted as a barrier to prevent them from falling out. The accident has shown that inadequate restraint of passengers and the absence of doors were the direct cause of one passenger being pinned under the helicopter as it tipped over and later dying. The AIBN investigation have also verified that the commander was following current and valid limitations with regard to maximum speed in combination with which doors could be removed.

2.12.4 Flotation equipment for emergency landing on water

The helicopter was not equipped with flotation equipment for emergency landing on water. If the flight had been conducted in accordance with BSL JAR-OPS 3, there would have been a requirement for the aircraft to be fitted with flotation equipment if it was outside gliding distance (autorotation) from land. A similar requirement exists if the flight is defined as aerial work, although this is not an absolute requirement. Regardless of these rules, the passengers were exposed to extra risk during the flight over the Oslo fjord as the doors had been removed and the helicopter would therefore sink quickly. In addition, the passengers' restraint devices would complicate a quick release and evacuation.

3. CONCLUSIONS

3.1 Investigation results

a) The aircraft was registered in accordance with regulations and had valid environmental and airworthiness certification.

b) The aircraft's mass was within prescribed limitations. The centre of gravity was close to, or just forward of the prescribed limitation. It is the AIBN opinion that this had no noteworthy impact on the helicopters manoeuvrability and subsequent sequence of events.

c) The investigation has not revealed any technical faults or irregularities in the aircraft that could have had an impact on the sequence of events.

d) The commander held a valid license and rating on the helicopter type

e) The commander did not have any formal instruction or training in flying with high speed at low altitude. Nor should he have been expected to have had such training or experience.

f) During training for the AS 350 type rating, the commander was made aware that the controls become stiff during servo transparency. However, he had not performed training on the phenomenon, and such training is not mandatory.

g) The commander had been employed with Airlift AS for a relatively short period.

h) The commander had a moderate workload before the accident and felt fit to carry out the assignment.

i) The load master did not have any formal duties on board during the two flights, but assisted by reading the map and keeping an eye on things.

j) On the evening before the accident, the commander watched a video produced by the client PS-arrangements in which Airlift carried out an event flight. The fact that the video had an influence on the conduct of the event assignment must be seen in the context of the task form contained little clear information and the procedures for the task not being documented in the operations manual.

k) By virtue of his position as a customer and experienced arranger of events the manager of PS-arrangements took active control over how the task was to be carried out. The fact that he got such an influence on how the flight was executed must be seen in the context of lack of documented procedures to which the commander could refer.

l) The agreed flight, which took place over the Oslo fjord, involved the doors being removed and the passengers wearing climbing harnesses and sitting on the floor in the cabin, attached to a climbing rope.

m) The assignment over Oslo fjord was authorised as a standard assignment only and was not subject to any separate risk assessment by the operator.

n) Commanders have a large measure of freedom to adapt assignments to the customers' needs. Provided the assignment does not require special approval from the operator, an extra flight was just a case of an agreed price and additional billing.

o) The commander considered the flight over Kolsås less demanding than the flight over the Oslo fjord.

p) The weather did not play a role in the sequence of events.

q) The general manager of PS-arrangements suggested that the flight should go to the Kolsås hill. The commander agreed, as the area was unpopulated and the distance was short.

r) The helicopter was flown with the doors removed and the passengers secured with climbing harnesses attached to the cabin floor by a rope. This made it possible for them to sit with their legs and upper bodies reaching out through the door openings and in reality there was only a protection against falling out of the helicopter during the flight.

s) The actual flights with the doors removed was allowable according to the helicopter Flight Manual.

t) The first part of the flight to the Kolsås hill proceeded as expected and without problems.

u) The commander made a turn towards rising terrain so that he consequently flew under the general minimum altitude of 500 ft. However, it could be asked whether the commander was aware that this restriction applied during this particular flight.

v) AIBN considers it unlikely that the commander experienced servo transparency or vortex ring state during the flight.

w) Eurocopter's flight manual contains incomplete and one-sided information about the servo transparency phenomenon.

x) The commander considered the vibrations during the first contact with the trees so severe that the helicopter had to make an immediate emergency landing. The emergency landing was in a sharply sloping forest terrain and the helicopter tipped over.

y) Passenger "1" fell out through the open door and was pinned under the helicopter when it tipped over. This could happen because he was attached to a long rope.

z) The restraint devices used for the passengers were not part of the operator's approved equipment for fastening in parachute jumpers.

