Aircraft Accident Investigation Board, Norway

REP 19/2003

REPORT ON AIRCRAFT ACCIDENT AT LÅGHELLERNUTEN ON THE HARDANGER PLAIN IN THE MUNICIPALITY OF ULLENSVANG, HORDALAND ON NOVEMBER 6 1999, INVOLVING EUROCOPTER AS 350-B2, LN-OCF OPERATED BY AIRLIFT AS

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Type:	Eurocopter AS 350-B2, Ecureuil
Registration:	LN-OCF
Owner:	Airlift AS Førde Airport NO-6815 Bringeland
User:	Airlift AS
Crew:	1, seriously injured
Passengers:	3, 2 killed and 1 seriously injured
Accident location:	At a height of approx. 1,460 m above sea level on the north-east slope of Låghellernuten on the Hardanger plain, bearings 60^{o} 16’ N, 007^{o} 17,5’ E
Time and date of accident:	November 6 1999, at time 1305.

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

ACCIDENT REPORT

At time 1540 on November 6 1999, the Aircraft Accident Investigation Board/ Norway (AAIB/N) was notified by the Oslo Police District Operations Centre that helicopter LN-OCF had been the subject of an accident on the north-west side of the Hardanger plain. Rescue action was put into operation. This was made difficult by the weather conditions. AAIB/N despatched three inspectors the following morning and they arrived at the county’s administrative office in Kinsarvik at time 1330. After a short briefing by the police, the group was flown to the scene of the accident where investigations were initiated.

In accordance with “Annex 13 to the Convention on International Civil Aviation ” the French commission Bureau Enquêtes - Accidents (BEA) appointed an investigator as an authorised representative. He used the Accident Investigator Manager from Eurocopter (the helicopter manufacturer) and an expert from Turbomeca (the engine manufacturer) as technical advisers.

SUMMARY

A single-engine Eurocopter AS 350-B2 helicopter, Ecureuil, from the company Airlift had been carrying out an assignment in the area of Låghellernuten on the Hardanger plain. On completion of the assignment, while climbing parallel to rising terrain, the helicopter's engine lost power. The height above ground was then so low that the commander's attempt to implement a controlled landing in autorotation was unsuccessful. The helicopter lost height and hit the snow-covered ground at forward speed and with a high rate of descent. After the heavy impact, the helicopter was thrown down the sloping terrain. The front part of the helicopter was completely destroyed and two of the four onboard were killed. The two others, one of them the commander, were seriously injured.

Despite numerous thorough examinations of the fuel control unit, engine and other components, both in Norway and France, it has not been possible for AAIB/N to ascertain the cause of the engine's loss of power.

Airlift has been most cooperative and both theirs and Lufttransports knowledge has been contributing.

There are two main contributing causes of this accident. One is that the engine failed in a critical phase of the flight. The other is the selection of the flight path.

On the basis of this aviation accident, AAIB/N has issued seven recommendations, which can be found in section 4.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The helicopter was on an assignment in which the passengers were to inspect the damage following a break-in at a cabin, which one of them used at Lægreidsoksla on the Hardanger plain. When the order was placed with Airlift, it was specified that there would be two passengers.

1.1.2 The Commander made preparations for the flight as he waited for the passengers to arrive at the helicopter base. The plan was to use an AS 315 "Lama", LN-OMU, for the assignment, and the Commander prepared the helicopter for the flight. The passengers arrived in Kinsarvik by ferry from Utne at approx. time 1200. Once at the base, the passengers, two brothers-in-law who were in their forties and the seven-year old son of one of them, were seated in the helicopter. The Commander gave the standard safety briefing and seat belts were fastened. Some thin plywood boards to bolt the cabin windows were also loaded and placed on the floor. A bag of tools and a video camera were also taken onboard. It was agreed to make a full shutdown of the helicopter's engine on arrival at the cabin, which meant there was no need for a second crewmember to accompany the flight.

1.1.3 As there were starting problems with LN-OMU, it was decided to change to another helicopter to save time and an "Ecureuil" LN-OCF, was prepared. The passengers and cargo were moved to this helicopter. The seatbelts were fastened again (the commander also used shoulder belts) and the Commander, assisted by a technician, gave a new safety briefing. The technician observed that the older brother-in-law (the client) was sitting at the front on the left of the pilot, while father and son sat behind in the middle seats.

1.1.4 The passengers were appropriately dressed for a flight to the mountains, while the Commander was wearing his normal flying suit with "synfiber" thermo winter jacket and helmet. He usually brought a bag containing warm survival equipment. However, he did not do so on this flight.

1.1.5 LN-OCF was fuelled to half capacity, which was sufficient for the planned flight. The helicopter has a fuel capacity of 540 litres and a normal consumption of approx. 170 litres/hour.

1.1.6 The start-up at approx. time 1215 at the Kinsarvik base was completely normal. The same applied to the take-off and the flight towards the mountains. They followed the following route: Up Husedalen to Stavali, then Veigdalen – Smågrananutane directly towards Lægreidsoksla. The client had a few problems locating the cabin from the air, but after about 20 minutes flying time from Kinsarvik, they made a normal landing next to the cabin at approx. time 1235. The landing caused little snow drifting. The engine was stopped and the passengers remained in their seats until the rotor had come to a standstill.

1.1.7 Weather conditions during the flight had been good, with a cloud height of about 1.000 feet, good visibility, no precipitation and almost dead calm. Conditions during the stay at the cabin were the same. There had been no snowfalls, which meant that no snow or other precipitation could be seen on any of the helicopter's surfaces. The pilot was aware of the Lettre Service 1270-00-9 concerning operations in snowy conditions and had that in mind when he inspected the helicopter.

1.1.8 The work at the cabin took 20-25 minutes and the pilot also helped with the work. The window that had been smashed during the break-in was filmed with the video camera and the plywood boards were nailed to the window. The pilot was asked to take a petrol-powered generator back to Kinsarvik. He agreed and it was placed in the basket (cargo hold) on the outside of the helicopter. The power generator had an estimated weight of 10 kg and the basket had a max weight limitation of 200 lb (91 kg).

1.1.9 Once the work was completed, the passengers were taken onboard again. The client was seated at the front and the father and son behind, with the seven-year old son on the right side of the middle with the father seated outside of him to the right. It was agreed that the helicopter would circle the area around the cabin before setting a course back to the base.

1.1.10 LN-OCF was parked next to the cabin with its nose facing north. The present fuel level was approx. 40% of a full tank. After a normal start-up, the Commander lifted the helicopter and made a 360^o climbing turn in hover before he turned southeastwards in a 270^o climbing turn (see map with staked-out flight path, Appendix no. 3). A course was then set to Låghellernuten and as they neared the top, he had planned to turn the helicopter on a southeasterly heading to fly round the top of the peak. The plan was to set a direct course to Kinsarvik when LN-OCF was on the south side of the peak.

1.1.11 The helicopter was climbing on a southeasterly heading, parallel to raising terrain of Låghellernuten at approx. 85% Tq (torque) power output and, according to the Commander, at a speed of 70-80 kt when the engine suddenly lost power. The Commander estimated the height above the mountainside to approx. 30 – 50 m. He noticed first a reduction in engine noise and then a warning light (HORN) to indicate low rotor revolutions per minute registered on the warning panel, at the same time as the warning horn sounded. He also saw that the low generator power alarm (GEN) was lit and noticed a "yaw" – a tendency to the left. He tried to put the helicopter into autorotation, but it was at too low a height above the ground for this to have any particular effect. The Commander is well trained in autorotation.

1.1.12 At time 1305, approx. 3,5 km after departure and 80 m higher than point of departure, the helicopter hit the snow-covered slope at a heading of 90^o. It hit with forward speed and a high rate of vertical descent. The helicopter stuck the snow covered mountain with a slightly nose up or flat attitude. It continued "airborn" 14 m and made the second impact, turned left, fell 4 m vertically and continued 23 m down the steep mountain slope. It came to rest on its side, almost upside down (see Appendix 2). The cockpit and cabin area were completely destroyed and the two front seats came loose (ref. 1.12.2). The Commander and the two adult passengers were thrown out from the cockpit and cabin. The boy remained strapped-in inside the helicopter. The adults were killed, while the Commander and the boy were seriously injured.

1.1.13 The emergency location transmitter (ELT) was activated after the collision and the signals were picked up by two scheduled flights that were passing over the area. The aircraft crews informed Stavanger ATCC, who alerted the main rescue co-ordination centre in Sola. The rescue operation was then put into action.

1.1.14 When he regained consciousness after the accident, the Commander found himself lying in the snow outside the helicopter. He was the worse for wear, but after a while managed to pull the boy out of the wreckage where he was still strapped in. He examined the other passengers who were lying on the snow at the side of the wreckage and realised there was nothing he could do for them. He wrapped himself and the boy in a freight bag ("big bag") approx. 20 metres below and a little in front of the helicopter. The bag, which is made of roughly woven nylon, is un-insulated, but still gave some protection against the cold and wind. At time 1412 the Commander managed to get through to the Airlift base at Kinsarvik by mobile telephone (he made two calls), and was able to report the accident. Mobile phone (GSM) coverage was poor in the area and the message was a little sketchy. At time 1616 he tried to contact the base again, but the conditions for using a mobile telephone, plus the fact that the Commander had serious injuries including facial injuries, made it difficult to understand the information he was giving.

1.1.15 Because the weather conditions had deteriorated shortly after the accident, it was not possible to access the accident site with a rescue helicopter. There was thickening fog and cold snow. It was not until approx. time 2200 that a rescue patrol arrived at the accident site. They had been flown to the area and arrived at the accident site on foot. The two survivors were taken to a small cabin (Huldrabu) in the area where they were treated. Next morning the weather conditions had improved enough for them to be transferred by rescue helicopter to Haukeland hospital in Bergen.

