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Report RM 2002:01e

Accident involving an HKP 10 helicopter from Norrland's Helicopter Squadron on the 11th of August 2000, at Mount Kaskasapakte, in the Tarfala massif, BD County, Sweden.

Case M-002/00

SHK investigates accidents and incidents with regard to safety. The sole objective of the investigations is the prevention of similar occurrences in the future. It is not the purpose of this activity to apportion blame or liability.

Translated by Dennis Lynn Anderson
From the original Swedish at the request of the Board of Accident Investigation.

In the event of discrepancies between the English and the Swedish texts, the Swedish text is to be considered the authoritative version.

The report is also available on our Web site: www.havkom.se

Statens haverikommission (SHK) Board of Accident Investigation

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APPENDIX

Technical investigations report (SHK file document 39).
Ten copies of the appendix have been compiled and attached only to those reports delivered to The Swedish Armed Forces, The Defence Materiel Administration, The Helicopter Wing and Norrland's Helicopter Squadron.

2002-04-29 M-002/00

Swedish Armed Forces

107 85 Stockholm

Report RM 2002:01e

The Board of Accident Investigation (Statens haverikommission, SHK) was notified on the 11th of August 2000 that an accident had occurred involving an HKP 10 helicopter "Super Puma" with registration H 94, assigned to Norrland's Helicopter Squadron. The accident took place at Mount Kaskasapakte in the Tarfala massif, BD County, Sweden, on that same day at 01:36 hours.

The accident has been investigated by SHK represented by Sven-Erik Sigfridsson, Chairperson until the 16th of September 2001, Ann-Louise Eksborg, Chairperson from the 17th of September 2001 until the 6th of January 2002, Lena Svenaeus, Chairperson from the 7th of January 2002, Rune Lundin, Chief Investigator Flight Operations and Klas Jonsson, Chief Technical Investigator (aviation).

Sam Lundgren has assisted SHK as flight operational expert, Jan Linder as aviation medicine expert, Kristina Pollack as aviation psychology expert, Tomas Casselgren as weather service expert and Laci Bonivart as technical expert.

The investigation has been followed by the Swedish Armed Forces through Agne Widholm and Lars Hall.

Thomas Nilsson has participated as a union representative from Norrland's Helicopter Squadron.

In accordance with section 14 of the Ordinance on the Investigation of Accidents (1990:717) the Board herewith submits a final report on the investigation.

SHK kindly awaits a reply within six months concerning those measures the Swedish Armed Forces take with reference to the recommendations presented in this report.

Lena Svenaeus

Rune Lundin Klas Jonsson

List of Abbreviations

ARCC Air Rescue Coordination Center

CVR Cockpit Voice Recorder / For the recording of onboard communication

DIDAS Service data system for the Swedish Armed Forces' fleet of aircraft, helicopters etc.

EEG Electroencencephalogram/ Brain wave examination method

ELT Emergency Locator Transmitter

EMI Electromagnetic interference

FAA Federal Aviation Administration (USA)

FDR Flight Data Recorder / For the recording of onboard flight data parameters

FFSU Continuous aviation type training

FMV Swedish Defence Materiel Administration

FRÄD Search and Rescue

GSM Global System of Mobile Communications

ICAO International Civil Aviation Organization

NTSB National Transportation Safety Board / The USA's Federal Accident Investigation Authority

OSF Regulations and Safety Directives for Flight Service in the Swedish Armed Forces

Rpm Revolutions per minute

SAR Search and Rescue

SFT Special flight duty

SOAP Spectral analysis of oil samples

VÄDC Military weather center

SUMMARY

On the 9th of August 2000 an inquiry was initiated concerning two men missing in connection with mountain climbing of Mount Kaskasapakte in the Tarfala massif. The prevailing weather conditions were very bad with winds up to 25 knots and snowfall at the higher elevations. The police had the assistance of an alpine search and rescue group from the city of Kiruna. The operation was made more difficult due to the fact that no one knew which ascent route the two men had chosen up to the top of Mount Kaskasapakte.

On the morning of the 10th of August military assistance was requested and an HKP 10 from the Kallax SAR-Company, with a crew that was considered to be well suited to the nature of the mission, was assigned to the search effort. Due to the poor weather only forward placement of alpinists and material could be accomplished during the day. The area where those missing were believed to be located was enshrouded in clouds and no search efforts could be undertaken. Consequently the helicopter and its crew waited near the Tarfala scientific station.

During the evening of the 10th of August the missing men were located by the alpine group. The older of the two men was found to be in such bad shape that it was not possible to get him down the mountain without the help of a helicopter. At midnight the wind subsided and skies cleared. At 01:30 hours the helicopter took-off and was observed during climb with searchlights on, to approach alongside the south face of Mount Kaskasapakte, directly towards the site where those in distress were located. Several members of the alpine group have stated that the helicopter came very close to the face of the cliff at time 01:36 and that they observed the main rotor contact the cliff-face approximately 25 meters from the men in distress, which created a violent shower of sparks. The helicopter turned itself to the left, away from the mountain, with the nose descending and slammed against the cliff-wall a few dozen meters lower. Thereafter it bounced downwards some fifty meters and exploded, creating a substantial fire. The three persons onboard were killed instantly at the time of the accident. Later that night the persons in distress were rescued by a search and rescue helicopter from Bodö in Norway.

A very strict technical investigation has been accomplished (SHK's file document 39). SHK has also looked into the operational and organizational conditions within the helicopter section of the Swedish Armed Forces. The investigation has brought resource, reorganization, and command problems to light that have not had a direct relationship to the accident but typically imply risks to flight safety.

The accident was caused by the helicopter's main rotor colliding with the vertical mountain wall, after which the helicopter was broken up against the mountain and caught fire. All those on board perished.

The direct cause of the collision with the mountain has not been able to be established with certainty. It has not been possible to establish any technical fault on the helicopter. It is improbable that conditions of ill health were contributory to the accident.

The investigation has shown that difficult visual conditions were prevalent at the site. Looking into the light of early dawn in combination with the terrain's sometimes light swaths of snow and sometimes dark rock formations may have affected the crew's capacity of scotopic vision and rendered the judgement of distance more difficult. In these circumstances, the choice of flight route has indirectly been a cause of what took place.

Fatigue and deficiencies in crew co-operation, brought about by an all too great confidence in each other's professional skill, may have been contributory causes of the accident.

SHK has presented 11 recommendations that affect education, flight training, aircraft equipment, maintenance and measures to improve safety and to facilitate the investigation of accidents.

1 FACTUAL INFORMATION

1.1 Crew

The Aircraft Commander:

Rank:	Captain
Age:	52
Training:	FFSU, Aircraft Commander
Total flying time:	6,000 hours
Total flying time on the HKP10:	1,900 hours
– previous 90 days:	15 hours

The Aircraft Commander began his military pilot training in 1966 and after reconnaissance flight training was stationed at F 21 in Luleå. He flew the S 35 Draken until 1979 and the S 37 Viggen until 1991. In 1987 he began helicopter pilot training and flew, among other helicopters, the HKP 3 during a few years time. From 1991 he flew only the HKP 10 on search and rescue duty and in the summer of 2000 attained the highest seniority among the aircraft commanders of the SAR- Company.

The Co-pilot:

Rank:	Captain
Age:	51
Training:	SFT: 1, Aircraft Commander
Total flying time:	4,730 hours
Total flying time on the HKP 10:	2,010 hours
– previous 90 days:	50 hours

The Co-pilot began his military pilot training in 1974 and thereafter underwent fighter pilot training on the J 35 Draken and was then stationed at F 12 in Kalmar and F 16 in Uppsala. In 1985 he was employed at F 21 where he flew, among other aircraft, the JA 37 Viggen. In 1990 he underwent helicopter pilot training and served as pilot and later as aircraft commander and instructor pilot within search and rescue duty.

The Flight Engineer:

Rank:	1st Lieutenant
Age:	41
Training:	Flight Engineer
Total flying time:	750 hours
Total flying time on the HKP 10:	750 hours
– previous 90 days:	12 hours

Upon completion of his national conscription, the Flight Engineer went through Air Force Flight Mechanic training and served the first few years as flight mechanic on the JA 37 Viggen. In 1994 he underwent a technical course on the HKP 10 and thereafter served as flight mechanic and flight engineer on the HKP 10.