3.2 Significant investigation results

a) Over time, a market has developed for event flights for passengers, which include elements such as low flying, jumps out of the helicopter etc. These flights, which are also referred to as event flights, have not been described or regulated by the CAA-N.

b) Prior to the accident, Airlift AS had carried out several flights in the boundary area between passenger flights and aerial work which were not described in the operator's OM A.

c) Airlift AS did not have an approved procedure covering flights where passengers sat on the floor fastened in with climbing harnesses and jumped into the water from a low altitude. The operator therefore gave the commander an assignment which they did not have an approval to carry out.

d) The commander had not been given any guidance, instruction or training in how the task should be carried out. The practical implementation of the assignment was very much influenced by the client's wishes and a video showing a previous flight for the same client.

e) The commander accepted an assignment which involved flying at low altitude and with inadequate passenger safety.

f) While flying with narrow safety margins, the commander misjudged the described turn in relation to the helicopter's performance limitations and altitude over the terrain.

g) Due to bad visual references during the turn, the commander did not notice the high rate of descent until it was too late to avoid hitting the trees.

4. SAFETY RECOMMENDATIONS

The following safety recommendation is issued by the Accident Investigation Board:[21]

Safety recommendation SL no. 2010/01T

Event flights are not defined or regulated and have developed over time. These flights contain elements of passenger flights and aerial work, combined in a way which can present a major safety risk. The AIBN therefore recommends that the CAA-N ensures that this form of flying is appropriate regulated.

Accident Investigation Board Norway

Lillestrøm, 21 January 2010

[21] The Ministry of Transport and Communications forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation, § 17.

APPENDICES

LN-OPY APPENDIX A

RELEVANT ABBREVIATIONS

AIBN	Accident Investigation Board Norway (SHT)
AIC	Aeronautical Information Circular
AMC	Aeromedical center
AME	Authorised medical examiner
AMS	Aeromedical section
AOC	Air Operator Certificate
BSL	Bestemmelser for sivil luftfart (Civil aviation regulations)
CAA-N	Civil Aviation Authority – Norway
CPL(H)	Commercial Pilot License (Helicopter)
ELT	Emergency Locator Transmitter
FLI	First Limit Indicator – indicates how much engine power is available
ft	feet (0.304 m)
GPS	Global Positioning System
hPa	hectopascal
HSLB	Havarikommisjonen for sivil luftfart og jernbane – the AIBN's name in Norwegian prior to September 1, 2005
IFR	Instrument Flight Rules
JAR	Joint Aviation Requirements
JAR-FCL	Joint Aviation Requirements - Flight Crew Licensing
JAR-OPS	Joint Aviation Requirements – Operations
kt	Nautical Mile(s) (1,852 m) per hour
kV	kilovolt
LPT	License Proficiency Test
MHz	megahertz
MTOM	Maximum Take Off Mass
NM	Nautical Mile(s) (1,852 m)

OM	Operating Manual – operating manual in relation to JAR
PC	Proficiency Check
PFT	Periodic Flight Training
QNH	Altimeter setting relating to the pressure at sea level
RPM	Revolutions Per Minute
SHT	Statens havarikommisjon for transport (Accident Investigation Board in Norwegian)
SL	Service Letter
SOP	Standard Operating Procedures
TAS	True Air Speed
UTC	Universal Time Coordinated
VEMD	Vehicle Engine Management Display
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VNE	Velocity not to exceed

LN-OPY APPENDIX B

Extract from CAA-N’s 2005 annual report

Focus areas:

Improved helicopter safety in mainland operations

Accidents associated with mainland helicopter flights have increased in recent years. The operations are often demanding and in relative terms the risk is higher than in offshore helicopter operations. In 2005, CAA-N identified this type of aviation as a focus area.

Most accidents are connected with aerial work, non-ambulance flights or carriage of passengers. Typical aerial work operations include freighting of materials to building sites, wood cutting along power lines and aquatic liming. The accidents often happen during takeoff and landing and are normally due to collisions with the ground, trees or cables.

High accident rate

Mainland helicopters are normally of the smaller type and are used for freighting equipment and personnel in large development projects. These are demanding operations which normally involve flying with a suspended external load with maximum performance, often at low altitude and in tight areas. Despite formal safety systems and procedures, the number of accidents has steadily increased over the last ten years. At present, the chances of being involved in an accident in the mainland market are 18 times higher than in the offshore market. Flights connected with aerial work represent approx. 40 percent of all mainland helicopter flights, but also account for more than 60 percent of accidents.

The number of reported incidents in aerial work does not correspond to the high accident rate. CAA-N therefore assumes under-reporting of incidents in this area of mainland helicopter operations compared with ambulance flights, school flights and private flights. This is in conflict with CAA-N’s wish for an integrated safety and reporting culture for all parts of Norwegian civil aviation.