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHER
FATALITIES		2	
INJURED	1	1	
MINOR/NONE			

1.3 Damage to the aircraft

The helicopter was completely destroyed. In the first impact with the ground, the underside of the helicopter smashed and the skid (landing gear) on the right side broke off. A least one of the rotor blades stuck the ground. The next impact caused the doors, glare shield and windows to become separated from the helicopter. The helicopter continued down a small precipice, where also the left skid broke off, before it came to rest upside down. When it came to a rest, both front seats and the engine were detached. The tail boom was torn off, the transmission was pushed forward and the fuel tank ripped. The whole structure above the cabin floor to the back bulkhead of the cabin was ripped off.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 The Commander, male, 33 years of age, completed his flying training in 1985-1986 at Omega Helicopters in the USA. He converted his American licences to Norwegian ones in 1988 and joined Airlift A/S as an air-cargo worker from 1989 to 1991. The Commander holds CPL-H, which is valid until on August 18 2006. He had his last PFT on August 13 1999. His last medical examination was carried out on April 17 1999.

1.5.2 The Commander was employed as an air-cargo worker and a pilot with Helikopterteneste A/S between 1991 and 1993. He was employed as a pilot with Lufttransport A/S in 1994. Since 1996, he has been employed by Helikopterteneste A/S. This company became part of Airlift A/S, where he is currently employed based in Kinsarvik. At the time of the accident the Commander acted as chief pilot at this base.

1.5.3 The Commander has extensive experience flying in mountainous terrain. He had a total of 2.505 flying hours, 135 of which are on aeroplanes.

FLYING TIME	TOTAL	THIS TYPE
LAST 24 HOURS	2:00	0:25
LAST 3 DAYS	9:00	0:25
LAST 30 DAYS	20:10	1:20
LAST 90 DAYS	134:05	46:10

1.5.4 At an enquiry the Commander has stated that he felt healthy and in good spirits at the start of the flight. He was rested after a normal night’s sleep.

1.6 The aircraft

1.6.1 The aircraft, general

1.6.1.1 The aircraft was a six-seater, single-engine Eurocopter AS 350 B2, serial number 2478. The helicopter was type-approved for the Norwegian aircraft register on type certificate no. 04A/86.

1.6.1.2 It was built in 1991, and was placed on the Norwegian register on May 16 in the same year. The helicopter was operated by Helikopterteneste A/S until August 9 1999 when the company merged with Airlift AS (Helikopterteneste had been a part of Airlift since of April 9 1996). At the time of the accident the helicopter had a total flying time of 5,292:09 hours and had made 11,087 landings. The engine's flying time was 5,302:00 hours. The last 500-hour inspection of the helicopter and engine was performed October 11 1999, at a total helicopter flying time of 5,254: 36 hours, 26 days before the accident.

1.6.1.3 The 500-hour inspection also includes a fuel control unit (FCU) characteristics check (NR versus NG%, MM 73-20-01). The result from the check was within the limits defined by the manufacturer.

1.6.1.4 AAIB/N did not find any lifetime components that exceeded the lifetime. The "Hold Item List" (HIL) contains only one open point, which relates to the changing of bolts in the main rotor head.

1.6.1.5 Shortly before this flight, work on the fuel system was carried out. The result of an in-house check (Airlift AS) of this work (Maintenance Manual 73-20-01) was within the manufacturer's specifications and tests performed by AAIB and Turbomeca carried out after the accident confirmed the result. The G check (a main inspection) was performed on February 19 1999 at a total of 4,704:36 hours. Because of a bird strike, the engine's modules nos. M2, M3 and M4 were changed on September 29 1997. At that time the engine time was 3,983:00 hours. The FCU was also replaced at the same time.

1.6.1.6 The Norwegian Civil Aviation Authority renewed the helicopter's airworthiness certificate on May 20 1999 and made no notes in its inspection report.

1.6.2 The engine

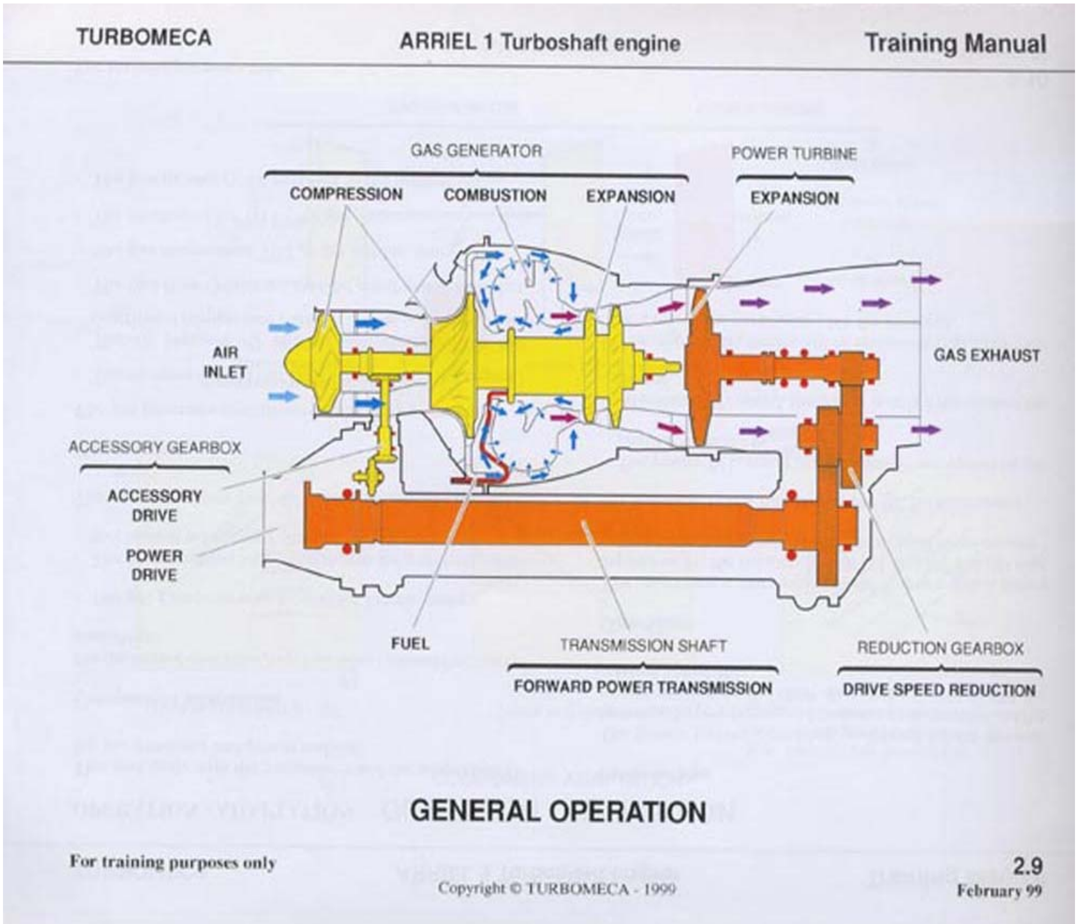
1.6.2.1 The engine was a Turbomeca Arriel 1D1 engine with the serial number 9407. This engine is a free turbine turboshaft engine made up of five modules.

Module M1, consists of a drive shaft, accessory gearbox and freewheel. The FCU S/N C 508B is installed on the left front face of the accessory gearbox.
Module M2, axial compressor module.

Module M3, gas generator (high pressure) including centrifugal compressor, combustion chamber and turbine.
Module M4, power turbine.
Module M5, reduction gearbox.

The gas generator consists of a single stage axial compressor, a centrifugal compressor, the annular combustion chamber with centrifugal fuel injection and a two stage axial turbine (M2 and M3). The accessory gearbox is connected to the gas generator (M2) and is part of M1.

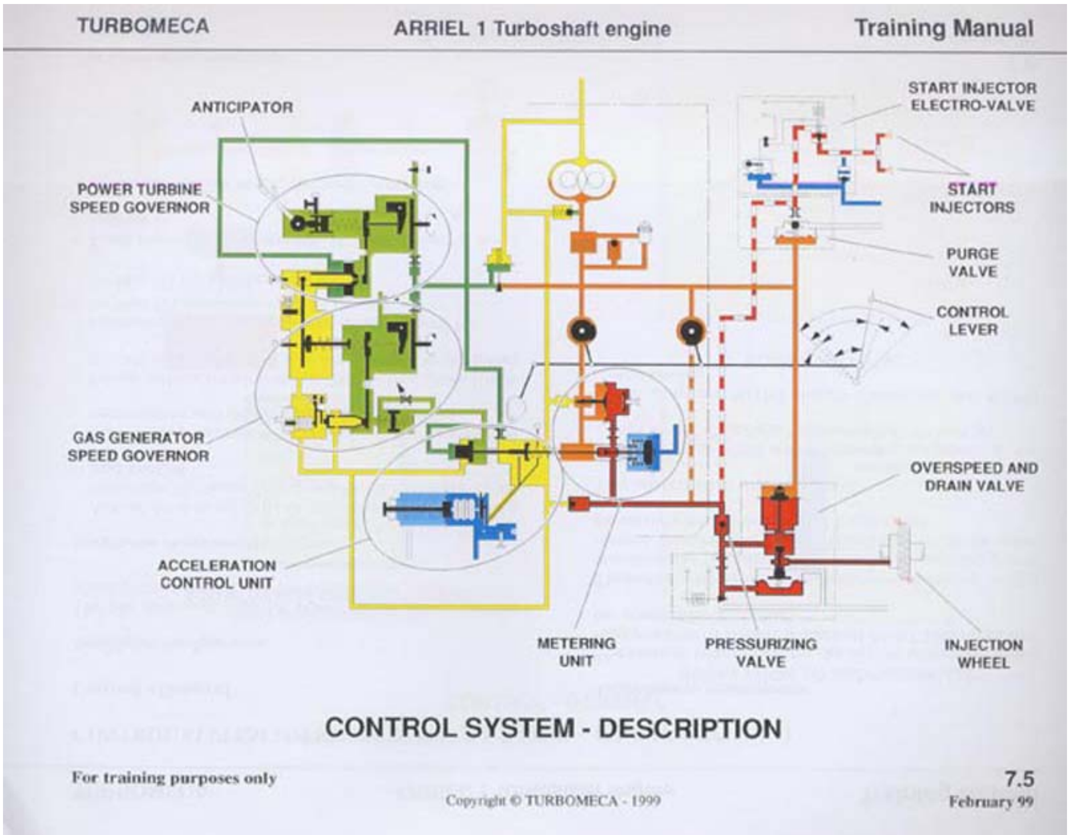
The power turbine (M4) is a single stage axial turbine connected with the reduction gearbox (M5). The reduction gearbox (M5) is connected with the transmission shaft M1. The gas turbine's revolutions per minute, N_1, at 100% correspond to 51,8 00 RPM. The power turbine (free turbine) transfers power via the reduction transmission, drive shaft and freewheel to the main rotor gearbox. The power turbine's revolutions per minute, N_2, at 100% correspond to 41,586 RPM.

