Statens haverikommission
Swedish Accident Investigation Board

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Report RM 2007:02e

Aircraft accident to helicopter type HKP10 number 409 in the sea east of Rörö, O county, on 18 November 2003

Case M-11/03

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.

This report is also available on our web site: www.havkom.se

Translated by Interpreter Centre, City of Göteborg, from the original Swedish at the request of the Swedish Accident Investigation Board.

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

Statens haverikommission (SHK) Swedish Accident Investigation Board

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Statens haverikommission
Swedish Accident Investigation Board

2007-01-25 M-11/03

The Swedish Armed Forces

107 85 STOCKHOLM

Report RM 2007:02e

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an aircraft accident that occurred on 18 November 2003 in the sea east of Rörö, O county, involving a HKP10 (Super Puma) helicopter with military registration “Hotel” ninety-nine (H99).

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.

The Board will be grateful to receive, by 1 August 2007 at the latest, particulars of how the recommendations included in this report are being followed up.

Carin Hellner Carl R. Hellström

Duplicate copy to
The Swedish Civil Aviation Authority

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Contents

APPENDIX

Abbreviations and explanations of Terms

AP — **Autopilot** – the HKP10 AP enables the maintenance of attitude and course and/or damping in the pitch, roll and yaw axes

ARCC — **Aeronautical Rescue Co-ordination Centre**

BOF — **Decision on flying** – the Flight Operations Commander or Flying Squadron Commander decides whether a flight is to be performed. They therefore take on the flight safety responsibility for flights. BOF covers the clarification of the command and responsibility relationship within operational flying and the necessary directives governing the implementation of the flight. BOF may be given verbally or in writing, and may be in respect of individual flights, one or more flying sessions or periods with several flying sessions.

Callouts — Mandatory verbal reports within a crew when certain important factors concerning flight safety, such as speed, height, descent rate, etc. are observed.

Calm Sea — Doppler sensitivity range to be selected by the crew at low wind speeds (less than or equal to 10 knots).

Checklist – Instructions for aircrew, defined in the Flight Manual (SFI), stating the obligatory checks and actions before, during and after flying

Coupler — The control unit between the navigational equipment and the AP that permits the following functions to be selected:

- airspeed - **A/S**
- altitude - **ALT**
- cruising height - **CR.HT**
- fly up - **FP**
- glide slope - **G/S**
- ground speed - **G.SPD**
- heading - **HDG**
- hover - **HOV**
- hover height - **H.HT**
- localiser - **LOC**
- navigation - **NAV**
- transition down - **T.DWN**
- transition up - **T.UP**
- vertical speed - **V/S**

DA — **Operational reporting (Driftstörningsanmälan)**

DIDAS — **Operational data system (Driftdatasystem)** – a computerized planning and fault analysis system for aircraft and related equipment

DOPMEM — **Doppler memory** – means that the Doppler goes into its memory mode

EFIS — **Electronic flight instrument system** – flight situation instrument which presents its information on a TV-type display

ELT — **Emergency locator transmitter** – emergency transmitter in an aircraft/helicopter that will start operating in the case of an accident, when certain conditions are met

FBS — **Air Force Flying Commanders School (Flygvapnets flygbefälsskola)**

FLYGI — **The Inspectorate of Military Flight Safety**

FlygSäk — Abbreviation for Flight safety department within the Swedish Armed Forces operational safety department at Headquarters

FM — **The Swedish Armed Forces (Försvarsmakten)**

FMV — **Swedish Defence Material Administration (Försvarets Materielverk)**

FRÄD — **Airborne search and rescue standby (Flygräddningsberedskap)** – means that a helicopter with its crew shall be able to take off and start a search at a possible accident site within 90 minutes after a crash alarm. For the crew this means that they must take off within 15 minutes and begin searching within an area of 250 km radius from the helicopter's base

FSI — **The Inspector of Military Flight Safety (Flygsäkerhetsinspektör)**

ft **Foot** – abbreviation of the British word foot, a measure of length, where 1 ft is equivalent to approximately 0.3 m

GND **Ground** – the height of an aircraft defined in relation to the underlying terrain or water, stated in metres or feet above ground level

GPS **Global positioning system** – a satellite navigation system

HKP10 **Helicopter type 10 (Helikopter 10)** – Eurocopter AS332 "Super Puma"

HKV The Swedish Armed Forces Headquarters

Hov **Hovering** – flying a helicopter at speeds between 0 - 40 knots. Hovering may be performed automatically using automatic control or under manual control

hPa **Hectopascal** – unit of pressure, e.g. barometric air pressure

IFR **Instrument flight rules**

INS **Inertial Navigation System**

MilAIP **MilAIP – Military Aeronautical Information Publication**

MRCC **Maritime Rescue Co-ordination Centre**

MSL **Mean Sea Level**

OFFG **Air Mission Briefing (Order för flygningens genomförande)** – flights are preceded by orders issued by the pilot assigned by the aircraft commander, who has the responsibility for flight safety. In BOF the stated authority and limitations are the basis for OFFG