An increasing number of operators also results in smaller financial margins. In individual cases, there is reason to believe that financial considerations reduce safety margins. Event flights are being increasingly marketed as an experience product. Individual companies have experience and adrenalin kick-off events in their product range, and these include helicopter flights. It is an unfortunate fact that risk has evolved into a new industry. CAA-N works actively to get these event products regulated.

Measures for increased safety

Safety for mainland helicopters has been a focus area for CAA-N in 2005, and this work will continue in 2006. The authority will work to impress among pilots and operator managers the importance of respect for flight safety, flight safety work, legislation and regulations. The authority has established a helicopter group in its operative department which will focus on analyzing safety for mainland helicopters. As a result of a Norwegian initiative, a Nordic cooperation program has been established, in which the Nordic countries exchange experiences and keep each other updated about developments in the market.

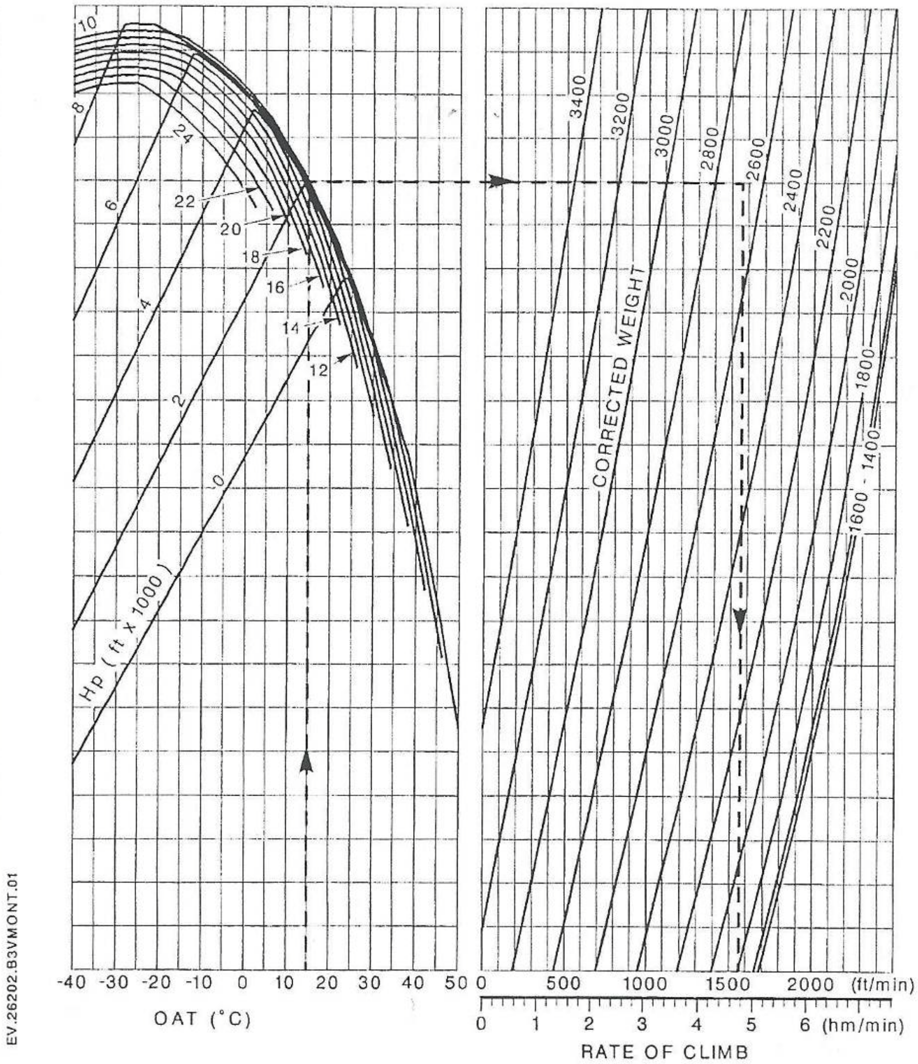
As part of our safety work, we have also carried out unannounced inspections of helicopter companies. In addition, the inspectors will participate in safety meetings in each operator, review the training for pilots and assess new reporting routines for mainland companies.

CAA-N's goal is to improve respect for the regulatory framework among pilots, and improve operator managers' understanding and enforcement of the regulatory framework. Attitudes to safety and risk during flights must be improved at every single stage. Event flights must be conducted in controlled form, safety training at schools must be strengthened and Scandinavian cooperation must be developed.

LN-OPY APPENDIX C

7 RATE OF CLIMB

CONDITIONS	RATE OF CLIMB
- NO P2 AIR BLEED - WITH ELECTRICAL CONSUMPTION ≤ 50 A - FOR ELECTRICAL CONSUMPTION > 50 A PERFORMANCES ARE DECREASED 70 ft/min. - NOTE : WITH P2 BLEED AT T4 LIMIT, REDUCE PERFORMANCE DATA BY 250 ft/min.	