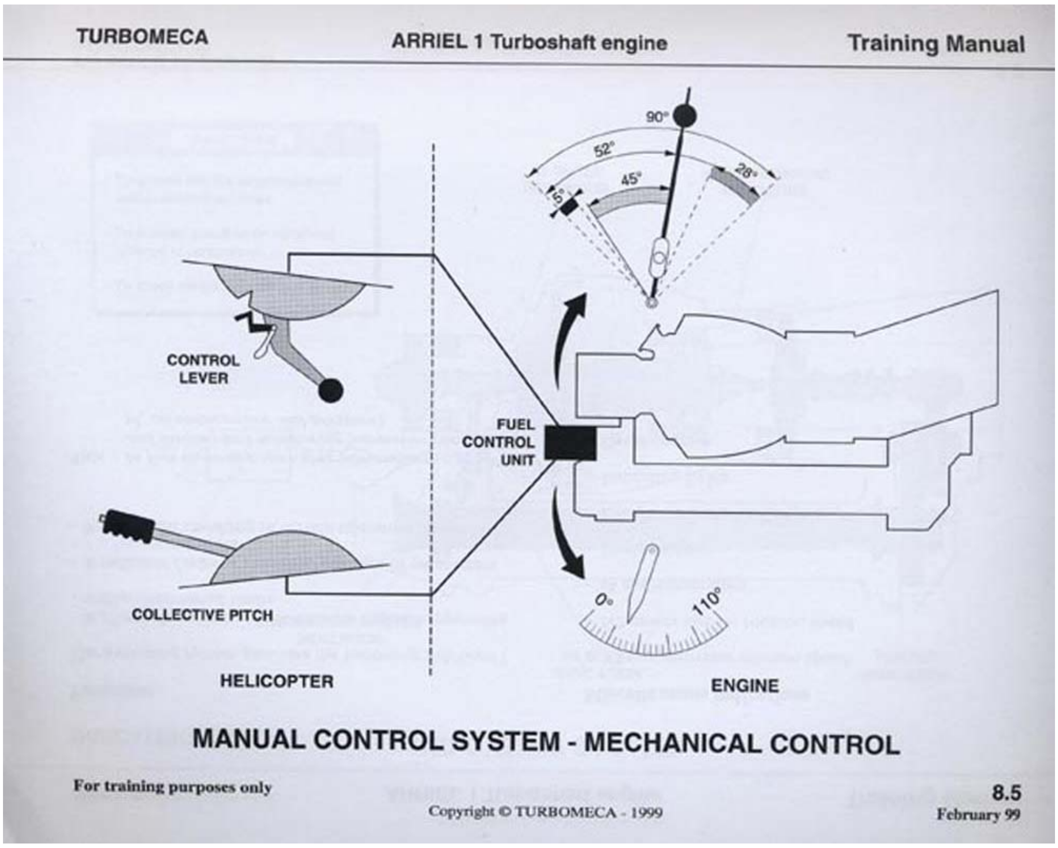


1.6.3 Fuel system/Control system

1.6.3.1 The fuel system consists mainly of a fuel tank, fuel pumps, fuel filter (with bypass), a hydro-mechanical fuel control unit (FCU), which uses fuel as a hydraulic medium, start injector valve, start injectors, overspeed and drain valve and injector wheel. The fuel flow to the engine is regulated by the FCU, with the aim of maintaining a virtually constant N2 and rotor revolutions per minute. The FCU detects changes and acts to compensate for these, on the basis of the revolutions per minute information (N1 / N2). The changes will take place in such a way that no limits are exceeded, such as overspeed/underspeed of N1, T4, torque etc. The FCU is dependent on P2 air to function.

The Commander has two methods of controlling the fuel supply. One is by using the fuel control lever in the cockpit. This actually has three positions: shutdown, open and emergency position. The emergency position is used if the automatic part of the FCU fails. In this position the Commander must monitor all engine parameters manually and try to compensate for deviations. The other method by which the Commander controls the fuel is by using the collective. The collective is connected to the FCU, which advances the phase of detection of changes in order to reduce the response time (anticipator) and to compensate the static drop. There is also a handle, which controls a separate fuel shut off valve.





1.6.4 Flame out

The engine is sensitive to snow and small amounts of snow in the air intake can result in a flame out. The engine is not equipped for an automatic restart after a flame out. Lettre-Service No 1270-00-9 describes measures to be taken before and during flying in snow.

1.6.5 Indications of deviating engine speed

P2 bleed valve (compressor bleed valve) is open at start-up and closes when N_1 exceeds 93% and opens when N_1 drops below 92%. Inside the helicopter a green and yellow flag in the specific ΔNg indicator indicates that the P2 valve is open. When the rotor speed (N_r) fall below 362 RPM an audio alarm will be triggered (continuous sound) and an amber light marked HORN will flash (controlled by the "horn" pushbutton). The horn will sound until the speed falls below 250 RPM. In the "off-horn" position, the light will continue steady until RPM drop below 170. The same audio alarm will also indicate a hydraulic fault (when the pressure falls below 30 bar), but the red HYD light will also come on. In the case of excessive rotor speed (over 410 RPM), the light will come on, or an intermittent sound alarm will be triggered (depending on "horn" pushbutton position, ON or OFF). When the generator is not providing sufficient voltage the GEN light comes on.

1.6.6 Control of the helicopter

The helicopter is controlled by use of hydraulic servo-actuators. In the case of a drop in hydraulic pressure, there is a pressure accumulator in the main rotor actuator, which allows short-term corrections. The hydraulic pump is driven by a drive belt (green) from a drive on the transmission. Airlift always had, and still has, an extra belt in its helicopters in case a change is needed in the field.

1.6.7 Additional equipment on the accident helicopter

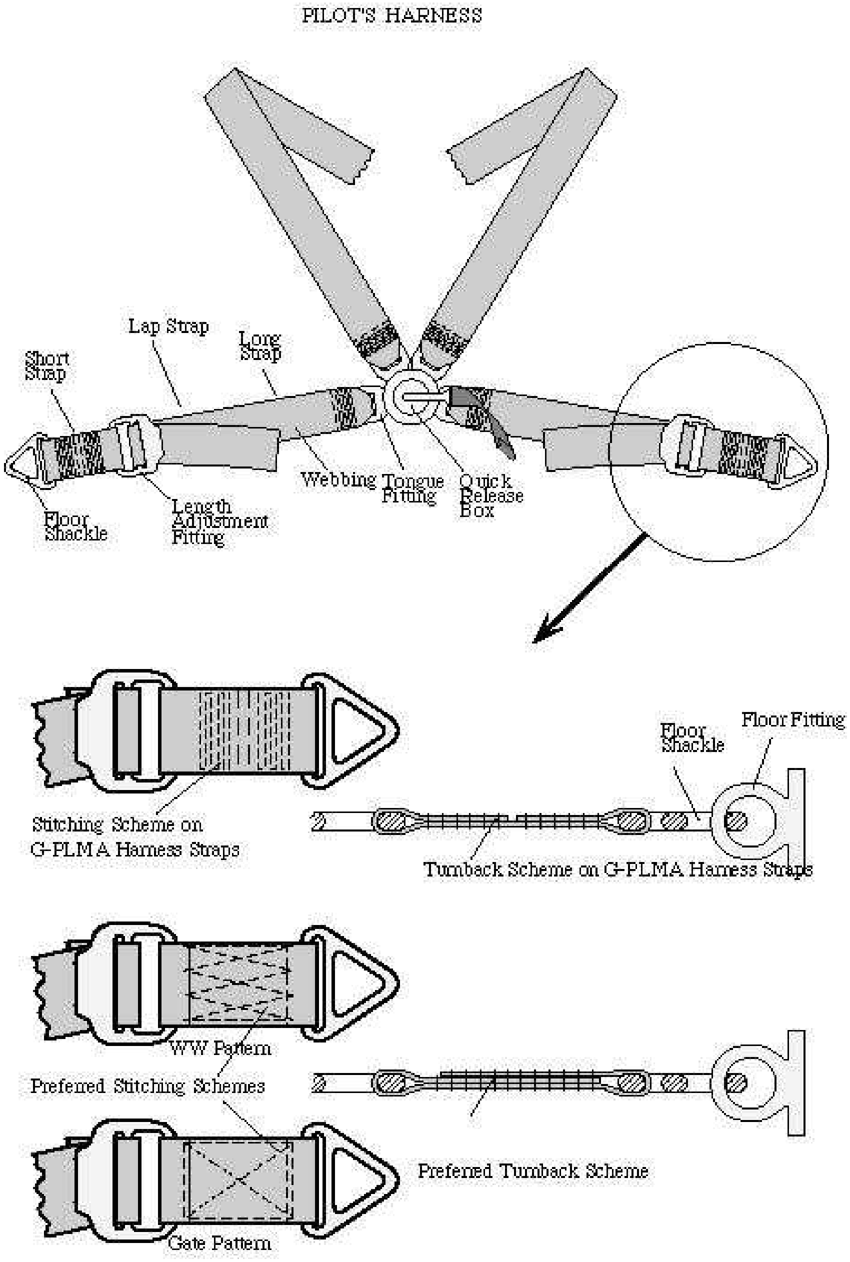
The helicopter had fuel pre-warming (heat exchange with the oil in the oil cooler). It had double control units and in addition to the standard navigation equipment it was fitted with a GPS mounted in a holder at the front of the glare shield. In the helicopter there were installed two batteries. The helicopter had extra fuel filters, which were used for filling from barrels.