1.2 The helicopter

Helicopter 10 No. 404 belonged to The 1st Helicopter Squadron (1. Hkpskv.) The civilian designation is Eurocopter (formerly Aerospatiale) AS 332 M1-SAF, with serial number 2274. The helicopter was equipped with two engines of type Turboméca Makila 1A with serial numbers 2209 (left) and 2433 (right).

At the time of the accident the helicopter carried complete search and rescue equipment, plus it was winter equipped except that the skis were not installed. The gross weight of the helicopter at the time of the accident has been calculated to be 7,500 kg. This includes fuel weight and the weights of those on board. Maximum allowed takeoff weight for the helicopter is 9,000 kg. Earlier that evening the helicopter had flown with an identical configuration without log remarks. No remarks have been noted from these flights.

The helicopter was delivered to F 21 in Luleå in August of 1990 and at that time had a service time of 42 hours. The total service time on the helicopter at the time of the accident was 3,212 hours. The latest 500-hour inspection was completed on the 14th of January 1999 with 3,000 hours of operation. The latest 50-hour check was completed on the 2nd of August 2000 with 3,200 operating hours.

A search of the DIDAS shows that there were relatively many (13) remaining log remarks that had not been taken care of, a condition that was observed to be similar throughout the Swedish Armed Forces' medium heavy helicopter fleet.

In addition, 34 deviations in the maintenance structure of DIDAS and a number of other deficiencies in flight time documentation and maintenance documentation were ascertained. Among other things, several discrepancies between Control/Follow up cards, Log-cards and DIDAS were observed; furthermore that maintenance steps had been deleted in service routines without being signed or motivated and that flying time had been summed-up on the same log page as a single sortie although the same crew had performed several sorties.

In January of 1998 the helicopter was transferred to the newly established Helicopter Wing and was included in the provisional organization which was designated the FRÄD-Division, based at Kallax in Luleå. The technical organization was administratively transferred to the Helicopter Wing. The technical personnel at Kallax remained the same with the exception of the technical chief, who belonged to the Helicopter Wing.

In January of 1999 the Norrland's Helicopter Battalion was established through a merger of AF 1 and HKP 10 activities at Kallax and Östersund/Frösön. The technical organization was essentially unchanged, except that a new technical chief was appointed. The helicopter remained at Kallax.

On the 1st of July 2000 the operations were reorganized once again and the helicopter was assigned to Norrland's Helicopter Squadron, which is a reduced version of Norrland's Helicopter Battalion. The intention at that time was that the HKP 10 operation at Kallax, along with personnel and materials was to move to Boden. This, however, had not yet been accomplished when the accident occurred.

1.3 Account of the course of events

On Wednesday the 9th of August 2000 an inquiry was initiated concerning two men, 49 respective 81 years old, who were missing in connection with mountain climbing of Mount Kaskasapakte (2,043 meters above sea level), situated approximately 8 kilometers N-NW of Kebnekaise mountain

station. Through the agency of the police, helicopters and the alpine search and rescue group from Kiruna searched in the area.

The prevailing weather conditions in the area were very bad with winds up to 25 knots and snowfall at the higher elevations. Clouds obscured most of the mountain. During Wednesday evening and night, the alpine search and rescue force made several attempts from different directions to ascend the mountain. The operation was made more difficult, in that no one knew which ascent route the two men chose.

On Thursday morning at 07:05 hours ARCC called the SAR-Company at Kallax and informed them that a rescue mission could come to the fore. As the crew that was then on ordinary alert possessed limited mountainous terrain flight experience, a more experienced captain was called-in as aircraft commander. The aircraft commander originally on alert, participated as co-pilot. Also included in the crew were a navigator/system operator, a flight engineer and a conscript rescue man. Later ARCC called the aircraft commander with complementary information, whereupon the decision was made to engage an HKP 10 in the rescue effort. The mission was planned and ordered according to the SAR-Company's standing orders for SAR-activities.

The helicopter took off from Kallax at 10:00 hours and flew to Kiruna, where it was refueled and some alpine rescuers were boarded. Thereafter they flew to Tarfala scientific station (approximately 4 km SE of Kaskasapakte), where the police had established a base for the rescue effort. During the afternoon an approximately 45 minute reconnaissance flight, with two mountain rescuers aboard, was undertaken above and below the clouds in the search area. Subsequently a few shorter flights were made up to the mountain ridge, where two alpine groups were winched down in order to participate in the rescue effort. Gradually it also became clear that those in distress had contacted Kebnekaise mountain station via GSM telephone and with a very poor connection, that was cut-off several times, reported that they were located on the southwestern ridge of the mountain. The search area could now be delimited.

During Thursday night the wind subsided and one of the alpine groups acquired contact with those in distress. At the same time another group, that had ascended via the northeastern ridge joined the site from above.

From the information that was given by the alpine group (among others, by the physician that was present) it was evident that the prevailing climbing conditions were extreme at the site (clouds, wind, snow, moisture, moss and ice covered rocks) and that the older of the two men in distress was in such poor condition that he must immediately be taken down. To lower him down on a rope entailed very large risks, as his hands were swollen and he was not able to hold a firm grip on a rope on his own. An attempt was made to lower him by rope, but was discontinued for safety reasons after a few hundred meters near a cliff ledge, at a height of approximately 1,860 meters.

During the second flight, when the alpinists were winched down onto the mountain ridge, the system operator and the rescue man remained in Tarfala. After having winched the alpinists down the helicopter flew to Nikkaluokta and refueled. Thereafter they flew back to Tarfala scientific station and parked the helicopter. The time was then approximately 23:20 hours.

Around midnight the skies began to clear and the wind subsided. At 00:20 hours the group stated via radio that it should be possible to winch up those in distress with the helicopter.

The crew, which during this time had received food and been provided two rooms for crew rest, was contacted. However, the aircraft commander judged that it was impossible to carry out the mission at that time.

At approximately 01:00 hours a new proposal came from the group. It had now become somewhat lighter, and therefore the aircraft commander decided to launch. As during the previous flight, the system operator and the rescue man were left on the ground.

At 01:30 hours the helicopter took off and its approach could be observed both from the position of those in distress and from the base station. It was observed during climb to approach alongside the south face of Mount Kaskasapakte, directly towards the site with searchlights on. Several members of the alpine group have stated that it came very close to the face of the cliff at time 01:36 and that they observed the main rotor contact the cliff-face approximately 25 meters from those in distress, which created a violent shower of sparks. The helicopter turned itself to the left away from the mountain with the nose descending and slammed against the cliff-wall a few dozen meters lower. Thereafter it bounced downwards some fifty meters and exploded, creating a substantial fire. Pieces of the rotor from the helicopter landed on the cliff ledge where those in distress were located, however no one there was injured. During the course of the fire, several smaller explosions were heard.

1.4 Injuries to persons

The three persons onboard were killed instantly at the time of the accident.

1.5 Damage to the helicopter

Completely destroyed.

1.6 Other damage

None.

1.7 The search and rescue effort

The alarm concerning the accident was given via the police unit commander at the Tarfala station at 01:45 hours.

A civilian helicopter without winch equipment, based in Nikkaluokta (approximately 22 km E-SE of the accident site), arrived at the Tarfala station approximately 90 minutes after the accident. Its pilot, who was alone in the helicopter, boarded the system operator and the rescue man and flew towards the accident site. They observed no signs of life. They have stated to SHK that the lighting conditions at the site were troublesome and that they had great difficulties in judging the distance to the dark mountain wall.

A Norwegian search and rescue helicopter from Bodö, of type Sea King, was alerted via ARCC at time 02:22 and departed for the site at time 03:36.

When it became a bit lighter one of the alpinists on the ridge made his way down to the accident area in order to search for survivors. He found no signs of life at the site.

At 07:40 hours, those in distress and the alpine group had been winched up and transported to the Tarfala station.

Not until later in the day on Friday was a relief alpine group from Östersund able to make its way to the helicopter crash site. At that time they established that the three persons onboard had been killed and that the helicopter had been severely broken up during the collision with the side of the mountain.

There were no signals received from the helicopter's Emergency Locator (ELT).