EXAMPLE : OAT = 15°C Hp = 8000 ft

CORRECTED WEIGHT = 2700 kg => RATE OF CLIMB = 1560 ft/min

Figure 5

DGAC Approved: 350 B3 **5.1**

A 98–36 Page 9

AS 350 B3 Rate of Climb

Ref. AS 350B3 Flight Manual, 5.1, Figure 5.

LN-OPY APPENDIX D

Chapter 14

Angle Limitations

IN movies, we've recently seen various helicopters performing such airshow maneuvers as full rolls and Immelmann turns. This may seem surprising, considering that flight restrictions imposed on most helicopters limit the allowable bank and sideslip angles.

Listed in the pilot's handbook, these restrictions are there to ensure flight safety, structural integrity, and generally to keep the pilot out of some potentially dangerous conditions.

Bank angle

The bank-angle restriction warns the pilot that while his helicopter may have the control capability to roll steeply, it has only enough power and/or thrust to maintain a turn up to a certain limit of tightness. A number of helicopter (and airplane) accidents have been attributed to losing altitude while trying to exceed this limit too close to the ground.

The load factor in a turn is related to the bank angle (**Figure 14-1**). For instance, a bank angle of 60° corresponds to a load factor of 2.

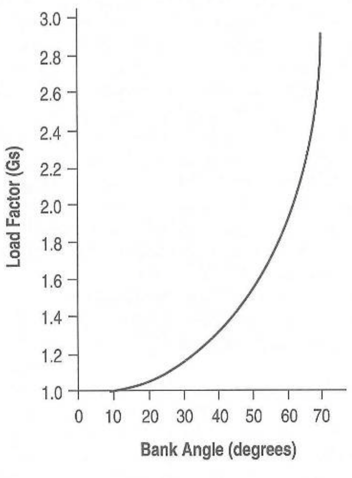
To hold this bank angle in a turn, the rotor has to develop twice as much thrust as in straight and level flight. For the helicopter not to lose altitude or speed during the maneuver, the engine must have enough reserve power to satisfy the requirements of this suddenly doubled effective weight. Very few helicopters can rise to this challenge.

The result: the engine limit is reached and the rotor slows down—leading to rotor stall and loss of thrust just when it's needed most. Making use of the kinetic energy of forward flight by slowing down in the turn may supply some of the extra power required.

Calculations for a typical helicopter indicate that slowing down from 115 knots to 100 knots while going halfway around a 2-G turn can increase the available power by an increment equal to about 70% of that required to fly level. But that still might not be enough.

Similarly, some potential energy can be converted into power by losing altitude (if there is altitude that can be lost). Calculations for the same typical helicopter show that a loss of 100 feet during the 180° turn at 2 Gs could provide an effective boost of power equal to about 50% of the level-flight power.

Figure 14-1
Load Factor In Steady Turn



Sideslip angles

Many helicopter pilot's manuals contain allowable sideslip envelopes such as that shown in **Figure 14-2**. The sideslip angle is restricted at high speed to avoid excessive loads on the tail boom and excessive flapping of the tail rotor.

The limits were set after the helicopter's builder studied the results of his "flight-strain survey." This survey involves using a prototype with a full set of instrumentation, including strain gauges, flapping sensors, and a sideslip indicator.

50

Bank angle limitations

Ref. Even More Helicopter Aerodynamics. R. W. Prouty. Rotor & Wing. Phillips Business Information Inc. 1993.

Chapter 2

Vertical Climbs and Descents

Compared to other aircraft, the helicopter is unique in its ability to go straight up and down.