OSC **On-Scene Co-ordinator** – person assigned by the rescue leader at ARCC/MRCC to co-ordinate rescue efforts within a particular area

OSF **Rules and safety requirements for Military Aviation (Ordnings- och säkerhetsinstruktioner för militär flygverksamhet)**
Part of RML (RML-D-1)

PFT **Periodic flight training (Periodisk flygträning)**

QFE Barometric air pressure at airfield elevation or runway threshold

QNH Sea level barometric air pressure (at MSL)

RHM **Radio Altimeter (Radarhöjdmätare)**

RML **Rules of military aviation**
RML are the Swedish Armed Forces rules for military aviation

SFI **Flight Manual (Speciell förarinstruktion)** for a particular aircraft type – in this case the HKP10

SHK **The Swedish Accident Investigation Board (Statens haverikommission)**

SSR **Secondary Surveillance Radar** equipment that reports the identity and altitude of an aircraft

SSRS **The Swedish Sea Rescue Society (Svenska Sällskapet för Räddning av Skeppsbrutne)** – usually called Sjöräddningssällskapet in the Swedish language

Standard atmosphere
A standard reference value for air pressure and temperature. The barometric air pressure at sea level for the standard atmosphere is 1013.2 hPa and air temperature +15°C. The temperature decreases at the rate of 0.65°/100 m up to an altitude of 11 000 m

STD **Standard** – the height of an aircraft can be defined in relation to the standard atmosphere and is stated in metres or feet

TAF **Terminal aerodrome forecast**

TAF AMD **TAF Amended**

T.DWN **Transition down** – preprogrammed procedure in the Coupler that means a reduction in height and speed until hovering is achieved at a preset height

TRAB **Technical report/Work order (Teknisk rapport/Arbetsbeställning)** – document with information concerning technical faults or discrepancies in an aircraft

UHU HKP10 Training instructions for HKP10 crews. Nowadays called Training regulations (Utbildningsreglemente - UtbR Hkp10)

VFR **Visual Flight Rules**

WGS84 **World Geodetic System –** mapping reference system (mapping datum). The format dmm is used in this report

Report RM 2007:02e

M-11/03
Report finalised 25 January 2007

Aircraft; registration and type	HKP10 (Eurocopter AS 332M1) No. 409 (manufacturer's serial number 2302)
Owner/Operator	The Swedish Armed Forces/ 2nd Helicopter battalion, Säve
Time of occurrence	18 November 2003, 18:42 hours, in darkness *Note:* Unless otherwise stated all times are given in Swedish standard time (UTC + 1 hr)
Place	At sea east of Rörö island, O county, 57°47.14′ N 11°41.05′ E (WGS84), 0 m above sea level
Type of flight	Military training flight
Weather forecast according to the Swedish Armed Forces weather centre (VädC)	Wind SSW approx. 5 m/s, visibility 2–5 km, in rain, cloud base at 30–120 m, temperature +9°C, QNH 1003 hPa
Persons on board;	
crew members	7
passengers	0
Injuries to persons	6 fatalities, 1 slightly injured
Damage to aircraft	Destroyed
Environmental impact	Approx. 1200 kg aviation kerosene and 40 litres of oil escaped
First pilot:	
Gender, age	Male, 49 years.
Total military flying hours [1)]	5180 hours, of which 267 hours on type
Military flying hours previous 90 days [1)]	51.3 hours, of which 51.3 hours on type
Second pilot/Aircraft commander:	
Gender, age	Male, 50 years.
Total military flying hours [1)]	3308 hours, of which 1826 hours on type
Military flying hours previous 90 days [1)]	29.3 hours, of which 29.3 hours on type
Operator:	
Gender, age	Male, 42 years.
Total military flying hours [1)]	2447 hours, of which 270.9 hours on type
Military flying hours previous 90 days [1)]	58.7 hours, of which 47.7 hours on type
Flight engineer:	
Gender, age	Male, 52 years.
Total military flying hours [1)]	1737 hours, of which 996 hours on type
Military flying hours previous 90 days [1)]	37.3 hours, of which 37.3 hours on type
Conscript rescue swimmer:	
Gender, age	Male, 19 years.
Total military flying time	Flying time is not logged for conscripts
Student flight engineer:	
Gender, age	Male, 47 years.
Total military flying hours [1)]	2217 hours, of which 6.1 hours on type
Military flying hours previous 90 days [1)]	6.9 hours, of which 5.5 hours on type

Conscript student rescue swimmer:	
Gender, age	Male, 19 years.
Total military flying time	Flying time is not logged for conscripts

1) According to the crew card dated 18 December 2003

The Swedish Accident Investigation Board (SHK) was notified on 18 November 2003 that a helicopter type HKP10 with call sign "Hotel" ninety-nine (H99) had an accident at 18:42 hours on that day at sea east of Rörö, O county.