1.8 The salvage project

The salvage project was complicated by the fact that the helicopter had been severely broken up, causing its parts to be spread down along the steep slope of the mountain wall and lodging in protruding rock formations. The operation was highly weather-dependent and the salvage personnel from the Swedish Armed Forces were not able to work without the continuous assistance of the alpine group.

The positions of the pieces of wreckage and impact marks were roughly documented from a helicopter, after which a system of secure ropes was assembled down the mountain. Reflective paint was used to mark-off a coordinate system in order to facilitate documentation of the position of the parts. The pieces of wreckage were visually inspected and gathered into larger bundles, for helicopter transport down the mountain. Larger parts, such as the transmission housing, tail boom, right-hand engine, landing gear, etc., were removed from the site with a helicopter, to a driveable road for further transport to the city of Boden.

In the first week of September 2000 the salvage project had to be discontinued due to snowfall. Not until July of 2001 was the area relatively free of snow and the remaining pieces of wreckage could be removed. Also at this time, to the extent possible, a clean up of the site was accomplished.

In total, 71% of the helicopter's weight was salvaged. The greater part of the remaining 29% had burnt up in the post-crash fire, however some small pieces may remain on the accident site, hidden under boulders.

1.9 Weather

Gusty west or northwest winds with velocities of up to 25 knots characterized Thursday the 10th of August 2000. The ceiling, with 5–8 octaves was, during the day, 1,500–1,700 meters above sea level, which meant that Mount Kaskasapakte was, for the most part, enshrouded in clouds.

Showers of rain or sleet occurred with the lowest visibility temporarily down to 5–8 km. Light icing was reported by the HKP 10 during one of the sorties during Thursday afternoon.

It is an accepted fact that the area has difficult flying weather, among other things, in regard to turbulence where the most difficult wind direction is westerly to northerly. This was the prevailing wind direction on Thursday.

Late Thursday evening, the wind subsided and at the same time the clouds began to break-up. Around midnight the Tarfala station (1,150 meters above sea level) reported a northwesterly wind of approximately 13 knots.

At 1:00 AM on Friday the 11th of August a rapid clearing took place and all of the mountaintops in the immediate vicinity were free of clouds. At the location of those in distress at 1,860 meters above sea level, the wind was then so slight, that according to witnesses, "you could have lighted a candle". The visibility was good, more than 40 kilometers, and few cloud

fluffs of stratus/fog could be seen down in the bottom of the Tarfala valley. From photographs that were taken immediately after the accident by tourists camping at Tarfala Lake, one can discern not only the burning helicopter, but also bands of fog or low clouds along the valley floor.

A temperature reading at 02:00 hours from Bodö on the Norwegian side indicated that the temperature at the departure point of the helicopter was +3°C and that it decreased to –1° at 1,400–1,500 meters above sea level, to thereafter increase again to +3° at an altitude of 1,850 meters.

The crew had participated in a standard weather briefing at Kallax at 07:45 hours on Thursday. Their next known contact with the weather services was probably made through a non-crew member around 2:00 PM, when the meteorologist at the military weather center (VÄDC) was contacted. At about 21:30 hours ARCC called the weather center to inform them that the flights in Tarfala were suspended and that the requirement for weather follow-up was therefore discontinued.

At the time of the accident the available light was approximately 1 lux along the flight route. This can be compared to moonlight, which produces approximately 0.2 lux, and a lighted road, which corresponds to approximately 25 lux. The sun was at this time approximately 7° below the horizon. Witnesses on the mountain ridge have reported “decent light conditions”, however these persons had likely attained complete visual dark adaptation, after such a long period of time on the ridge.

1.10 Aeromedical investigation

The investigation shows that the three persons on board were killed instantly at the time of the accident. The medical inquiry has not been able to establish any state of ill health of those who were on board. There were also no prohibited substances detected in the remains of the crew.

Prescribed medical examinations were accomplished with approved results, except concerning the co-pilot, whose latest annual medical check-up (1B) was carried out in January of 1999. The latest circulatory examination was dated in February of 1999. According to current regulations concerning medical examinations he should have accomplished these at the latest during his month of birth (September) in 1998 (1B), respective three months after his birth month (circulatory examination). There were no examinations accomplished for the years of 1999 and 2000. The individual is personally responsible that these examinations are accomplished.

SHK has also audited documents pertaining to the visual ability of both pilots. Both were found to have the required visual acuity during their eye examinations. However the co-pilot wore bifocals during flight duty.

The investigation has shown that in March of 1995 the aircraft commander suffered a brain concussion with subsequent symptoms in the form of memory lapses. He was, in addition to other procedures, examined with repeated EEGs. The results did not indicate any brain damage. Subsequent to these analyses he returned to flying with dual control in December of 1996 and was allowed to fly without limitations from October of 1998. In May of 2000 he consulted with a flight physician for neck pain with emanation pain in the left hand and was at that time taken off of flight duty. The condition improved during the summer and he returned to flight duty on the 1st of August 2000.

1.11 Technical investigation

1.11.1 General

The technical investigators' task has been to respond to, among other things, the following comprehensive questions:

- Was the helicopter technically and formally airworthy before the accident occurred?
- Was there any technical malfunction on the helicopter before the main rotor hit the mountain wall?
- Who occupied the aircraft commander's position?
- What speed and what flight path angle did the helicopter have when the rotor made contact?
- Was the flight engineer secured in the winch operator's harness or in his seat?
- Was the right-hand side door open?
- Was the autopilot, the searchlights or the radar on?
- Did the crash safety systems and the flight safety materials function in an acceptable manner?
- Can experiences from the accident be utilized in order to increase the safety of flight?

The investigation has been time consuming and difficult, mainly due to the extreme location and character of the accident site (high alpine, steep, loose boulders) and the fact that large portions of the helicopter were broken-up and burned during the accident. There was no equipment on board for the recording of flight data or communication, making eye witness testimony of essential significance.

1.11.2 The accident site

The terrain at the site of the accident consisted to a large extent of large loose lying boulders of varying size on a steep mountain slope.

The place where the main rotor initially impacted is in such a steep (vertical) section of the mountain wall that only alpinists have been able to make their way there to study and document this.

The second point of impact, where the helicopter hit the mountain was 17.2 meters under and 10.2 meters west of the initial point of impact. Distinct remnants of a green position light of the type that is mounted on the helicopter's right-hand sponsor tank were found at this position.

Of the outer hull of the helicopter, only the tail boom was somewhat intact, however the tail rotor was missing. The tail boom was lying loose and unstable relatively high up at the accident site, only 10 meters vertically below the second point of impact.

The remaining hull structure of the helicopter was for the most part broken-up into small pieces. Large portions were burnt beyond recognition.

The largest whole piece was the transmission mounting deck (produced from fire-resistant material) where the main rotor gearbox, main rotor hub, left-hand motor, output servo, certain portions of the hydraulic system and approximately one meter long stumps of the main rotor blades remained. This piece, the weight of which was estimated to be approximately 1,300 kg, was lying approximately 50 meters vertically under the second point of impact.

No pieces of wreckage were recovered along the route of flight to the initial point of impact, or otherwise abnormally far away from the accident site.

The emergency transmitter was recovered on the mountain, mounted in its bracket. This had been deformed and torn from the structure of the helicopter without the transmitter having being activated. The circuit breaker connector was damaged and both connecting pins were broken-off. The transmitter and its installation have been analyzed in detail.

Above the second point of impact very few pieces of wreckage were retrieved, apart from pieces of the tail rotor blades and main rotor blades.

With reference to the second point of impact, in addition to the green position light, a number of details traceable to the area around the right-hand sponsor tank were recovered. These included, among other items, the side door, landing gear, the aft holder for the ladder and reinforcement mountings from the tail boom attachment point.

Parts of the logbook were retrieved. The page with the latest log entry was (No 182327). The pages that followed in the number series (No 182328 and onward) were found blank in the logbook.

The tail rotor gearbox, with tail rotor, had been torn from the fin due to its anchor lugs having been broken. It was recovered, with cracked gear housing and without input drive a few hundred meters farther down on the side of the mountain. Between 20 and 30 cm remained of the blades.

The right-hand engine had separated from its mounting on the transmission housing and was recovered approximately 300 meters below it.