Conditions of flow

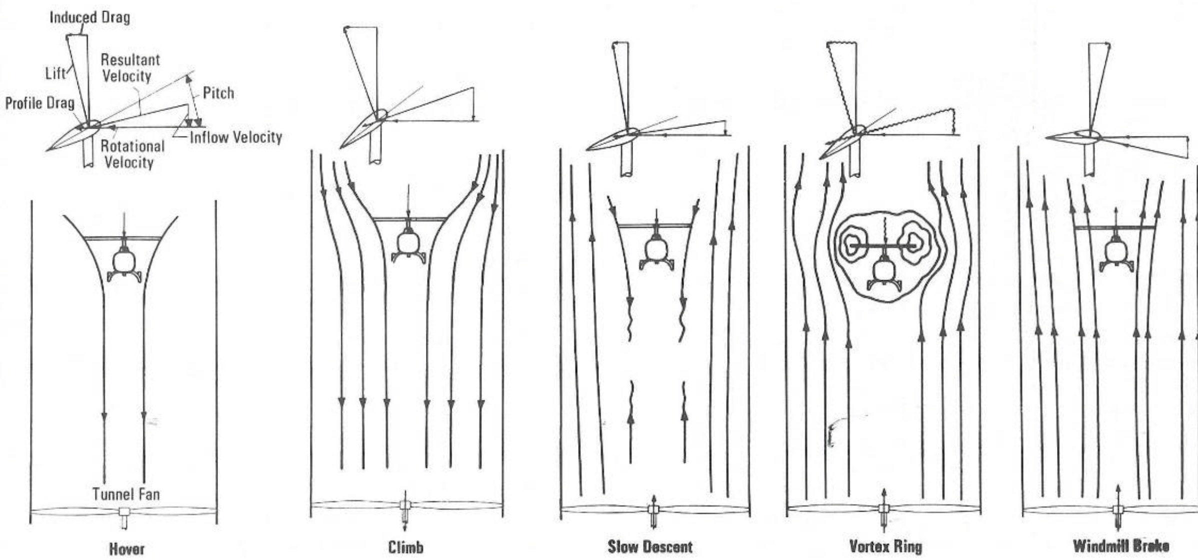
For an understanding of these maneuvers, we must distinguish between cases in which flow goes up through a rotor and those in which the flow goes down through it. To illustrate the various possibilities, Figure 2-1 shows a small rotor—developing a constant thrust—installed in a large vertical wind tunnel. The tunnel fan can generate a flow either up or down. (Aerodynamicists like this kind of analogy because they are all firmly convinced that aircraft stand still while the air blows past them.)

For hover, the tunnel fan is turned off and the rotor is inducing flow downward as it would for a normal hover. To represent a vertical climb, the fan is used to suck air down the tunnel, increasing the downflow through the rotor.

Vertical descent is simulated by reversing the pitch of the fan to blow air up the tunnel. For low levels of tunnel upflow (representing a slow descent), the rotor-induced downwash will still dominate the flow in the vicinity of the rotor and, except for a decrease in rotor power, conditions will be similar to hover.

Turning the fan up a notch puts the rotor into the vortex-ring state where the tunnel upflow is approximately the same as the rotor-induced downwash. In this condition, tip vortices cannot move away from the rotor disc and some of the air becomes trapped in a smoke-ring-shaped body enclosing the outer rim of the rotor. For the pilot trying to fly the aircraft under these conditions, the

Figure 2-1
Examples of Rotor Flow States in Vertical Wind Tunnel



7

Vortex Ring State (1)

Helicopter Aerodynamics

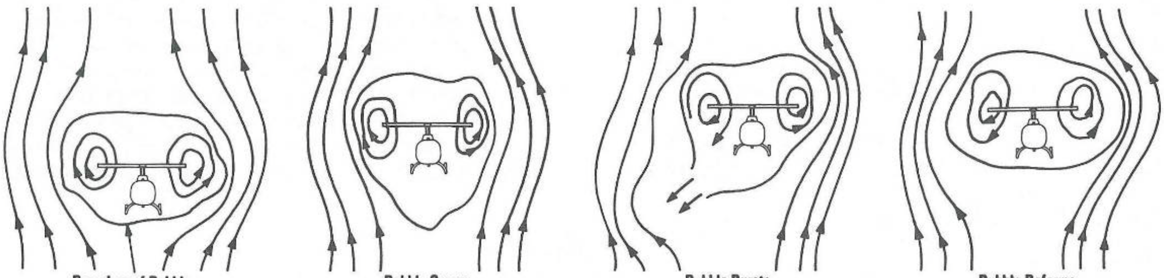
vortex-ring state produces some interesting effects, which we'll get into a little later.

Turning the fan up full blast so that the flow is greater than the rotor-induced velocity makes the net flow *upward* through the rotor. The rotor is now slowing the tunnel flow a little and actually is extracting energy from the passing wind. Naturally this condition is known as the windmill-brake state. It is important to windmills that pump water, grind corn, or generate electricity, but it is somewhat academic in our discussion – since helicopters have no good way to either dissipate or store energy.

Also shown in Figure 2-1 are the conditions at a blade element. Comparing these diagrams, we can see how the net flow through the rotor disc changes the collective pitch required to maintain constant thrust. The flow also causes the lift vector to tilt back in climb – increasing the power required. At low rates of descent and in the windmill-brake state, the flow causes the lift vector to tilt forward – decreasing the power required.

The vortex-ring state is more difficult to characterize, since the inflow pattern is not well-defined. We know from experiments, however, that both the collective pitch and the power required to maintain a constant thrust are high and, therefore, the average conditions at the blade element must be similar to those in climb.