1.6.8 Front seats

The front seats are made of thin fibreglass composite shell. They are glued together into one piece and are bolted to the floor structure. The seat belts are integrated into the seats by bolting the reel down on the seat back and feeding the harnesses from the reel at the seatback up the seatback through openings on the upper part of the seatback.

1.6.9 Seat belts

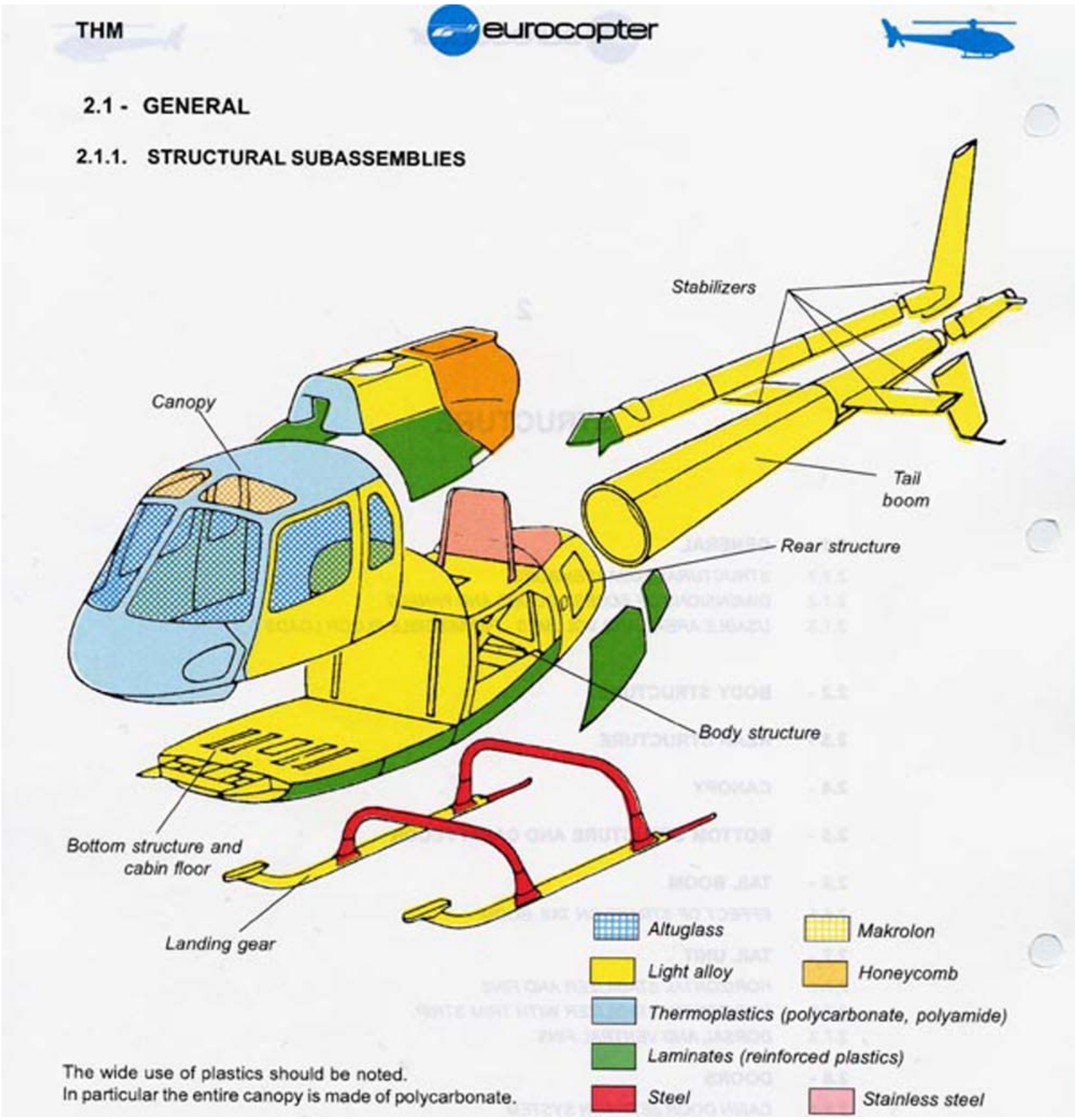
The front seats were fitted with both lap and shoulder belts, while the 4 seats behind were only fitted with lap belts. The front-seat belts were sewn with 6 seams at the buckle attachment, while the back ones were sewn with 4 or 5 seams. The seatbelts were of an approved make (Autoflug BAGU FAG 7B-27 / 09/90 in the front and Anjou Aeronautique SA type 343 1 / 47/90 in the back). The belts had a limited life (10 years) and were scheduled to be changed on September 1 2000.
The top part of the lap belts on the front seats had no individual identification. Only the part of the belt secured to the helicopter structure was marked. The lap belt is installed by using carabin hooks.



Seatbelts, details

1.6.10 <u>Materials</u>

To obtain the lowest possible weight, a lot of composite and thermoplastic material is used in this type of helicopter. The canopy and window frames in the cockpit/cabin section are made of thermoplastic.



1.6.11 Rotor

The rotor hub is a “Starflex” and each of the three arms is made of glass resin laminate. Each of the 3 rotor blades is attached to its arm by means of glass resin sleeves and flexible connections without the use of bearings.

1.6.12 Mass and balance

The mass and balance were within the permitted limits (3 adults, one child and a limited amount of luggage). Maximum take-off mass is 2,250 kg.

1.6.13 Fuel

The helicopter was filled with approx. 270 litres of JET A1 fuel.

1.7 The weather

1.7.1 AAIB/N has received the following report from the Meteorological Institute for West Norway

The weather for the Dyranut/Hårteigen area, Saturday November 6 1999.

"General situation: Low pressure in the North Sea, with an associated cold front south of Sauda, slowly moved north. (Appendix 1). Some precipitation on the west side of Langfjella. However, Sauda reported heavy rainfall, but relatively high cloud base/ceiling (approx. 3,000 ft). On the east side many stations reported precipitation, poor visibility and a low cloud base, e.g. Geilo with 400 metres visibility, rain and +1^{o}C. By 12 UTC (Appendix 2) the cold front had moved to Sogne fjord, but with a trough behind, which was fairly close to the site of the accident. The following observations can be seen on detailed map (Appendix 3) from 12 UTC: Eidfjord cabin: 09010kt 9999 bkn 070, Mjølfjell: 14010kt 9999 radz few 010 bkn 070, Finse 14010kt, temp –1, Geilo: 00000kt 0900 fg vvv// +1 and Haukeliseter: 12025kt temp +1. The IGA forecast 0918 (Appendix 4) applies to coastal and fjord areas and is typical of an east- southeast situation, so the lowest visibility and cloud height is given for the Lista – Stavanger coastal stretch. It is also usual for precipitation, reduced visibility and low cloud to be observed up in the mountains right up to the Kinsarvik/Odda area. The sonde diagram for Sola gives SE / 15-25kt around 4 000 – 5 000ft (FL050), and 0 isotherm was also at a height of around 4,000 ft, which is confirmed by Finse with –1 ^{o}C. The sonde diagram also shows massive cloud coverage from 4,000 ft to FL 150 (cold front).

As can be seen on the map (Appendix 3) there are no observations from the actual area. The weather reported tally with the observations from Finse, Mjølfjell and Geilo,
i.e. ESE/ 10-20kt, snow showers over 1,200 – 1,300 metres and above, ceiling 1,000 – 1,500ft, lower in precipitation, (0300-0600ft), and periods in which the cloud was down (fog). In the lowland west of the mountains there was some precipitation, good visibility and high cloud coverage all day."

The meteorologist's report is included in Appendix 4.

1.7.2 The Commander reported the following weather conditions at the time of the accident:

"There was daylight with a gentle southeasterly wind (0 – 5 kt), visibility above 10 km, cloud height of about 1,000 ft (approx. 7/8), temperature approx. 0 ^{o}C and no precipitation."

1.8 Navigational aids

Not applicable.

1.9 Communication

1.9.1 There was no communication between LN-OCF and other communication units during the flight.

1.9.2 At time 1412, the badly injured Commander managed to get a message to the base in Kinsarvik on his mobile telephone (GSM). He made two calls. He also tried to make contact later (at time 1616), but was unsuccessful that time.

1.9.3 At time 1205Z on Saturday November 6, the duty flight control officer for the North sector at Stavanger ATCC received messages from two aircraft flying in the area, BRA 65 (Oslo – Bergen) and NO 004 (Trondheim – Stavanger) to say that they had received ELT (emergency location transmitter) signals. The rescue co-ordination centre (HRSS) was alerted at time 1206Z.

1.9.4 GSM mobile telephone communication in the area at the site of the accident was poor during the rescue work and subsequent investigation work.

1.10 Airports and aids

Not applicable.

1.11 Flight data recorders

Not mandatory and not installed.

1.12 The accident site and helicopter wreckage

1.12.1 <u>The accident site</u>

1.12.1.1 The accident site is situated on the north-east slope of Låghellernuten on the Hardanger plain, approx. 1,460 m above sea level on a steep mountain incline (35°) some 80 m above the floor of the valley (approx. 60.16 N, 7. 17,5 E).