1.11.3 Eye witness reports

During Thursday a total of seven sorties were accomplished with the helicopter, including the accident flight. There is nothing in the witness testimony that would indicate that the helicopter did not function as it should during all of Thursday and during the final flight. In this matter it should be taken into consideration that the witnesses (among others, the system operator, the rescue man and the alpinists) may be considered well qualified to comment on this type of questions in view of earlier experience of working with helicopters. However, during the course of the investigation, it has been shown that different witnesses observed different amounts of the final 100 meters of the flight path. Some of the witnesses on the ridge and at Tarfala station were standing a long distance away. The mountain blocked the view of some and some were looking in another direction. Therefore, all of them did not see the final part of the flight path, but first reacted when the sound of the helicopter changed to a “chopping” character, after which they observed the shower of sparks. Nevertheless, many had such good visual contact, that the reported observations may be considered to have very high reliability.

In addition to the refueling that took place after the flight from Kallax to Kiruna, the helicopter was fueled prior to the sixth sortie as well, at Norrlandsflyg in Nikkaluokta. It has not been possible to analyze this fuel, due to the fact that it first became known on the 17th of August that this refueling had taken place, and at that time the fuel depot had already been filled with new fuel. However, a number of other helicopters had been refueled with the fuel in question without anything abnormal being reported.

Witness reports indicate that at least one or two searchlights were lit at the time of the accident and that an extra searchlight may have been turned on during the final stage of the flight. However, based on the witness reports, it has not been possible to establish exactly which searchlights were lit or when they were turned on. Furthermore, the witnesses had had

the possibility to discuss the occurrence for a few hours prior to being interviewed. It cannot be ruled out that they unconsciously may have influenced each other's recollection of the sequence of events. In this context it should be noted, that it takes approximately 2–5 minutes before three of the HKP 10's four searchlights are lit after initiation. The fourth searchlight (SX-16) takes a minimum of 6 seconds to become operational. It can also be pointed out that it can be difficult to see if a searchlight is on or not in clear weather at a long distance, if one does not see the light source itself or some object illuminated by the searchlight. The witnesses on the ridge have however not felt that the searchlights illuminated those in distress.

Several witnesses have spoken about a "chopping" sound experience of approximately 3–6 Hz in connection with the rotor impact. The HKP 10 has a nominal rotor speed of 265 rpm and a four-bladed rotor, which results in a frequency at blade impact of 265 x 4/60 Hz ≈ 17,7 Hz, which differs greatly from 3–6 Hz.

Attempts have been made to calculate speed and flight path at the time of impact. As a witness, it is probably difficult to judge how fast an object is approaching if you are directly in front of it, which is what certain witnesses have been. However, there is a relatively good consensus between calculated speed, the impressions of the witnesses and reconstruction flights accomplished subsequent to the accident. The witnesses have stated that the helicopter had a relatively low speed, however not stationary, and the calculation has shown a maximum speed of 10 knots.

1.11.4 Technical investigative results

A comprehensive technical investigation has been accomplished concerning the helicopter's flight control system, main rotor system, tail rotor system, engines, instruments and controls. This has been carried out partly at the accident site and partly in specialist workshops. During the investigations of these systems and components nothing has been found that would indicate any technical failure.

Searchlights

Very early on in the investigation it appeared that the lighting conditions at the accident site were a topic of great interest. As a method of attempting to survey this, an inquiry has been made into which of the helicopter's searchlights were on at the instant of impact and how these were aimed.

The HKP 10 is equipped with four searchlights, all placed on the underside of the body of the aircraft:

- Two on the nose section – one on the right and one on the left side.
- One immediately aft of the right-hand sponsor tank (controlled by the flight engineer).
- One farthest back on the forward body next to the aft ramp, designated SX-16.

Of the recovered parts from the co-pilot's and the flight engineer's searchlights, it can be stated that both were most likely extended and pointed somewhat to the right. This indicates an angle that corresponds well with a point on the mountain wall obliquely to the right and in front of the helicopter.

From the investigation of the jack that is used for extension and retraction of the SX-16 searchlight, it could be ascertained that this searchlight was either lit or about to be lit.

No conclusions could be drawn from the investigation concerning the illuminating parts of the lights. The fact that the switch on the co-pilot's collective was in the on position is also not a certain indication of a lit searchlight, as the switch can have ended-up in that position during the destruction of the helicopter.

The fact that the searchlights were probably extended and pointed to the right does however indicate a relatively large probability that they were on at the time of the accident.

The statements of the witnesses are also a very clear indication that one or more searchlights were on.

The rotor blades

The balance weights on the tips of the main rotor blades and the erosion protection on the leading edge of the main rotor blades are made of stainless steel. The tail rotor blade erosion protection is made of titanium. The rotor blades have a dark underside. The tips of the blades are not color-contrasted and they can be difficult to distinguish under poor lighting conditions. The fact that the pilots sit far forward in the helicopter and have the main rotor disk's largest rotational diameter a number of meters behind them can render it more difficult to safely maneuver in tight locations.

This question has been discussed with Eurocopter, which has replied that a prepared modification package has been produced that entails the painting of the rotor tips. On the other hand, there is a lack of a total concept that would also include illumination of the rotor disk from underneath.

The radar

The helicopter's radar shall, according to pilot instructions, be turned off in connection with winch operations due to radiation risk. The radar is useable to detect obstacles down to approximately 50 meters from the helicopter.

During the investigation at the accident site and the subsequent investigation inside a hanger, only the radar antenna disk, a small piece of the wave propagator and one of the two radar panels have been recovered and identified.

It has not been possible to determine whether the radar was turned on or not at the time of the accident.

The emergency transmitter

The helicopter was fitted with an ELT of fabrication/type Emergency Beacon Corp / EBC 302-HM (Armed Forces designation: Emergency Transmitter 715) that was mounted in the cockpit on the wall behind the co-pilot. The transmitter bracket is riveted to the helicopter structure with six 2.4-millimeter diameter rivets.

The emergency transmitter has a three-position rocker switch with the positions ON (manual on), ARM (automatic initiation at an acceleration of 8 ± 2g in x-, y- or z-plane with a duration of 30 ± 10 ms), and OFF/TEST (spring-loaded position for testing and turning off an active transmitter respectively). This emergency transmitter is specially manufactured for helicopter use and shall detect all accelerations regardless of direction.

A control check with ARCC determined that no emergency signal was detected after the accident. The transmitter, which was in the off position, was still attached to the bracket, which had separated from the helicopter's structure in that some of the rivets had broken and others had come loose.

There were however strike marks on the top of the transmitter and it had been pushed down in the bracket, which caused it to become deformed. The investigation showed that the transmitter was fully functional and met all specified initialization criteria and the requirement for output effect and battery power. The remaining battery charge showed that the transmitter couldn't have been shielded and transmitted until the battery was dead.

The possibility that the transmitter may have started but immediately thereafter been turned off, through some form of external influence on the rocker switch, has been investigated. The rocker switch only needs to be momentarily placed in the OFF/TEST-position in order that an activated transmitter should be turned off.

A search into the acceleration and time impulse limits that result in an activated transmitter being turned off has shown that it requires a power impulse of approximately 2000 g during 1–3 ms from the right for this to occur. In this research three different emergency transmitters have been used and it was possible to turn off two of these by subjecting them to the acceleration pulses mentioned above.

Personnel at the HKP 10 Company at Kallax have been interviewed concerning the routines for the safetying of the emergency transmitter. The assessment of the personnel was that it was unlikely that it had been safetied.

Within the installation instructions for the emergency transmitter there are stated demands pertaining to the rigidity of the structure where the emergency transmitter is mounted, since the risk of accidental activation increases if the structure is too pliable. The investigation has shown that the installation in the HKP-10 does not satisfy these demands of rigidity.

Who sat where in the helicopter?

None of the witnesses, not even those who were at Tarfala station during the departure sequence, have been able to decide with certainty which of the two pilots sat in the right-hand pilot's seat; the position from where the helicopter is flown. The seats in the HKP 10 are identical and lack information as to where they have been mounted. During discussions with the technical personnel at the HKP 10 Company at Kallax it was stated that they had the routine to always mount the central lock unit for the pilot safety harness on the right-hand pilot seat, so that during unlocking the lock ends-up on the right side of the seat. This is to avoid that the lock moves to the left during unlocking and in doing so creates a risk of damage to the electronic panels that are placed there.