Figure 2-2 Vortex-Ring Conditions



Climb and descent power

If a climbing helicopter were a rising elevator, the power required above that necessary to hover would be simply the product of the gross weight and the rate of climb in feet per minute (fpm) – all divided by 33,000 to get it into horsepower. (Our horsepower unit comes from old British coal-mining technology. A "standard" horse could lift 100 pounds out of a vertical shaft while walking away at about four mph or 330 fpm.)

A helicopter is not quite like an elevator. The aircraft gets a windfall advantage from the extra flow through the rotor due to the climb velocity. With this increase, the rotor doesn't have to work quite as hard as might be expected – with the result that the extra power required for climb (above that required for hover) is theoretically only half of what it would be if the helicopter were an elevator.

Two other benefits exist in climb that even further reduce the power required; first, the trailing tip vortices are further down when the next blade passes by and, second, the tail rotor is less disturbing to the induced-velocity distribution of the main rotor. Recent Army tests on the Sikorsky Black Hawk have shown that these effects are significant. Although, as on all helicopters, more collective pitch is required to climb than to hover, the power required is actually less for low rates of climb.

For rates of descent low enough to stay away from the vortex-ring state, the same relationship applies – only half the rate of change in potential energy could possibly be realized as a power reduction. Of course, the two benefits that apply in climb are detriments in descent, so the power required is somewhat higher than theory says.

Flight in the vortex ring

Because of the nonuniform and unsteady characteristics of the flow through the rotor in the vortex-ring state, the challenge to the theoretician is greater than for the other more straightforward flight conditions and much of our knowledge of this state comes from flight and wind-tunnel tests. Based on this experience, we know that unsteadiness starts at about one-quarter, peaks at three-quarters, and disappears at 1¼ times the hover induced velocity.

Depending on their disc loading, various current helicopters enter the state when descending 300 to 600 fpm and have to be going 1,500 to 3,000 fpm to get clear of it. Staying in the vortex ring for any length of time isn't easy. It depends upon

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Vortex Ring State (2)

LN-OPY APPENDIX E

Vertical Climbs and Descents

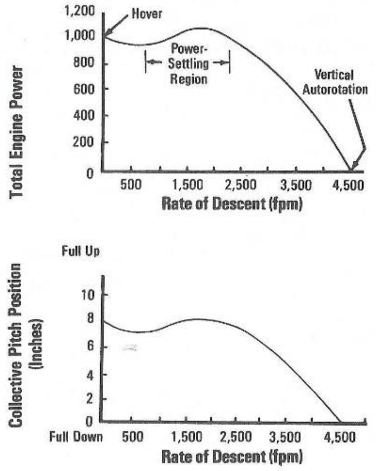
maintaining a nearly vertical flight path. There is some evidence, however, that a "glide" slope of about 70° is worse than a true 90° descent. Shallower approaches than about 50°, corresponding to forward speeds of 15 to 30 knots, will introduce enough fresh air into the system to blow the tip vortices away from the rotor and free it from the clutches of the vortex-ring state.

The unsteadiness of the flow has been seen during wind-tunnel tests of model rotors using smoke for flow visualization. Figure 2-2 is a sequence of events based on an interpretation of the smoke movies. According to this concept, the rotor is continuously pumping air into a big bubble under the rotor. This bubble fills up and bursts every second or two, causing large-scale disturbances in the surrounding flow field. The bubble appears to erupt first from one side and then another so that not only does the rotor thrust vary, but the rotor flaps erratically in pitch and roll – requiring prompt pilot action.

Power settling

Besides the unsteadiness, one of the most unusual characteristics of the vortex ring is the high power required to maintain rotor thrust. Pilots call it "power settling" based on their observation that in some cases the helicopter keeps coming down even though full engine power is being used. Figure 2-3 shows the power and the collective pitch required to maintain constant rotor thrust in vertical descent for a typical helicopter. Not only does the power required increase in the vortex-ring

Figure 2-3—Power And Pitch Required In Vertical Descent For Typical Helicopter



state, but so does the collective pitch – apparently due to local blade stall during flow fluctuations.

The range between 750 and 2,300 fpm for the helicopter shown in Fugure 2-3 is the power-settling condition. This situation can become a problem when making a nearly vertical landing approach with a heavily loaded helicopter on a hot day when the power available is low.

Another scary scenario is an engine failure on a multiengine helicopter making a takeoff from a rooftop. In this operation, the prudent takeoff path is vertical – or even slightly backward – so that in case of an engine failure the helicopter can either return to the rooftop or (if high enough) go into forward flight without descending below the level of the roof—according to FAA rules. It is obvious that if the rate of descent back to the roof with one engine inoperative puts it into the vortex-ring state, then the landing may be more traumatic than the pilot might have anticipated.