The mountainside was covered in snow, varying between crusted snow and drifting snow, of varying depths. Large stones were sticking up out of the snow in the area, which meant that there was good reference to ground contours (it was not a “white out” condition). The helicopter touched the ground twice up on a slightly flatter part of the mountainside before descending a vertical drop of approx. 4 m. First impact was with a heading of 90° it bounced 14 m and impacted again, fell 4 m vertically before it continued 23 m downhill and came to a rest upside down.

1.12.1.2 The tracks in the snow up on the flatter part showed that the helicopter was on an easterly course when it first made contact with the ground. First contact was probably flat or with a slight nose up configuration (based on position to right hand landing skid remaining at the impact crater and the crater itself) After this contact, the helicopter was catapulted forward to the edge of the precipice and then went over it. It finally came to rest with its nose pointing in a direction of approx. 110°. Due to the winter condition with falling and drifting snow between the time of the accident and the AAIB/N arrival to the scene many details were gone.

1.12.1.3 Parts of the rotor blades and some of the right landing gear were found at the site of the first contact with the ground. The right-hand front door, some glass from the windshield and pieces of the glare shield were found at the second point of impact. The GPS was a little to the right, between these two points. The other detached parts were found between the helicopter wreckage and the vertical drop.

The accident site
1: First impact / 2: Second impact / 3: precipice

Helicopter wreckage

1.12.2 Helicopter wreckage

The helicopter was lying upside down on a snow-covered slope approx. 35° steep, which made it necessary to secure it before work on the wreck could progress.

1.12.3 Seats

1.12.3.1 Both front seats had become detached because their glass fibre shell gave way. The pilot's seat (on the right) had virtually no damage to the sitting part of the seat shell, but the attachments had come apart on both sides, causing the seat to become detached from the helicopter floor. The seat back had also given way at the shoulder belt feed-through.

1.12.3.2 The left seat was more damaged in its sitting part. It had also become detached from the helicopter floor although bolts, attachment plates and parts of the seat shell were left on the floor. This seat was not damaged up on the seat back

1.12.3.3 The rear seating accommodation is two double seats able to seat a total of four passengers. Each of these seats are mounted by "hinges" to the rear cabin bulkhead and got two front supports fitted to the floor structure by quick release pins. Forces on the right seat hinges had created a rupture in the bulkhead above the hinges. The hinges (with the seat) and lower side of the bulkhead were forced down. The floor structure had been pushed up and contacted the bottom of the seat.

The seat and front support of the seat were nearly undamaged.

1.12.4 Seat belts

The stitching on the lap belts on both front seats had given way. The stitching on the pilot’s belt had given way up near the buckle, while the stitching on the belt on the left seat had given way down near the snap hook. The lap belt used by the adult in the far right seat had come away at the webbing to the buckle.

Right chairs anchorage and thorn lap belt

Left chair and details of the anchorage

1.12.5 Cabin structure/Cabin

The whole structure from the cabin floor to the back wall was ripped off. The instrument console was hanging by its wires. The instrument panel and throttle quadrant had minor damage.
The position of the manual fuel control lever was normal and not in the emergency or shutdown position. Fuel shut off valve was open.

1.12.6 Engine/FCU

The engine mounts had broken and the engine had come away from the chassis. The engine was complete and had minor damage. The manual fuel control indicator on the engine's fuel control unit (FCU) showed 42º, slightly lower than could be expected based on the lever's position in the cockpit. The collective indicator on the FCU (Anticipator) showed approx. 70^o. The fuel supply to the engine had been cut off because the fuel pipe had broken at the fuel filter. The airframes fuel filter by-pass indicator had popped. Fuel shut off valve was open. P2 bleed valve (compressor bleed valve) was open. P2 valve opens at 92% RPM (N_1).

1.12.7 Airframe/drive train

The tail boom was torn off, 3 of the 4 struts supporting the main gearbox were broken in bending (fwd right was undamaged), the fuel tank was ripped and the left and right landing skid was broken off. The cargo holds fitted above the landing skids had become separated from the skids and the airframe. The tail rotor gearbox could be rotated and had minor external damage. The tail boom had become separated from the airframe in the mounting flange and the boom itself had minor damage. The flexible couplings on the tail rotor drive shaft had fractured and one flexible coupling flange had rotated and caused minor damage to the forward portion of the drive shaft tunnel. The flexible couplings were broken with clean fractures and did not have a "broom" appearance. Main gearbox drive shaft was broken in bending at gearbox side.

1.12.8 Main and tail rotor

The main rotor blades were all damaged, but only the red blade had the outer part missing. The blue and the white blade remained in one piece, and all tree (2,5) remained attached to the rotor head. All 3 arms of the Starflex fractured. Blue and yellow had a clear 45^{o} fracture with the longest remaining part in direction of rotation. The red where more damaged, but also with a 45^{o} fracture. This 45^{o} fracture where in opposite direction, i.e. with the shortest remaining part in direction of rotation. The tail rotor blades were virtually undamaged.

The rotor head

1.12.9 Decent rate

Instrument readings at accident site indicated a decent rate of 850ft/min.

1.13 Medical and pathological conditions

1.13.1 The post-mortem carried out on the deceased passengers showed injuries consistent with the high deceleration forces the helicopter was subjected to at the impact.

1.13.2 The Commander was treated and examined at the surgical department of Haukeland hospital. No traces of alcohol or drugs were found.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 The search and rescue phase

1.15.1.1 At time 1305 on November 6 1999, Stavanger ATCC received messages saying that ELT signals had been detected by an aircraft flying over the Hardanger plain. At time 1306, the main South-Norway rescue co-ordination centre was alerted by the ATCC. They in turn notified the Hardanger police district in Odda. Following confirmation with Airlift's Kinsarvik base, it became clear that one of their helicopters was missing in the area in question. There were four people onboard. At time 1407, a helicopter from Lufttransport, contracted by Airlift, took off from the Kinsarvik base and the crew attempted to fly into the Hardanger plain, but the fact that the weather conditions had changed to snow showers and low cloud coverage made this impossible. The helicopter was close enough to detect signals from the ELT. At approx. time 1412 the badly injured Commander called the base on his mobile telephone. The display showed that it was the Commander calling, but there was no other contact. A few minutes later he called again and this time was able to report:

> "We have crashed, there are fatalities, serious injury, position Lægereidoksli, but I am in shock".

The call was cut off. At time 1616 the commander tried again to make contact with the base, but GSM mobile telephone conditions were so poor that it was not possible to exchange information.

1.15.1.2 A huge rescue operation was put into action led by the Hardanger police district, Odda. The local county administrator's office in Kinsarvik made preparations for the rescue operation with caterpillar vehicles and snowmobiles from different locations on the roads around the Hardanger plain. The snowmobile patrols gradually set off to the presumed accident site.

1.15.1.3 A rescue helicopter from 330 squadron took off from Sola at time 1445. Based on the ELT signals, the commander estimated that he came very close to the accident site at (2-3 km), but weather conditions made it impossible to land. The rescue helicopter continued to Eidsfjord where it touched down at time 1655. A team consisting of a local guide, two doctors and a nurse was taken onboard and at time 1707 a new attempt was made to fly to the mountains. The weather had improved and at time 1720 a landing was made at the accident site close to a cabin, Huldrebu, after which the rescue helicopter continued to Kinsarvik and further on to Bergen.

1.15.1.4 The rescue team got installed in the cabin and started the search on foot. Thanks to great efforts on the part of the rescue patrol in poor weather conditions and darkness, the accident site was found approx. time 2200 (9 hours after the accident) and the two seriously injured survivors were attended to. They were slowly carried down to Huldrebu. Next morning the rescue helicopter returned in better weather conditions and took the boy and the Commander to Haukeland hospital in Bergen.

1.15.2 Inadequate personal protection in the helicopter

1.15.2.1 In the accident the Commander and two adult passengers were thrown out of the helicopter into the snow. The Commander was wearing a helmet, which most probably saved him from more serious injury. All those onboard suffered serious physical injuries, due to the high rate of descent and the forward speed on impact with the mountainside. The selection of materials and chosen design is not providing desired passive safety and offer poor personal protection in the event of an accident (the helicopter is approved according to JAR (FAR) 27 regulations at time of design). The cockpit and cabin area were completely destroyed. The front seats became detached, the stitching of several seat belts gave way and any possible protection that the superstructure of the cockpit and cabin area should have given did not function, because it was all ripped off. The commander used 4-point harnesses without this helping him particularly, as the attachment for the shoulder harnesses is on the back of the seat and the whole seat became detached. The passenger sitting in the front was not using shoulder harnesses. His seat also became detached.

1.15.2.2 In AAIB Bulletin No. 1/2001 AAIB/N has registered the following: Accident involving Aerospatiale (Eurocopter) AS355F2, G-SAEW, April 21 2000 in Cardiff, Wales. The following is an excerpt from the report:

”In consideration of the relatively benign nature of this impact, concern was raised over a failure which had occurred to the front left seat. Although this seat remained attached to the floor, the inboard seat rail had sheared though the glassfibre moulding over most of its length, as shown in the photograph at figure 10. This was one of the modes of failure found on the same type of seat in a fatal accident to an AS350 helicopter which occurred in 1995, and which was reported upon in AAIB Formal Report 4/96. In the latter report a related Safety Recommendation (No 96-58) was made to the CAA, recommending that the CAA in conjunction with DGAC should require, amongst other considerations, reassessment of the crashworthiness of the AS350 and AS355 forward seat design. As a result of this, two identical recommended Service Bulletins (25.00.63 for the AS350 and 25.00.43 for the AS355) were issued by the manufacturer in December 1999, which related to strengthening of the front seats and floor structure in order to improve the anchoring of these seats. At present, the CAA have stated that the ‘Recommended’ status of these SBs is being reviewed with regard to possible change to ‘Mandatory’ status for UK registered aircraft.”

On the October 11 2002 AAIB/N received information from AAIB saying that CAA UK has decided that the retrofit shall not be compulsory.