Due to the fact that the wreckage was severely broken-up, damaged by fire and structurally twisted 180°, it was not even possible during the subsequent accident site investigation to see, which of the two pilots had sat where. Both the pilot's safety harness central locks were however recovered in the locked position, which shows that both pilots had their seat belts donned at the time of the accident.

During the forensic medical investigation of the co-pilot, remaining fastening in the form of hip straps from the chair seat were removed with a scalpel. When these incision surfaces were compared with non-burned sections of the safety belt harness it could be determined that the central lock was not turned around; that is to say this central coupling had been mounted to the left. It was furthermore determined that the retainer fitting between the central coupling and the right hand side of the seat sheath on the aircraft commander's seat was reversed compared to the corresponding retainer fitting on the co-pilot's seat; in other words this central coupling had been mounted on the right hand side. When the anchoring in the helicopter of the aircraft commander's seat sheath was compared with

remnants of the seat rail anchoring on the cabin floor it was found that his seat had sat on the right side in the helicopter. By reason of this, it has been demonstrated that it was the aircraft commander that sat in the right- hand pilot's seat. Owing to that, in all probability it was he who flew the helicopter, as it normally always is flown from the right-hand seat position.

The investigation of the flight engineer's position at the time of the accident shows that he was neither in his seat with his seat belt on nor in the winch operator's harness. In the regulations and safety instructions manuals (OSF Chapter 10.2.2.1) it is stated that the aircraft's securing and fixating devices shall be worn and adjusted. It is however allowed to make deviations from this in the helicopter, if it is required for tasks on board.

Determination of flight phase

Through the analysis of parts of wreckage and impact marks, calculations have been made in order to as far as possible determine phase of flight, airspeed and approach angle at the time of the accident.

Given the fact that the main rotor rpm is known, one can in certain cases, by measuring the displacement between the scrape marks from the main rotor on rock walls, calculate speed and angle of approach. This was also SHK's ambition. However, due to the brittle character of the mountain wall, there was a lack of sufficiently distinct scrape marks in order that such a calculation could be accomplished with sufficient accuracy. Therefore, calculations of speed and angle were instead made from photographs that were taken and reconstruction flights. The calculations showed a maximum speed of 10 knots and a maximum climb angle of 10 degrees.

It was also concurrently investigated if the right-hand side door had been opened in preparation for the up-coming use of the winch. The damage in the closed position on the right-hand door rail indicates that the steel rollers were in place there, when they were violently forced out of this position. None of the other damage on the door rail indicates that the door had been in a more open position than the aft most locked position. Even the positions of locking handle and the locking pins indicated that they were in the locked position. This would indicate that the door was closed and locked.

The crew's flight equipment

A special report concerning the crew's clothing and equipment has been produced.

It shows that the aircraft commander probably used regulation equipment. The co-pilot and the flight engineer did not wear the recommended undershirt. Both were wearing a green T-shirt, which provides poorer fire protection than the regular undershirt.

The co-pilot wore white leather gloves (Flight Glove M/55) and used ordinary shoes. According to FMV's administrative official, the gloves have been "recalled" several times and are not approved for use during flight duty. Flight Glove M/55 shrinks if it is exposed to fire, which can have the consequence that even otherwise minor burns can become severe injuries (disability and/or amputation) if the gloves are used. A generally frequent complaint about the approved flight glove M/80 is that it is too short and does not cover the wrists.

The flight engineer wore no long underwear under the flight suit, which considerably reduced the fire protection.

The aircraft commander probably had the chin strap on his flight helmet secured, while the co-pilot likely had not secured his helmet. The flight engineer's helmet has not been recovered.

The investigation has also shown that the flight suit (flight suit 96 HKP) which the co-pilot was wearing is not flame resistant.

Fire/explosion

The fact that neither any steel nor titanium alloy has been found that has been deformed solely by the affects of heat or has melted indicates that no fire existed prior to the helicopter colliding with the mountain. This is also reinforced by the statements of the witnesses.

The conditions that prevailed and those that arose at the accident site concerning temperature, altitude above sea level, type of aviation fuel, fuel mist in the air from disintegrated fuel tanks and sources of heat and sparks in the form of engine parts and shorted electrical wiring were of such a nature that a fuel fire could be expected to break out.

The smaller explosions that the witnesses reported hearing probably arose from some of the helicopter's tires or from pressure cylinders for oxygen, air, nitrogen gas, freon, etc., that were exposed to fire.

Based on literature studies, witness testimony about hearing the sound of an "explosion" is judged to coincide well with how explosions are interpreted and perceived by witnesses. A powerful turbulent fire within a large atomized cloud of turbulent fuel mist creates a sound that is reminiscent of the distant rumble of thunder.

1.12 Operational flight conditions

Mission character

SAR activities entail to a large degree varying and complicated missions, depending upon the emergency situations that arise. Certainly, operational demands and limitations exist. If one studies the safety instructions (OSF) it becomes evident however, that in many respects it rests with the aircraft commander to make crucial decisions which lie outside normal operational limitations. The objective of saving lives must be weighed against the crew's own safety.

A normal approach procedure to those in distress had consisted of a reconnaissance over-flight followed by an approach turn and descent towards an intended winching position. In the helicopter training handbook (Handbook HU) which is the basis for mountain flight training, it is stated that a descent towards a landing sight in the mountaintops should be made from a height of approximately 100 meters above the landing site. In the case in question a normal approach procedure has not been utilized. All the signs indicate that the crew had already initiated an ascending hover in order to position themselves directly above those in distress when the main rotor collided with the mountain. The training instructions speak specifically against the use of this methodology for the ascending hover.

The rescue mission up to the mountain ridge can be considered unique in several respects. The crew was probably standing indoors at the Tarfala station and observed the signaling of those in distress up on the ridge. Consequently there were many things that would indicate that the mission did not seem to be complicated. At that time the crew had been active since early in the morning on the previous day and had accomplished six sorties, of which the latest had been concluded approximately two hours earlier. There had been limited possibilities for rest.

During the arising emergency situation at Kaskasapakte, ARCC and the search and rescue leader at the site agreed that the rescue effort required the application of section 34 of The Rescue Services Act. By that means the

possibility existed of recruiting military resources as well, as long as this did not hinder the Armed Forces' normal activities. The requirement expressed by the alpine group was that a helicopter equipped with a functional winch was needed for the rescue mission, which was lacking on civilian helicopters in the vicinity and on several of the military helicopters based at the squadron in Boden.

The HKP 10's primary task is SAR. It has winch equipment and in the requirement specification for the HKP 10 unit it is stated that, among other things, the helicopters shall be able to serve around the clock throughout the entire country. In the case at hand ARCC could regroup another HKP 10 from Sundsvall to Umeå in order to satisfy the Armed Forces' SAR readiness in the area.

SHK has been informed that the alpine group in the Kiruna area had trained together with the squadron's HKP 3 in Boden and that they preferred this smaller helicopter, especially because of its weaker rotor wind.

The composition of the crew

At the time of the alarm on Thursday morning, when it became clear that the mission concerned high alpine terrain with the element of snow included, it was decided to alter the composition of the crew. The aircraft commander on alert (afterwards the co-pilot) realized that his co-pilot on alert had recently completed basic training and SAR training on the HKP 10, but had not completed mountain flight training. As the time for planning was adequate and it so happened that the SAR Company's most experienced aircraft commander was available, the crew composition was changed. There was support for this within the standing orders.

The two pilots were the same age, knew each other well and both had similar solid flying background as ex-air force pilots on heavy jet fighter systems. Both had transferred to the helicopter operations during the latter portion of their vocational activities. The investigation has proven that both were considered to be competent professionals who stood up for their opinions. Concerning the aircraft commander it can be added that he, besides being considered a competent pilot through the years, was perceived by many as dominant and in certain situations reluctant to accept the viewpoints of others.

The aircraft commander had only flown 15 hours during the previous three months owing to the fact that he had been on sick leave. It has been revealed during the investigation that he had experienced problems of a private nature for quite a long period of time that may have affected his sense of well-being.