The accident was investigated by SHK representatives Carin Hellner, Chairperson, Carl R. Hellström, Chief investigator flight operations, Tomas Krave, Chief technical investigator aviation, Gerd Svensson, Chief investigator, human factors (MTO) and Urban Kjellberg, Chief investigator rescue services.

The Board was assisted by Ola Mårtenson as a technical expert, Magnus Persson as an assistant technical expert, Per Kallerhult as an operational expert, Ronnie Larsen as an assistant operational expert, Jan Linder as a flight medicine expert, Claes Danielsson as a safety materials expert and Anders Ottoson as a meteorological expert.

The investigation was followed by the Swedish Armed Forces, most recently by Lars Hall.

Summary

During a sea rescue practice in the Göteborg archipelago, in darkness, with a search and rescue helicopter (HKP10) of the Swedish Armed Forces (FM), the helicopter impacted the sea and six of the seven crew on board perished.

The intention was that the helicopter crew would practice winching with a stretcher in company with the rescue vessel *Märta Collin* of the Swedish Sea Rescue Society. While it was flying towards the *Märta Collin* the boat's crew saw the helicopter (*Hotel 99)* descend into the sea to the east of Rörö. The boat's crew steered immediately towards the accident site and were able to rescue the surviving conscript rescue swimmer before the helicopter wreckage sank below the surface.

The *Märta Collin's* crew initiated an alarm to the Maritime Rescue Coordination Centre – MRCC, and reported the accident. During the evening and night a comprehensive search took place for the rest of the helicopter crew. Within one hour of the accident, four of the deceased crew had been found and picked up. During the search about ten civil and military vessels participated.

On the day after the accident the helicopter wreckage was found at two locations on the sea floor, about 500 m apart. The bodies of the two missing crew were found at the location of the front part of the helicopter, and retrieved.

Despite thorough investigation, no technical faults, external influences, medical reasons or other explanation to account for the accident were found or proved.

The flight that was in progress did not include any extreme measures. The crew were competent and experienced. Witness information was scarce and provided no decisive information to help determine the cause of the accident. The technical records of the flight are limited. The helicopter did not carry an FDR or CVR. Communication with air traffic control only took place on one occasion during the flight out, and contained no information that could explain the accident. Radar recordings of the helicopter's flight path showed a normal outbound flight. Just before the accident the helicop-

ter was below the radar's line of sight, so it has not been possible to establish its flight path immediately before it impacted the water. Taken as a whole, this means that it has not been possible to plot the course of events during the final "critical part" of the flight sequence.

It has not been possible to establish the cause of the accident.

A complete assessment indicates that the crew did not have full situational awareness while taking off after hovering at a low height. The investigation revealed that several safety barriers to prevent an accident were missing. Such barriers that are important are a ground collision warning system, a combined risk assessment of this type of helicopter's Human-System interface, prescribed flight operation procedures and callouts, and risk assessment of organisational changes with decisions on measures to be taken and the evaluation of their effects. In addition the FLYGI inspection was inadequate.

Recommendations

It is recommended that the Swedish Armed Forces:

- Takes action to secure the function of EFIS and minimise the risk of the display being blanked out during flight (*RM 2007:02 R1*).

- Equips helicopters with ground proximity warning systems (*RM 2007:02 R2*).

- Introduces an audio warning to draw attention to the disconnection of all modes of the AP/Coupler (*RM 2007:02 R3*).

- Modifies searchlights so that the time from switching on to maximum illumination power is minimised (*RM 2007:02 R4*).

- Modifies the radio altimeter ON/OFF function so that it cannot be switched off by mistake thus affecting the decision height (DH) function (*RM 2007:02 R5*).

- Determines and describes in the Flight Manual for HKP10 helicopters the emergency measures to be taken in the case of engine surge, and updates the basic values for mass and balance calculations (*RM 2007:02 R6*).

- Ensures that the forthcoming modification package for the HKP10 takes into account the crews' experience and human factors requirements (*RM 2007:02 R7*).

- On procurement, sets requirements that helicopter interfaces meet human factors requirements, and performs documented verification and validation of the Human-System interface (*RM 2007:02 R8*).

- Ensures that current education and training are expanded, implemented and documented in respect of situation awareness (SA) and spatial disorientation (SD). (*RM 2007:02 R9*).