1.15.2.3 AAIB/N quotes from the Aircraft Accident Investigation Board’s report on the accident at Åsgårdfonna, Svalbard on August 22 1987 involving LN-OMQ, AS 350 B1, (issued in September 1989), the same type of helicopter:

“Both seats in the cockpit were ripped away from their brackets in the deck in almost the same/an identical way. The right seat rail, which is an integral part of the seat, was ripped away leaving it lying on the deck, while the left rails of both seats were torn out from the attachment to the door rail. ……”

The report continues with details that are identical to the damage found on LN-OCF. The section finishes as follows:

“The deceleration forces were not great enough to overload/damage the belts sufficiently to indicate this. Corresponding and almost identical damage to the two seats indicates that both persons were using seat belts, both lap belts and shoulder belts. ……”

1.15.2.4 AAIB/N also refers to the Swedish report: RL 2001:31 involving helicopter SE-JCA, an AS 350-B2, in which similar damage occurred to the Commander’s seat.

1.15.2.5 AAIB/N also refers to our report on the accident at Tyin April 24 1998 with AS 350 B2, LN-OPX (operated with original constructed seats). In this report the following recommendation, no. 11/2000, was given:

"AAIB/N recommend the Norwegian CAA in cooperation with CAA in France to reconsider the approval of the construction and fastening of the front seats with regard to the forces the seats are exposed to when the helicopter tilts."

1.15.3 Clothing in the mountains

1.15.3.1 The passengers were appropriately dressed for a stay in the mountains. However, the Commander was wearing a flying suit with a "synfiber" thermo winter jacket and helmet, equipment suitable for operating the helicopter. He usually took an extra bag containing equipment for being out in mountain terrain, but did not have the bag with him on this trip.

1.15.3.2 Regulations for Civil Aviation BSL D 1-8 pt. 4, Regulations for flying single engine aircraft over mountains and at Svalbard

Personal equipment.
In order to be prepared for an emergency both crew and passengers shall furnish themselves with adequate clothing and equipment with regard to the present and expected weather- and temperature condition. Crewmembers should bring clothing giving good contrast to the terrain.

1.15.4 The Commander and boy's situation after the accident

When the Commander regained consciousness out in the snow, seriously injured as he was, he managed to release the boy from his safety harness. He took him approx. 20 m down the slope below the helicopter wreckage. He did not use any of the survival equipment that was in the cargo hold. This equipment did not contain warm clothing either. The Commander took a freight bag (big bag) with him, which he had found outside the helicopter. This is made of coarsely woven nylon. He placed himself and the boy inside this bag. The bag was not insulated, but still gave sufficient protection against the wind and snow. It is likely that the Commander saved his own and the boy's life by this action. Many long hours passed before they were found by the rescue patrol.

1.16 Special investigations

1.16.1 Engine

It was of great interest to establish whether the engine was running at the time of impact and, if that was the case, to try and ascertain the power. The engine was first examined at AAIB/N's Kjeller premises with AAIB/N and a representative of Turbomeca present. The following results emerged:

- -The P2 system was apparently in order.
- -The cables and ignition plugs were correctly connected, but a slightly damaged in the accident.
- -The gears in the Accessory transmission were intact.
- -The fuel pump gears were intact.
- -The setting on the fuel control unit was normal, which could be expected provided the emergency position was not selected.
- -There were no particles on the magnetic plugs.
- -The fuel filter was clean.
- -The free turbine rotated without resistance.
- -Remnants of the green drive belt were observed in P2 bleed valve and in the compressor.
- -Minor contact damage to the centre cone of the first-level compressor after contact with the air intake duct.
- -All locking wires were intact.

The engine and fuel control unit (FCU) appeared to be in such good condition that it was decided to take them to Turbomeca for performance testing.
In addition to AAIB/N, representatives from Airlift, the French Aircraft Accident investigation board (BEA) and Eurocopter were present at Turbomeca's premises.

Before testing could take place, the FCU was dismantled for separate testing before being re-mounted on the engine so that the engine could be tested with the original FCU. The magneto plugs were inspected without any findings. The engine was inspected by borescope and foreign bodies removed. Foreign bodies were found in P2 bleed valve (compressor bleed valve), inside the compressor and on the outside of the combustion chamber. The foreign bodies consisted of fragments from the engine air intake and from the drive belt to the hydraulic pump (green drive belt).
The fragments showed no heat damage.
The fuel pump gears were undamaged.
The engine was dismantled for further inspection.

The following observations were made:

- -There was only minor contact damage inside the engine.
- -There was no geometric fault after contact between blades and stators inside the engine.
- -The drive gear nut (over torque nut) had not moved.
- -The centre cone of the axial compressor showed contact marks after having rotated to the damaged air intake duct.
- -There was no damage to the freewheel unit (another unit where fitted before testing in the test cell).

Conclusion: No fault or abnormal wear and tear was found in the engine and it appeared to be very well maintained.

Before installing the engine in the test cell new cables were fitted to the ignition plugs, new power point axles (the original had suffered crushing damage) and a new exhaust duct were mounted.

Testing was carried out in accordance with the specifications used for the testing of new engines and testing during inspections. The testing revealed the following:

-The P2 system was functioning normally and the bleed valve opened and closed correctly.
-The engine's performance was within the specification (topping and cycling).
-The spool down time was as specified.
-The time responses were as specified.

Conclusion: the engine appeared to be in good condition.

1.16.2 The fuel system

1.16.2.1 Fuel valves and fuel control unit were tested separately in accordance with the manufacturer's specifications. All the valves operated in the prescribed way (start valve did open late (218 vs. 180 + 20) and would delay fuel supply during start up).

1.16.2.2 FCU was fitted on the testing bench and a full test run was performed. The test was identical to the one that is carried out before delivery of a new FCU and after inspection or modification of an FCU.

1.16.2.3 While checking N1 and N2 regulation a discordant sound was heard in the N1 regulation, causing the test to be stopped and the FCU was dismantled for checking. No mechanical deviations were found (this includes the temperature compensator). However, it was noted that there was an abnormally low amount of fuel in the FCU. The FCU was then assembled with the same components and the test was completed on the testing bench.

1.16.2.4 All parameters were within those specified.

1.16.2.5 After this test the FCU was fitted on the engine again for testing of the complete engine.

1.16.3 Investigations of fuel controls from other helicopters

About six months after this accident, the company Lufttransport had an engine failure, which appeared to be similar to what was experienced by the Commander of the accident helicopter. This fuel control unit (S/N B054B) was sent to AAIB/N who sealed it and forwarded it to the manufacturer, Turbomeca in order to undergo the same testing as the FCU from the accident helicopters representative from BEA supervised the test. The FCU first underwent a performance check against the new manufacturing specifications, without any deviations being noted. The temperature compensator on this FCU was a different type from the one fitted in LN-OCF. There have been occasions where this type of compensators has collapsed and all FCUs with this type of compensator are now converted during the first major inspection or earlier (TU-183). The FCU was therefore dismantled on request and inspected for faults without any deviations noted.

In May 2001 a third fuel control unit with the same symptoms was taken to Turbomeca for examination. This was also from Lufttransport AS. The FCU, S/N 819B, was brought by an AAIB/N representative to Turbomeca for full examination with performance bench testing and complete dismantling. No faults or deviations from specifications were found here either.

AAIB/N had brought three above mentioned FCU’s to Turbomeca for investigation and the performance of all three FCUs was equivalent of new/reconditioned FCUs. Results from testing were compared with results from previous testing at Turbomeca without any major deviation between this historical data and that achieved in these tests.

1.16.4 Other investigations:

- Fuel samples both from the helicopter and the tank installation were analysed at LFK (Royal Norwegian Air Force laboratories). All tests were normal.

- Oil samples from the engine were analysed at LFK laboratories). No abnormal values were detected.

- The starter generator was examined. It was running freely and supplying power as required.

- The oil cooler was checked for free flow.

- NG and NR (power turbine and rotor speed) indicator was examined at KRIPOS (National Criminal Investigation Service). The white pointer for rotor speed had made imprints on the instrument face indicating between 285 and 300 RPM. Rotor speed is normally virtually constant and in the area 390 +4/-5 RPM.

- The light bulbs for HYD and HORN on the warning light panel were examined at DNV (Det Norske Veritas). There are major unreliability concerns relating to the examination of light bulbs and their filaments following accidents. If the filaments are obviously deformed, this is a clear indication of the presence of heat, which means the lamp lit up. However, the opposite conclusion is not always unequivocal. All the same, AAIB/N elected to send the panel with the warning lights to DNV for examination. The report concludes that the lights did not light up at the collision.

- The fuel pipe fracture was examined at LFK. The report concludes by stating that there was an overloading rupture, and thereby a consequential damage.

1.17 Organisations and management

The helicopter belonged to the company Airlift AS. Airlift's main base is at Førde airport, Bringeland, where it has modern offices and workshops. The company also has several other bases, including Kinsarvik, Fornebu (now Gardermoen), Dombås, Svalbard and Bergen.
The accident helicopter was stationed at the Airlift base in Kinsarvik. The Kinsarvik base was previously Helikopterteneste A/S which was taken over and incorporated into Airlift AS April 9 1996.
The company's main operations have been cargo flights with single-engine helicopters, but this has been expanded considerably in recent years to include larger helicopters and also other assignments such as ambulance flying and flying for the District Governor of Svalbard.

The company was JAR-OPS 3 approved August 9 1999.

Airlift's organisation was closely examined in the report describing the accident involving the helicopter LN-OPR in Førdefjorden October 14 1996. Please refer to AAIB/N report 17/2000 for further information. The company has been reorganised since.

1.18 Other information

1.18.1 <u>The company's Operations Manual (OM)</u>

Chapter 8, Operating Procedures, Flight Preparation Instructions, Minimum Flight Altitudes, pt. 8.1.1.1, General:

JAR-OPS 3.250
When an aircraft is operated for the purpose of commercial air transport, the minimum altitude/flight level at which it is permitted to fly may be governed by one, all or a combination of the following:

a. National regulations (BSL F, AIP)
b. ATC requirements
c. ------
d. ------
e. by the need to maintain a safe height margin above any significant terrain or obstacle en route.