SHK has learned from colleagues of the pilots that the co-pilot had great confidence in the aircraft commander and his experience of mountain flying that went back to the 1960s. Moreover, the co-pilot mentioned this to the rescue man at the start of the mission. Such a firmly rooted confidence can have a detrimental effect upon crew cooperation and contribute to the reduction of the co-pilot's roll in the monitoring of the aircraft commander's flying. Normally pilot cooperation is based on the principle that the pilot that is not flying always monitors the flying pilot's maneuvering and steps taken in the cockpit. A two-pilot concept that is based on pilot instruction, the Rescue Flight Handbook and the unit's division regulations, control this precisely.

Between the years 1994 and 1997 The Swedish Armed Forces on four occasions carried out "crew course helicopter" which focused on humane prerequisites and limitations seen from the viewpoint of the entire crew's cooperation on board. The course employed instructors with experience from the Swedish Commercial Pilot's College and researchers with expert

knowledge concerning crisis management and trauma training. During the transition to the Helicopter Wing organization this training was discontinued. In the spring of 2000 a similar course was carried out. The co-pilot who lost his life participated in this course.

A functional system of crew cooperation is essential to flight safety in all flight systems. Training in the prerequisites of crew duties and training in how one creates and maintains a keen and well-functioning two-pilot concept is therefore of the utmost importance. In these circumstances it is seemingly odd that the helicopter wing found itself compelled to diminish the frequency of these courses due to economical reasons.

The terrain conditions at the accident site

The reconstruction flights showed that the helicopter climbed relatively steep, along the western edge of a snow channel immediately east of the accident site, up towards those in distress. When they were almost on the same level as the rescue area they leveled-off and continued with a shallow climb along the mountainside, directly towards the position of those in distress.

At least two of the helicopter's searchlights were probably lit and aimed obliquely to the right. This means that the white snow channel was probably also illuminated, which can have caused an impairment of the crew's dark adaptation and thus their ability to see contrasts in the adjacent terrain deteriorated after they had passed the last snow channel.

The crew likely observed the silhouette of the alpinists and was able to judge the distance to them. Also, they probably observed the continuation of the snow channel up the mountain. On the other hand, they probably experienced difficulty in seeing contours in the area between the snow channel and the position of those in distress.

The shape of the mountain changes between the snow channel and the impact site. The area where this takes place consists of a dark-colored section of mountain without any snowfields. Under the prevailing light conditions during the final portion of the approach, this dark section of the mountain may have blended-in to the silhouette of the southwest ridge in the background. It is likely that the crew had difficulties in seeing what this dark portion of the mountain looked like. The mountain ridge where the rotor impacted protrudes somewhat but this was probably not observed against the background silhouette under the prevailing light conditions.

Mist on the front windshield?

A question that has been addressed is whether the helicopter's windows may have been covered with mist, which in that case could have impaired the visibility possibilities for the crew. The temperature during the night in question was a few degrees above freezing.

During the sorties earlier that evening they had flown without mist on the windows presenting a problem. During the last flight there were only three onboard, all with dry clothing. Nor did any onboard equipment contain any significant amount of moisture.

The HKP 10 does not have any pronounced tendency to develop problems with moisture on the windows. Its heating system for deicing of windows is considered to be effective. However it has not been possible to determine if this system was on or not.

Testimony from the civilian helicopter pilot who flew over the accident site about 03:15 hours that night shows, that no tendency for the windows to fog-up was experienced during that flight.

Therefore, all in all, the assessment is made that misty windows probably did not have an influence on the accident.

Falling rocks?

Notwithstanding investigation, it has not been possible to positively write-off or to confirm that some loose lying rock had fallen down the mountain and damaged the helicopter. However, nothing has been found which would indicate this. The HKP 10 is manufactured to withstand relatively extensive damage to the main rotor without this creating any critical flight situations.

Mobile phone interference?

All three crewmembers carried mobile phones during the flight and there were possibly other mobile phones onboard too. The question has arisen whether these may have disturbed a system in the helicopter through EMI effects and by this, contributed to the accident.

Telia's GSM network has contact with the accident site, but due to the damage it has not been possible to determine if any telephone was activated. Witnesses have reported that they did not perceive any deviation in the flight path. A check of all the disturbance reports from the entire HKP 10 fleet revealed that no occurrences have been reported where mobile telephones disrupted the helicopter in any way.

1.13 Command and activities of the helicopter organization

Subsequent to the accident SHK has meet with the flight safety inspector of the Swedish Armed Forces, the command of the helicopter wing, the command of the 1st helicopter squadron in Boden and several employees at the SAR company and the HKP 10 company at Kallax. The purpose was to as far as possible create a picture of how the activities are commanded, how flight safety is pursued and how the reorganizations that were undertaken, have affected the personnel and the operations.

During a period of only a few years helicopter operations have undergone several reconstructions, with the purpose of creating a central helicopter organization for all helicopter operations from the previous operations of the army, marines and air force. These earlier defense branch operations have had completely separate operational aims. Within the army aircorps the main areas of concentration have been the antitank groups' attack helicopter units with the HKP 9 and transport operations. In the marines the main emphasis was placed on anti-submarine operations with the HKP 4. Within the air force units the operations have mainly been search and rescue with the HKP 10.

During discussions with high-ranking commanders within the Helicopter Wing it has been found that the build-up of the new organization has not been without problems. The "cultural" differences have been especially conspicuous and have obstructed cooperation. Even the flight safety review board has been aware of this.

In the partial-year report from the SAR Company at Kallax, dated 2000-06-05, among other things, it is evident that the ongoing restructuring and limited availability of flying time on the HKP 10 system caused the operations to be characterized by irregularity and to be difficult to plan. The company commander considered the flight time utilized during 1999 and the first half of 2000 to be alarmingly low in relation to the tasks of readiness. Also, low personnel availability resulted in a high rate of overtime.

A particular source of concern at the SAR Company at Kallax was the impending move to Boden. The company personnel considered the decision to move to be a threat to flight safety and had a negative attitude to relocation. How many people experienced the squadron command's actions during the decision making process is described in an official letter from the flight safety representatives at the SAR and HKP 10 companies, dated 2000-06-19. In the communication, which is directed to the squadron and the Labor Inspectorate in Luleå at the time, the ability and competence of the squadron command to lead a SAR company was seriously questioned. The grounds for the letter were the small amount of flying time and the circumstance that relocation would further reduce flight time.

The squadron replied through its flight safety officer two days later by promising a meeting to discuss the subject after the summer vacation period. In addition it was stated that there wasn't yet a completely prepared plan for the move to Boden.

On the 18th of August 2001 SHK received the Labor Inspectorate's deliberations pertaining to the accident and to the letter from the Safety representatives. From this material it was evident that the Labor Inspectorate is dealing with certain working environment questions at the 1st Helicopter Squadron in Boden. The Inspectorate is preparing an inspection of the operation's planning, application and function in the context of the regulations of the National Board for Occupational Safety and Health (AFS 1996:6).

The problems referred to above were known at headquarters level within the Swedish Armed Forces.

1.14 Recording and warning equipment

Flight data and sound recorders of type FDR/CVR were not fitted and were not required on the actual type of helicopter in military service. It should be noted in this connection that:

- The HKP 10 has a planned service-life that extends beyond the year 2010.
- The HKP 10 is complex with a high degree of systems integration.
- The HKP 10 is also utilized for transportation of civilian personnel and for civilian search and rescue service.
- ICAO introduced as early as 1987 the requirement for a CVR on civilian helicopters with > 7 tons maximum authorized takeoff weight in commercial operations and a requirement for a FDR on the equivalent category from 1989.
- In addition, the FAA made the requirements more stringent for commercial helicopter operations by increasing the required number of recorded parameters on the FDR, after repeated recommendations from the NTSB.

Of 97 Super Pumas sold for military use, more than 50 have been equipped with FDR/CVR.

Concerning equipment for the detection of obstacles, there are prototypes of systems on the market today for terrain avoidance which can, with great accuracy, detect and warn of several types of obstructions in the flight path during, for example, poor visibility conditions or darkness.

Use of this type of system during the flight herein under investigation had likely led to the crew being able to receive a precise reading of the distance to the mountain wall and based on this, been able to choose a suitable approach path.

Such systems should even be able to bring about a general improvement of flight safety for the HKP 10, i.e. with reference to the large number of GSM masts that are gradually being built throughout the entire country. With the present radar, these masts are not observable on the HKP 10. There is not sufficient time to update aeronautical charts frequently enough with information on new GSM masts and other obstacles. This is today a genuine flight safety problem during poor visibility.