Power settling has also been experienced during the downwind flare used for a quick stop or during a crop-dusting turn. In any case where the helicopter catches up with its own wake, the power required to keep from falling out of the sky will suddenly increase.

The tail rotor too

The problems of operation in the vortex-ring state were first discovered on main rotors, but tail rotors may get their share in conditions such as right hover turns and left sideward flight (for helicopters with main rotors turning counterclockwise). Not all helicopters experience these troubles, but for those that do, a common symptom is a sudden increase in the turn rate, referred to by some pilots as "falling into a hole." This is due to the collective-pitch characteristics shown on Figure 2-3. A more detailed discussion of this problem will be found in Chapter 9.

Vertical autorotation

After the helicopter is descending fast enough to pass through the worst of the unsteadiness in the vortex-ring state, it will achieve vertical autorotation. Usually, there is still a little induced downflow through portions of the rotor disc – although most of the flow will be upwards. This mixed-flow condition technically qualifies the rotor to still be classified as in the vortex-ring state.

In those portions of the disc subject to upflow, the lift vectors will be tilted forward. When enough of the vectors are tilted in this fashion, they will overcome the drag of the blades and even provide enough extra power to drive the tail rotor, gearboxes, and accessories, thus requiring no power from the engine.

Vertical autorotation is a stable condition and

9

Vortex Ring State (3)

Ref. Helicopter Aerodynamics. R. W. Prouty. Rotor & Wing. Phillips Publishing Inc. 1985.