Pk. 8.1.1.5.3, Performance Class 3
JAR-OPS SUBPART H
A helicopter with performance such that, in the event of power-unit failure at any time during the flight, a forced landing may be required in a multi-engined helicopter but will be required in a single engine helicopter.
The helicopter has a single-engine and is therefore in Performance Class 3/Category B.

Pk. 8.1.1.8, Performance Class 3 Helicopters
JAR-OPS 3.550
With all power units operating, the helicopter shall have the performance to continue along its intended route or to a planned diversion without flying at any point below the appropriate MOCA.

1.18.2 <u>The company's Flight Manual, Autorotation</u>

Autorotation Landing Procedure following Engine Failure:

-Set low collective pitch
-Monitor and control rotor rpm.
-Establish approximately 65 kts (120 km/h) airspeed.
-Move fuel flow control to the shutdown position.
-According to the cause of loss of the engine:
Re-light the engine
Otherwise: Close the fuel- shut off valve
Switch off: the booster pump
generator
alternator (if installed)
electrical power master “All-off” switch
(if smell of burning)
-Manoeuvre to head the helicopter into the wind in final approach.

-At height of approximately 65 ft (20 m) above the ground, flare to a nose-up attitude.
-At height 20-25 ft (6-8 m) and at constant attitude, gradually apply collective pitch to reduce the sink rate.
-Resume level attitude before touch-down, and cancel any side-slip tendency.
-Gently reduce collective pitch after touch-down.

1.18.3 Regulations for Civil Aviation (BSL)

Operational flight plan

According to BSL D 2-1-7 pt. 4.3.3.1, an operational flight plan must be produced for non-regular air-transport flying. A copy must also be retained so that the planning can be reconstructed as needed. The company's OM 8.1 also confirms, with reference to JAR-OPS 3.24/3.630: "An Operational Flight Plan must be completed for each intended flight except as shown in Para. 8.1.10 below".

One of the exceptions applies to this flight: "Operations with helicopters with a maximum certificated take-off mass of 2,730 kg or less (this helicopter has a maximum take-off mass of 2,250 kg), with a maximum approved seating configuration of 9 or less; by day; and over routes navigated by reference to visual landmarks."
This type of flight plan was not prepared for the accident flight, nor was such a plan required in the regulations.
However, there was a requirement to fill in a Navigation Log with a flight plan. This is part of the Mission Form (appendix A-16-5 in the company's OM). In accordance with JAR-OPS 3.140 and OM 8.1.12.5, this is not required to be left behind on the ground.

1.19 Useful or effective methods of investigation

In this investigation no methods have been used that qualify for special mention.

2 ANALYSIS

2.1 Technical investigations

At the time of the accident, the engine was running, but was not providing power in accordance with a "normal situation".

Evidence that the engine was running, but with reduced power, may be supported by:

- The minor damage to the engine.
- The fact that the hydraulic pump belt had gone into the engine without going through and went out in the P2 valve indicates that this valve was open. The P2 valve does not open in normal operation, only when the speed is below 92% RPM. The drive belt entered the engine after first impact. If the engine had rotated without power, the belt would have stopped the engine and not gone into the engine, which it didn't. If it had produced full power the belt would not have stopped in P2 valve and fragments would have bee burned. On the other side, if Commander attempted to enter autorotation and had low collective pitch, this could also make the P2 valve to open.
- If the engine had produced normal power, the overtorque nut would most probably have moved.
- Examination of the RPM indicator also supports the fact that the rotor speed was low, as indicated by the Commander.
- The airframe fuel filter bypass had popped. It is reason to believe that this is a result from rupture of the fuel line during impact. When the booster pump is working, a rupture will create a differential in pressure over the filter and it will pop.
- The Starflex and main rotor blades indicates that only one blade had serious impact with the ground. The red blade and Starflex are seriously damaged and with fracture pattern on Starflex indicating "contact". The yellow and the blue blade are less damaged and the yellow and blue Starflex has similar fracture pattern indicating that the blades continued while mast had stopped/lost rotational energy. This indicates that energy in the system was low at impact.
- Unlike other similar accidents with same type of helicopter in Norway, energy in the main gearbox did not shear the 4 struts. This also indicates low energy in the system.
- Drive shaft flexible couplings had fractures indicating low energy, but this indicates that there had been rotation during impact.
- Main gearbox drive shaft fractured due to bending and not torsion.

Examination of the free wheel unit gives no indication of slip.

The technical investigations did not reveal any substantial fault or defect to explain the accident. The engine setting selected by the Commander was correct for a normal situation.

2.2 Possible causes

2.2.1 There are two main contributing causes of this accident. One is that the engine failed in a critical phase of the flight. The other is the selection of the flight path.

2.2.2 It may be expected that an engine cease to provide the desired power. If this happens, safety requirements demand that flying is carried out in such a way as to get into a position that allows an emergency landing as quickly as possible and that accessibility of emergency landing areas is considered. In practical terms, this is not always achievable for single engine helicopters during take off and landings, but must be striven for. JAR-OPS and OM gives instructions for the operation of single-engine helicopters (ref. OM and JAR-OPS 3, see pt. 1.18).

2.2.3 The Commander's statement and findings at the accident site tally and it is clear that the engine was running, but not providing the expected power. As explained in section 1.16, despite many attempts, AAIB/N has been unable to find reasons why the engine ceased providing adequate power. Many conditions could cause an engine to stop giving the desired power, such as intake of snow/water in the engine, slipping of the freewheel, contaminated fuel, problems with the fuel pump, clogged-up filters, gear faults, faulty use of the helicopter etc. Despite major efforts, AAIB/N has not succeeded in finding technical failures or other deviations that can lead to a clear cause.

Intake of snow or water will cause the engine to flame out and completely. Such conditions were not present and the engine did not stop completely.

There was no damage inside the engine to indicate a gear, freewheel failure etc. No clogged-up filters were found (nor oil/fuel heat exchangers).
Fuel and oil checks do not give any indication that they were outside the specifications.

There are no indications to suggest that the operating conditions (snow, wind icing etc.) could have affected the revolutions per minute/engine power in such a way as to cause an accident.

AAIB/N is left with a question about the fuel control unit (FCU). It is known that there have been several similar cases of engine failure with this engine type, in which faults in the fuel control unit have been stated to be the most likely cause. Changing the fuel control unit with another and similar FCU has removed the fault symptom, but examination of the dismantled FCU has, as far as AAIB/N is aware of, not revealed any faults in this case.

2.2.4 The fuel supply handle (Control lever) in the cockpit was in the expected position for normal operation. In an accident such as this, there are huge forces at work. This explains a deviation between the position in the cockpit and the indicated position on the FCU. In accordance with normal procedure for autorotation (ref 1.18), the fuel control handle should be pulled forward to the shutdown position and the shut-off valve closed. But normal autorotation procedure requires sufficient height and time in which to implement the procedure. In view of this, it is not surprising that some of the "normal" points were omitted in this accident. Nor is it inconceivable that the handle's positions should have changed in the accident or during evacuation of the helicopter.

First impact indicates a flat or nose up attitude, which may support an attempt of entering autorotation.

Rate of descent and speed is hard to determine. Impacting the snow-covered mountain reduces the energy. The remaining energy made it possible to rip off the landing gear and continue another 14 m before it continued downhill. This indicates a reasonable forward speed, but does not indicate anything about rate of retardation other than stating that it was not "sudden" (Helicopter stopped completely 41 m after first impact). Instrument reading indicates a decent rate of 850 ft/min, i.e. within JAR design requirements.

2.2.5 At the client's request, the Commander was following a path that brought the helicopter close to the mountainside and prolonged the take off phase. The reason that the helicopter was at a low altitude above the ground when the engine problem occurred is because it was in the take-off phase and was climbing parallel to rising terrain. However, the terrain around the take-off point allowed alternative flight paths to be selected. This could have brought the helicopter out above flatter/lower terrain and the commander would have obtained greater effect when he attempted to apply autorotation. This would also have been more in line with the instructions in the OM and JAR-OPS (see pt. 1.18).

2.3 Relationship to the Operations Manual (OM) and Regulations for Civil Aviation (BSL)

2.3.1 <u>OM</u>

2.3.1.1 It can be said that this engine failure happened during the start and climbing phase and that the Commander was proceeding for his cruising height. In its OM instructions, the company specifies that a Commander shall not fly at or below a specified minimum height apart from when necessary during take-off and landing. This instruction also means that it should always be possible to reach an emergency landing location. AAIB/N considers that the selected flight path gave reduced safety margins.

2.3.1.2 A passenger list (manifest) was not completed for this assignment. The company has not been able to explain to AAIB/N how this manifest should have been produced.

2.3.1.3 Previous instructions state that a copy of the manifest should be provided at the place of departure. In this accident the not existing manifest, for a while in the search and rescue phase, created uncertainty about who was onboard.

AAIB/N questions whether the current practice is satisfactory.

2.4 Commander

2.4.1 The Commander was well qualified to carry out this assignment. He was very experienced in flying over mountain terrain. AAIB/N has no reason to doubt that the Commander did everything he could to avoid an accident when the engine stopped producing power. The Commander deserves credit for his initiative and efforts, badly injured as he was, to save the boy and himself after the impact with the ground. However, there is reason to point out that the choice of flight path towards rising terrain, which reduced the possibility of a safe landing in the case of an engine failure, was unfortunate. The helicopter was flying parallel to the raising terrain in a steady climb and was not subject to any abrupt manoeuvres (e.g. sudden turns or climb), which may have contributed to the accident.

2.4.2 AAIB/N is aware that the Commander's statement regarding warning light simultaneously with sound (horn) and yaw to the left is not coherent with normal behaviour of this helicopter. The Commander states that this is what he felt/remember. AAIB/ find it convincing that a Commander will inform about what he remember instead of making a story with "correct" information based on what is expected to happen.