According to reports, an adequate obstacle warning system can detect this type of mast at a range of approximately 500 meters, which is sufficient to allow for evasive action.

This aspect to enhance performance ability with increased/maintained flight safety is most pronounced during so-called severe SAR missions. In these situations the crew has the choice between attempting to complete the mission, where often lives are at stake, or to fly with sufficient margins of safety, which of course in certain situations implies limitations in performance ability.

The effect and the reliability of obstacle warning systems is, according to the knowledge of this investigation, not to any large extent tested within the helicopter operations of the Swedish Armed Forces.

2 ANALYSIS

2.1 The crew

The composition of the crew is deemed to have been adapted to the mission, apart from the fact that from experience there can be difficulties in achieving a well-functioning cooperation, when two older and experienced aircraft commanders are included in the same crew.

Nothing has been found during the technical investigation of the helicopter that could explain the sequence of events. The essential question is therefore how could it happen that two experienced pilots in a two-pilot crew– with in all probability a functional helicopter – could fly into the mountain wall?

Firstly it can be stated that the crew did not accomplish any overhead reconnaissance flight but chose another route of flight than expected and initiated an ascending hover in order to stop directly above those in distress. It has not been possible to determine what the cause, viewed from the premises of the crew – could have been of these deviations from an expected course of action.

SHK can however state that the crew had waited a number of hours in order that the weather would allow a rescue effort. Those in distress sat completely unprotected from wind and rain/snow. The police unit commander had relayed the information that the older of the two persons in distress should be brought down immediately. Furthermore the crew was aware that the persons on the mountain ridge were spread-out in several different locations and that several sorties would be required to bring them all down. In light of this, it cannot be ruled-out that the crew felt a bit pressed for time, in order to be able to manage to make the most of the weather situation. That the crew chose to fly along the mountain wall, straight up towards those in distress, could have been due to the fact that they wanted to maintain visual contact with the silhouettes of those in distress against the light of early dawn, as long as possible.

Regardless of the choice of flight route, one must find a reasonable explanation why neither of two experienced pilots observed, that the helicop-

ter was too close to the mountain wall. One explanation that cannot be excluded is that the light conditions actually were such that it was not possible – or in any case exceedingly difficult – to determine the distance to the vertical mountain wall. The variation between dark and snow-covered sections of the terrain, in combination with the brightening of the morning sky, is judged to have obstructed the possibility of appraising critical portions of the terrain. The morning sky should have had the greatest influence on twilight vision and the ability to distinguish details, especially considering the large portion of the retina that was exposed to this light, in connection to their approach of the mountain ridge from below. Upon approaching the ridge, the light sky from behind the mountain grew to constitute a more dominant portion of the pilots' field of vision. In addition to this the crew had probably not attained complete dark adaptation, after having been inside the lighted research station at Tarfala. These factors are deemed to have impaired the possibilities to judge the distance to the mountain and to distinguish its form. It can also be questioned if the tips of the rotor disk could be perceived and to what extent the pilots could determine the margin of safety to the mountain.

Another possible explanation of the collision is of course that the flying aircraft commander made a misjudgment that the co-pilot did not observe or manage to react to in time, because he was momentarily occupied with some other task onboard. If, to a great extent, the co-pilot trusted highly in the aircraft commander's ability, deficiencies may have existed in crew cooperation that caused a lack of attention. In this context, the decision to reduce the crew to three members can be questioned, because by doing this one did without several watching eyes during the mission. It is conceivable that this reduction was chosen with the good intention to increase the load capacity of the helicopter.

However the question at issue still remains, why did the crew expose themselves at all, to the increased risk it involved to choose the flight path that they did, in the severe light conditions that prevailed. Everything indicates that the mission was considered to be comparatively simple. The collective flying experience and the confidence in each other may have lulled both the pilots into a false conception that the mission was relatively simple. It had been a long day and almost no possibility for sleep had existed. Furthermore, it should be noted that already at the initiation of the mission, the aircraft commander in all probability was mentally disharmonious and suffered from lack of sleep, which could have affected his mental and physical state.

From the expressed opinion of the medical expert concerning the crew it can be inferred that conditions of physical illness should not have contributed to the accident. The deficiencies found in the co-pilot's medical examinations are in themselves serious, but are judged in this circumstance not to have had any significance in the occurrence of the accident. However SHK would like to see a more effective system to follow up the medical status of flying personnel.

The investigation has pointed out several deficiencies in the crew's flight equipment. None of these are considered to have had any decisive significance in the outcome of the accident, however the situation indicates lack of abidance to explicit rules of conduct and discipline concerning equipment regulations. The case of the white flight gloves being "recalled" a number of times indicates that it has not been sufficiently well emphasized from the headquarters that the rules must be conformed to.

Crew cooperation is of extremely great significance to flight safety. A number of circumstances have been pointed out above, which raise questions as to whether crew resources concerning cooperation have functioned

optimally. SHK, who has learned that the helicopter wing has, for budget saving purposes, reduced the training for helicopter crews that addresses crew cooperation, is of the opinion that it is important that such courses are given priority.

2.2 The helicopter

It can be noted that the conditions for the technical accountability of the helicopter, after having been stable during a long period of time, had been altered several times during the past two to three years.

It can also be stated that the latest organizational change had not been fully accomplished within the technical administration of the helicopter. For example, the assumption of control of the aircraft and maitenance documentation had not been accomplished. It should however be noted that only 40 days, including the vacation period, had passed since the new organization had come into force and the occasion of the accident.

Taken together therefore, the organizational and accountability conditions of the helicopter are not judged to have degraded its technical or formal airworthiness. The helicopter was technically airworthy and it was for all intents and purposes maintained in accordance with applicable regulations during its entire operational lifetime.

The formal airworthiness of the helicopter had certain quality imperfections and the helicopter had relatively many remaining log remarks.

The routine that was utilized by the crew, to summate the flight time that one and the same crew had accomplished on one single log page, is incorrect and unsuitable and renders traceability more difficult and causes erroneous statistics.

Likewise, to delete working positions from work lists without signing this or providing a reason for the deletion is incorrect and makes tracking more difficult.

It has not been possible to exactly determine what the chopping sound impression at approximately 3–6 Hz that was described by the witnesses may have been. A possible explanation could be repeated compressor stalls in both engines brought about by disturbed airflow as the free turbine was slowed when the main rotor blades hit the mountain wall. The engine manufacturer also suggests that compressor stall may be a logical and conceivable explanation.

Fuel and oils from the latest fueling/refueling were without remarks.

The accident site had not been affected in such a way that the inquiry lost any relevant investigative data before the investigation of the accident site could be initiated.

Reconstruction flights have been accomplished and these support other observations concerning the sequence of events. The impact and break up sequences have been analyzed thoroughly in order to detect indications concerning the existence of any fault on the helicopter prior to the rotor hitting the mountain wall.

Most all types of faults on the helicopter should have allowed the pilot to steer away from the mountain by turning to the left when the problem appeared. There are a few exceptions to this, i.e. a mechanical failure in the flight control or hydraulic systems during the last seconds of the flight.

As there are two duplicate hydraulic systems and it is extremely unlikely that both systems acquire a mechanical failure simultaneously, the investigation has focused upon such factors that could conceivably constitute the lowest common denominator for both systems, for example incorrect or contaminated hydraulic fluid and filters. The investigation has shown that no such types of failures have been found.

The reported shower of sparks most probably arose when the balance weights on the tips of the main rotor blades and the erosion protection on the leading edges of the main rotor blades (stainless steel) and tail rotor blades (titanium) scraped against the mountain wall.

The damage on the blades indicates that the tail rotor had a relatively high rpm at the time it came in contact with the mountain. This conclusion is supported on the one hand by statements from the manufacturer and on the other by comparisons with other Super Puma accidents.

That the driving force to the epicyclic gear and therewith the main rotor had ceased is a reasonable and logical result of the main rotor being struck by blows from above during the course of events of the accident, specially taking into consideration that the helicopter, after having lost the tail rotor and boom, acquired a substantial center of gravity displacement forward. Similar sequences have been able to be observed even during other crashes abroad, which SHK has studied during the investigative work for the purpose of comparison.