LN-OPY APPENDIX F

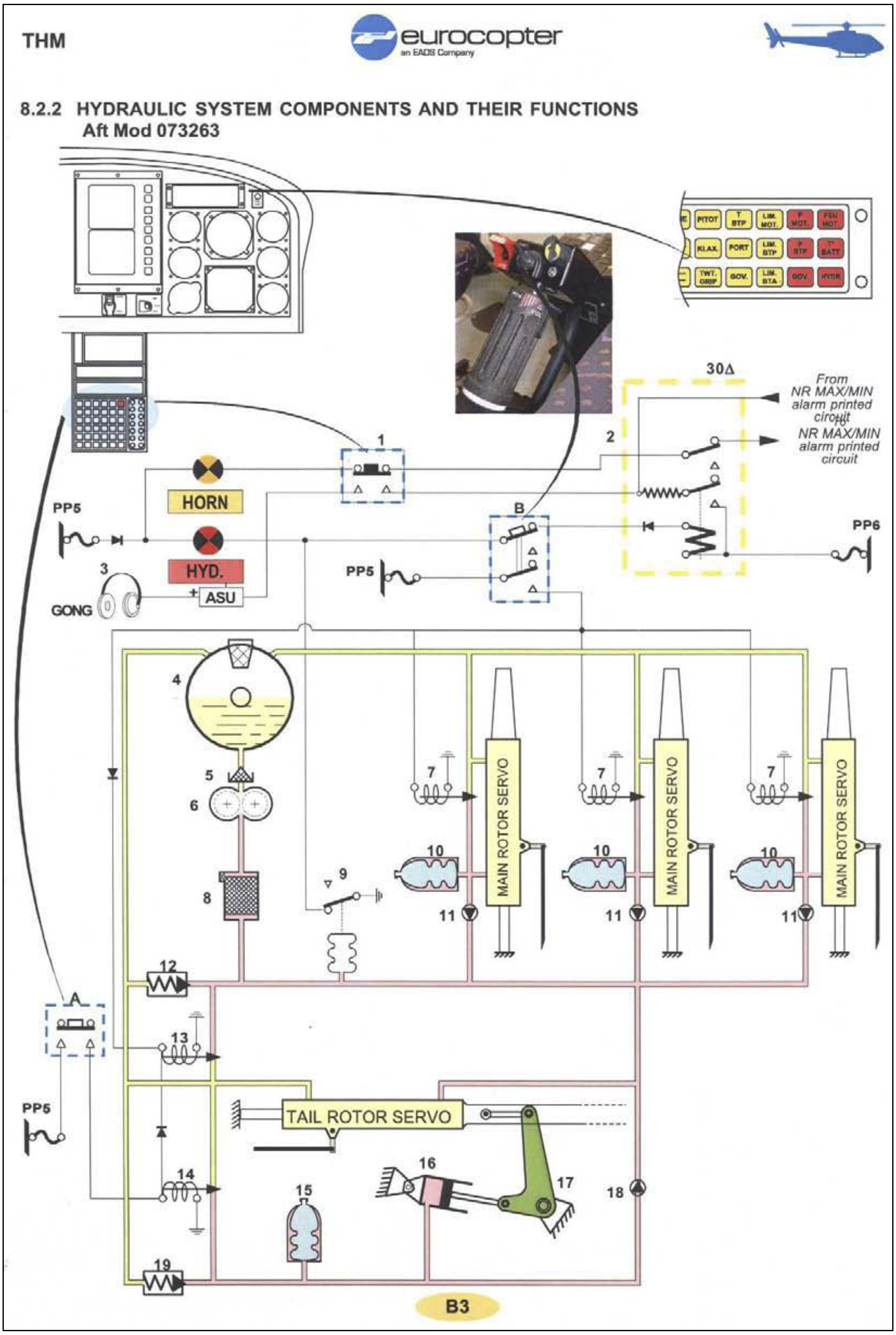


Figure 12. Diagram showing components in the hydraulic system.

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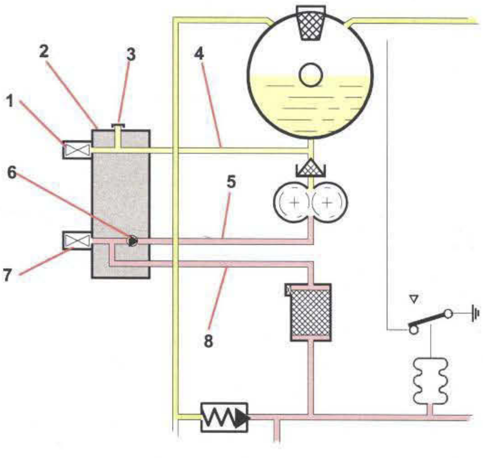
8.2.2 HYDRAULIC SYSTEM COMPONENTS AND THEIR FUNCTIONS (Cont'd)

1 **HORN pushbutton** on control pedestal. Used to disable the horn.
2 **Control relay**, energized in case of hydraulic pressure drop or loss of NR.
3 **HORN** providing aural alarm in case of loss of hydraulic pressure or drop in NR.
4 **Hydraulic fluid reservoir**
5 **Strainer** (mesh size = 0.8-1 mm) on pump inlet.
6 **Gear pump** driven by MGB, with flowrate = 6 l/min.
7 **Main rotor servo actuator solenoid valves**, controlled by pushbutton B. Used in case of hydraulic failure or seizure of a servo actuator distributor to route the servo pressure inlet line back into the reservoir; this eliminates back pressure in manual control and hence reduces the control loads.
8 **Filter unit** with clogging indicator. Filtering capacity = 3µ.
9 **Pressure switch,** which closes the "HYD" light circuit when P < 30 bar.
10 **Backup accumulators** on main rotor servo actuators. Used in case of hydraulic failure to provide a small energy reserve so that the pilot can attain a "least load" fallback speed for manual control.
11 **Main rotor servos non-return valves**, which are closed in case of hydraulic failure by the accumulators' pressure (the flow from the accumulators is only used by the servo actuator).
12 **Regulator valve,** which keeps the system pressure at 40 bar.
13 **"Hydraulic Test" solenoid valve,** controlled by pushbutton A. When energized it opens to route the servo actuator supply circuit back into the reservoir. This depressurizes the system and allows the backup accumulators (10) to be tested on the main rotor servo actuators.
14 **Solenoid valve** for discharging accumulator (15). When open, the valve allows the pedals to be operated with the rotor stopped.
15 **Accumulator,** which provides a power reserve for load compensator actuator (16).
16 **Hydraulic actuator,** which together with lever (17) facilitates tail rotor pitch changes in case of loss of hydraulic power.
17 **Multiplying lever**, which magnifies a small displacement of the actuator piston into a large movement of the servo actuator rod connecting point.
18 **Non-return valve,** which keeps accumulator (15) charged in case of loss of hydraulic pressure.
19 **Pressure relief valve,** which partially bleeds off the hydraulic fluid when the compensator piston returns from the extreme extended position; this eliminates hydraulic locking when the system is pressurized.
A **"HYDRAULIC TEST" pushbutton** (on control pedestal) which activates solenoid valves (13) and (14).
B **"Hydraulic cutoff" pushbutton** (on collective lever) which activates solenoid valves (7).

OPTION

INSTALLATION OF GROUND POWER CONNECTION



HORN "HORN" light; when lit indicates the aural alarm pushbutton is not in working position

HYD. "Hydraulic pressure drop" warning light

1 - Self-sealing suction ground connection
2 - Manifold on RH side of transmission deck
3 - Drain plug
4 - Suction pipe
5 - Helicopter pump delivery pipe
6 - Non-return valve
7 - Ground pressure quick release coupling
8 - Ground or pump delivery pipe

Figure 13. Description of the hydraulic components in the previous figure.