2.4.3 When AAIB/N interviewed the Commander some time after the accident he apologized for not remembering more from the accident situation. It is common knowledge that memories are easier to retrieve when the person is brought back to the same context in which the memory was encoded. We therefore asked the Commander to enter a cockpit of a similar helicopter and turn on the engine. In that situation, the Commander was surprised how things came back to him and how he could retrieve the situation just before the accident. These memories were also enforced in that they happened in a very emotional laden situation in which things are more strongly imprinted than in commonplace situations. The AAIB/N therefore feels that the information given by the Commander about the situation is credible and describes the actual succession of events as he recalled them.

2.5 Whiteout

There was not total snow cover on the Hardanger Mountains at the time of the accident. Individual parts of the mountainside at Låghellernuten were not covered with snow, while in other areas there were snowdrifts. Large stones were easily visible. Because of these conditions, AAIB/N considers that white-out was not a feature of this accident.

2.6 Survival aspects

2.6.1 Clothing/survival kit

The helicopter was fitted with various types of survival equipment for a stay in the mountains. For various reasons, these materials were not used. The Commander was seriously injured and the mountainside had an inclination of 35^{o}. The survival kit was inside the luggage compartment and both hard and dangerous to find. AAIB/N find it sensible that the kit was not used. The survival equipment did not include warm clothing. The individual pilot and passengers are expected to supply themselves with warm clothing, so that they are equipped for an unintentional stay in the mountains (ref BSL D1-8 pt. 4, requirement for clothing when flying single engine aircrafts above mountains or at Svalbard). All passengers were appropriately dressed for a mountain trip. This turned out to be of great benefit to the boy. AAIB/N believes that it is sensible insurance for everyone to be equipped to withstand a period out in the open when flying. The Commander was primarily dressed for his function as pilot. He usually protected himself when flying over mountain terrain by bringing a bag containing clothing for a longer stay in the mountains. The bag was not brought on this flight, reason unknown both for commander and AAIB/N. The pilot did wear a helmet while the passengers did not. In this accident a helmet would not have altered the outcome for the passengers.

2.6.2 Personal protection – Seat belts/seats

2.6.2.1 All those onboard received serious injuries from the impact with the mountainside and the subsequent plummeting downwards. The injuries resulted in the deaths of two of the passengers. The helicopter is constructed with optimum strength/weight in mind, which explains the extensive use of plastics and composite materials. The seats, parts of the floor and large areas of the superstructure (cockpit) are among the objects made of composite materials. The front seats cracked and became detached and the superstructure was completely destroyed. AAIB/N considers that it should have been possible to improve personal protection on this helicopter without great weight increases. With reference to this accident and others mentioned in para 1.15.2.1 about inadequate personal protection, AAIB/N proposes a recommendation for changes in the construction in the cockpit and passenger area, to allow greater personal protection in the case of collisions. We do also refer to the Aviation Accident Commission's report issued in September 1989 about the aviation accident at Svalbard on August 22 1987 involving an AS 350-B1.

2.6.2.2 Seat belts

All the belts were of an approved make and were not out of date. (Hard time)
The stitching on the lap belts on both front seats had given way, while the webbing had come away on one of the back seats (on which one of the adults sat). The number of seams at the attachments to the back seat belts varied, which also resulted in varying strength on these harnesses. The top part of the lap belts on the two front seats had no identifications and could have been replaced. This meant that they could easily be exchanged for another belt, also of inferior quality, but retained the original marking. This does not appear to have been the case on this occasion. It is AAIB/N's opinion that it should not be possible to change harnesses without changing the identification. The shoulder harnesses had reduced effect, as the reel was mounted on the seat, which became detached. AAIB/N recommend redesigning the attachment by having the reel mounted to the helicopter structure and not to the seat.

2.6.2.3 Seats

In this accident it is evident that shoulder harnesses were used by the Commander, but not by the person in the front left-hand seat. This is underlined by the damage pattern to the two seats. The seat in which shoulder harnesses were used had broken on the upper part of seat back, due to forces from the shoulder harnesses. The sitting part of the seat had not otherwise suffered much damage. In the seat in which shoulder harnesses were not used, the upper part of the back was intact, while the sitting part was more damaged. The sitting part will suffer more damage when the person in the seat has greater freedom of movement. The seat attachments to the floor structure on both seats were broken. However, the floor structure was undamaged. It is AAIB/N's opinion that shoulder harnesses must be used if available (the latest JAR 27.785 requires an upper torso restraint for all occupants). The Commission is aware that there is a modified version of the seats and floor structure, which is installed in new helicopters (Service Bulletin No 25.00.63). This modification is also available for retrofit in older helicopters. The modification gives improved anchorage and a stronger seat. The modification was not made mandatory by the certifying authorities in France, and both the British and Norwegian authorities chose to follow the same path. An improvement to the seats and anchorage to ensure that both seats and shoulder harness remain in place will be a big boost to personal safety in this type of helicopter.

2.7 The search and rescue phase

After the ELT was activated and the signals detected by an aircraft flying over the area, a rescue operation was put into action. An operational flight plan had not been produced for the trip into the Hardanger plain. Nor had a passenger manifest been drawn up. This meant that there was some uncertainty for a time during the start phase, both about who was onboard and how the flight was scheduled to progress. Only when the Commander managed to get an incomplete message through to his base at time 1412, did the full gravity of the accident become realised and the accident site identified. Then every effort was put into rescuing the injured. The difficult weather conditions meant it was not possible to get to the accident site before approx. time 2200 hours when a foot rescue patrol reached the area. AAIB/N considers that the rescue action was planned and implemented in a professional way. The rescue squadron (330 sqa.) and local resources was major contributors.

2.8 Mobile telephone communication

The experiences rendered during the accident, and the later rescue- and investigation work, indicated that the conditions for GSM mobile telephone communication were not satisfactory. Both the rescue personnel and the police at the accident site stated this is the case on large areas of the Hardanger plain. AAIB/N therefore recommends this condition to be improved.

3 CONCLUSION

3.1 Findings

3.1.1 Commander

a. The Commander held valid licences.

b. The Commander was an experienced helicopter pilot and had completed the training prescribed by the authorities. He was very experienced in flying over mountain terrain.

c. The Commander was well rested at the start of the assignment. He had a short service period and flying time before the accident.

d. The Commander also had the role of chief pilot at the company’s Kinsarvik base.

3.1.2 Aircraft information

a. The aircraft was registered according to regulations and had valid environmental and airworthiness certificates.

b. In this investigation, AAIB/N has not discovered any irregularities in the maintenance of the aircraft, which may have had an effect on the course of events.

c. No irregularities, faults or defects were discovered, which might refer to the aircraft's condition before the accident. It was pointed out by Turbomeca that the engine appeared to be particularly well maintained.

d. The aircraft's mass and centre of gravity was within the permitted limits at the time of the accident.

e. At the time of the accident the engine was running, but without providing power in accordance with a normal situation.

3.1.3 The company

The company had a valid licence and operating permit for this type of flying. The Norwegian Civil Aviation Authority had approved the routines and procedures.

3.1.4 Survival aspects

a. Despite great efforts, it took a long time to rescue the survivors.

b. The seats were made of composite materials, which cracked and became detached in the accident.

c. The stitching of the front seat belts gave way. The shoulder harnesses are anchored to the back of the seats and give little protection when the seats become detached from the floor.

d. Only the Commander used shoulder harness.

e. The cabin's superstructure did not provide the necessary protection in the accident.

e. The Commander was not equipped for a stay in the mountains.

f. The weather was fine at the time of accident, but deteriorated quickly after. This hampered the rescue operation.

g. The helicopter’s survival equipment was not used.

3.2 Significant investigation results important to safety

AAIB/N believes that the following investigation results had a decisive influence on the course of events or were particularly important from a safety perspective:

a. The engine ceased to provide power during the flight.

b. The flight was made parallel to raising terrain and the possibility for a safe emergency landing was therefore reduced. When the engine problem arose, the helicopter was at a too low height for entering autorotation.

c. Great efforts were needed and were provided on the part of the rescuers.

d. In this area of the Hardanger plain the GSM mobile telephone system functioned poorly.

4 RECOMMENDATIONS

AAIB/N recommends that:

The Norwegian Civil Aviation Authority considers the requirement of clarification to the operators of one-engine helicopters of the need to plan the departure- and approach paths over the area giving the best safety margins in case of an engine failure. (Recommendation no. 13/2003)

The Norwegian Civil Aviation Authority considers the certification of helicopters in the Norwegian aircraft register that is still operates with the original seat construction. A revised design is available as a “retrofit”, but this is not made compulsory. (Recommendation no. 14/2003)

The Norwegian Civil Aviation Authority considers the durability, strength and labelling of the seatbelts used in this type of helicopter. (Recommendation no. 15/2003)

The Norwegian Civil Aviation Authority considers making shoulder harness mandatory for all occupants in helicopters, like stated in the latest JAR 27.785 (Recommendation no. 16/2003)

The manufacturer of this helicopter type considers redesigning the cabin construction in order to improve personal protection in the case of an accident like this. (Recommendation no. 17/2003)

The manufacturer of the engine and fuel control unit follows up the FCU with a view to eliminating future engine failures and that the manufacturer informs all operators of the progress. (Recommendation no. 18/2003)

The Norwegian Post- and Telecommunication Authority should consider arranging an installation of a mobile telephone relay station (GSM) at one site, e.g. at Hårteigen, in order to ensure secure communication during rescue action over large areas of the Hardanger plain. (Recommendation no. 19/2003)

5 APPENDICES

1. The helicopter
2. Diagram of the accident area
3. Map with staked-out flight path
4. Detailed weather data
5. Abbreviations

AIRCRAFT ACCIDENT INVESTIGATION BOARD, NORWAY (AAIB/N)

Lillestrøm, March 2003