The reason that the ELT did not emit emergency signals was probably due to some object coming in contact with the disabling switch during the sequence of events of the accident. It has been established that the ELT functioned according to specifications and that it was probably not safetied. Its attachment had sufficient strength, despite certain deficiencies in the riveting.

It cannot be ruled out that the activation thresholds of the ELT in the HKP 10 are unnecessarily high, which increases the risk that activation is not forthcoming during a crash. If, instead of changing to a new ELT with higher activation thresholds, the attachment had been stiffened, one would have attained a system with fewer accidental activations and better flight safety. The location of the ELT in the HKP 10 is not suitable from a viewpoint of crash protection, as well as not from the circumstances wherein an activated ELT can be turned off by being subjected to a force impulse from the right, or from some external object coming in contact with the disabling switch.

It may be questioned if it is suitable to install the central lock for the safety harness in pilots' seats differently at the various HKP-10 companies within the Swedish Armed Forces. Since individual helicopters are loaned between the military units, this divergence in the installation probably entails an increase in the risk for mistakes in an emergency situation, especially if an emergency evacuation is necessary underwater.

A large number of the questions that the investigation has attempted to answer could have been answered a lot easier and in certain cases with greater reliability, if the helicopter had been fitted with CVR/FDR recording equipment. With a CVR, one would have possibly been able to elucidate what the intentions of the crew were and what was seen and not seen. With a FDR the helicopter's technical parameters and the flight path would have been able to be made clear.

The unambiguous witness statements indicate in no manner that any technical failure existed on the helicopter, either during Thursday's earlier flights or during the final flight. It has been possible to provide reasonable explanations for the sound and light phenomena that were experienced.

Investigative results

The investigation has shown the following:

- The helicopter was technically airworthy but its formal airworthiness (documentation) contained certain quality imperfections, however these did not have an influence upon the accident.

- No indications have been detected that there was any technical malfunction on the helicopter before the main rotor collided with the mountain wall.
- It has been established who was seated in the aircraft commander position (flying pilot).
- The helicopter probably had a speed of less than 10 knots and a climb angle that was shallower than 10°, at the instant the main rotor hit the mountain wall.
- The flight engineer was neither secured in his seat or in the winch operator's harness. The right-hand side door was closed and locked.
- It is likely that the autopilot was not used in the engaged mode.
- The co-pilot's and the flight engineer's searchlights were probably lit and aimed obliquely to the right. The SX-16 searchlight was either lit or in the process of being lit.
- It has not been possible to establish if the radar was activated.
- The helicopter probably first caught fire after the main rotor collided with the mountain wall and the helicopter began to break-up.
- The sequence of events of the crash was such that the applied forces exceeded the specified requirements of the helicopter's crash safety system.
- The personal flight equipment of the crew exhibited a number of deviations from stipulated requirements. In addition, several deficiencies have been discovered within the uniform regulations and shortfalls in the choice of material for flight suits as well, which are judged to have a negative affect on fire protection in the aircraft of the Swedish Armed Forces.
- The automatic emergency transmitter was undesirably turned-off during the sequence of events of the accident. This was likely caused by some object coming in contact with the disabling switch.
- The fact that the tail boom and the tail rotor gearbox separated only a few seconds after the main rotor hit the mountain implies that the pilot, in all probability, did not have any possibility to save the situation.

2.3 Organization and command

The investigation has pointed out several conditions within the SAR organization that negatively influenced both personnel and materials. Several implemented reorganizations and budget reduction demands in rapid succession may have, according to SHK, influenced both effectivity, the working environment and therefore indirectly, flight safety. It is however, not possible to demonstrate any direct relationship between these conditions and the accident.

Nevertheless, SHK considers it serious, that these conditions were known at headquarters level within the Swedish Armed Forces, without anything constructive being done in order to rectify them. A plausible reason for this is that the reorganization decisions were made at the highest level, which made the possibility of influence by the safety inspectorate more difficult. Yet, people were very much aware of the long-standing cultural differences that prevailed between the diverse branches of defense and their various viewpoints about the principal tasks of helicopter operations.

The SAR companies' viewpoint is based on the assumption that cost savings and curtailments in their operations – that normally consist of

rescue missions that are similar to wartime conditions – cannot tolerate the reductions that other military units undergo with the lofty thought that confronted with an altered level of threat, they will be able to recover knowledge and proficiency if required.

3 MEASURES TAKEN

Subsequent to the accident Eurocopter has sent a memorandum to the Defence Materiel Administration that it is recommended to inspect and correct possible faults with the riveting on the ELT container during the next 500-hour inspection.

Owing to the deficiencies in flight equipment that were pointed out, the Swedish Armed Forces have been informed that there are still pictures of a pilot in the proposed issue of the 2002 uniform regulation, that is wearing the forbidden white flight gloves, M/55. A decision about changing these pictures has been promised. SHK has furthermore called it to the attention of those responsible for equipment that the flight suits M/96 HKP and M/98 TP lack acceptable fire protection and therefore should not be used during flight. On the 22nd of February 2002, The Swedish Armed Forces ruled that when a flight suit is required (OSF 10.2.5.1), the flight suits 96 HKP and 98 TP may not be used.

The basic technical data for the painting of the rotor blade tips on the HKP 10 have been forwarded from Eurocopter to the responsible unit at FMV for further measures.

4 CONCLUSIONS

The accident was caused by the helicopter's main rotor colliding with a vertical mountain formation, after which the helicopter was broken up against the mountain and caught fire. Therewith perished all those on board.

The immediate cause of the collision with the mountain has not been able to be determined with certainty. It has not been possible to indicate any technical failure on the helicopter. No states of ill health should have contributed towards the accident.

The investigation has shown that very difficult light conditions prevailed at the site. Direct light from the early dawn sky and the terrain's at times light streaks of snow and at times dark rock formations could have affected the crew's scotopic vision ability and impeded the judgement of distance. In light of this, the choice of flight path has indirectly been a cause of the occurrence.

Crew fatigue and shortcomings in crew cooperation due to an over-ambitious confidence in each other's professional skills may have been contributory causes of the accident.

The investigation has furthermore pointed out resource, reorganization and command problems within the Armed Forces' helicopter organization that have not had an immediate relation to the accident, but as typically viewed, imply risks to flight safety.

5 RECOMMENDATIONS

5.1 The Swedish Armed Forces should insure that training in crew co-operation as well as training for aircraft commanders is carried-out on a regular basis *(RM 2002:01 R1e)*.

5.2 The Swedish Armed Forces should enhance supervision of the flying personnel's completion of required medical examinations *(RM 2002:01 R2e)*.

5.3 The Swedish Armed Forces should more clearly define the allowable equipment alternatives and enhance supervision that the correct flight equipment is worn during flight *(RM2002:01 R3e)*.

5.4 The Swedish Armed Forces should take adequate measures to insure flight safety within the SAR operations. Therein is included prioritizing of an active flight safety program, mountain flight training and flight medical education for various groups of flying personnel *(RM 2002:01 R4e)*.

5.5 The Swedish Armed Forces should revise the ELT installation in the HKP 10 *(RM2002:01 R5e)*.

5.6 The Swedish Armed Forces should consider providing the HKP 10 with equipment for the recording of communication (CVR) and flight data (FDR) and also consider the question for other helicopters within the Armed Forces *(RM2002:01 R6e)*.

5.7 The Swedish Armed Forces should, in order to minimize the risks for mistakes, direct uniform mounting of central locks on the pilot seats in the HKP 10 *(RM2002:01 R7e)*.

5.8 The Swedish Armed Forces should take measures to facilitate positive identification of where a crew seat is mounted in the HKP 10 *(RM2002:01 R8e)*.

5.9 The Swedish Armed Forces should carry out painting of main rotor blade tips according to the proposal that SHK has received from Eurocopter. It should also be considered to paint the blade tips of the other helicopter systems within the Armed Forces *(RM2002:01 R9e)*.

5.10 The Swedish Armed Forces should insure that the stipulated regulations for flight time and maintenance documentation are observed and that required resources are made available to audit, correct, maintain and follow-up the technical documentation of the flying systems so that it attains the accepted standard of quality *(RM2002:01 R10e)*.

5.11 The Swedish Armed Forces should consider the introduction of sensors for the detection of objects in close proximity to the helicopter *(RM2002:01 R11e)*.