- Sets detailed goals for SAR/FRÄD operations by helicopter units (*RM 2007:02 R10*).

- Introduces prescribed flight operations procedures with callouts and checklists (*RM 2007:02 R11*).

- Reviews the allocation of flying hours and training content, in order to achieve established goals for crew members included in SAR/FRÄD operations (*RM 2007:02 R12*).

- Introduces documented procedures for a systematic review of the conditions prior to organisational changes, with decisions on risk-minimising measures and the evaluation of the effects of these measures (*RM 2007:02 R13*).

- Ensures that the organisation and resources enable the Air station commander and Flight operations commander to check flight operations and support Flying Squadron Commanders and flight crews on a regular basis and to a high standard (*RM 2007:02 R14*).

- Introduces an outher garment for flying personnel that will facilitate detection in water and on land in conditions of darkness (*RM 2007:02 R15*).

- Takes measures so that personal emergency equipment, in accordance with OSF, can be carried by rescue swimmers dressed in immersion suits (*RM 2007:02 16*).

- Establishes an expiry age for personal flight safety material (*RM 2007:02 R17*).

- Ensures that securing of medical equipment inside the cabin meets the prescribed requirements (*RM 2007:02 R18*).

The SHK report RM 2007:01 concerning an incident to a transport aircraft on 11 December 2003 contains among other things the following recommendations, which this investigation also finds applicable:

- To arrange so that supervision of military aviation is provided with such an organisational setting and with such resources that independent and efficient inspections can be put into effect *(RM 2007:01 R1)*.

- That RML will as soon as possible be developed in accordance with the ambitions in U-RML *(RM 2007:01 R3)*.

- The developed RML will as soon as possible be implemented in all areas of military aviation *(RM 2007:01 R4)*.

Earlier submitted recommendations to the Swedish Armed Forces:

- The introduction of regulations concerning how training schedules for flying personnel shall be documented (*RM 2005:03 R5*).

It is recommended that the Swedish Civil Aviation Authority

- Introduces procedures so that rescue helicopters capable of hoisting are provided at an accident site where the need for such a resource cannot be excluded (*RM 2007:02 R19*).

- Introduces procedures for following up the work carried out by participating units during a rescue operation, as a basis for future planning and the management of rescue efforts that are in progress (*RM 2007:02 R20*).

- Develops procedures for bringing emergency airborne rescue operations to a close (*RM 2007:02 R21*).

1 FACTUAL INFORMATION

1.1 History of the flight

It was planned to carry out an exercise to practice rescue at sea using air-sea rescue helicopter H99 (HKP10 type), as part of the training of two conscript rescue swimmers, including winching with a stretcher in conjunction with the rescue vessel *Märta Collin*. The winching procedure would be carried out with the boat under way, and in darkness. The two planned flights were the first practice runs of this kind for the rescue swimmers after they had completed their basic training. The flights would be implemented by five ordinary crew members, along with a student flight engineer and one conscript rescue swimmer on board.

The normal crew of a HKP10 consists of five personnel: first pilot, second pilot (one of the pilots is the aircraft commander), an operator, a flight engineer and a rescue swimmer (who at the time of the accident was a conscript).

During the practice flight, FRÄD (SAR readiness state) would also be maintained.

The flight which preceded the accident flight began at 17:25 from Säve, and an approach was flown to *Märta Collin*, located in the coastal waters east of Rörö. During the preparations for winching and getting the stretcher out, the flight engineer experienced a disturbance to the helicopter which "*wobbled*", so he asked the pilots the reason for this. The aircraft commander replied "*I accidentally pressed a button*".

From the recorded radar returns it has been established that the helicopter's SSR response at 17:33 showed a descent from about 200 m STD[1] to about 90 m STD followed by a climb back to about 200 m STD. According to the radar recording, the crew carried out an approach to the *Märta Collin* that was aborted and the helicopter accelerated away. After this the crew carried out a new approach procedure to *Märta Collin* and performed the agreed winching practice. After completing the winching practice the helicopter crew informed the *Märta Collin* that they wanted to return for another winching practice after a crew change.

The crew of the *Märta Collin* agreed to a further similar practice and went back to their original position, to await the arrival of the helicopter in the coastal waters north-east of Rörö.

The helicopter landed at Säve at 18:11 to change the crew and refuel. The aircraft commander wanted to refuel and change crew with the engines running, but since there was no rescue vehicle at the refuelling point the engines were shut down after this was pointed out by the flight engineer.

After engine shut-down the flight engineer, with the aid of the rescue swimmer, refuelled and performed a pre-flight inspection of the helicopter, and then handed over the helicopter as ready at 18:20 to the relieving flight engineer.

The two pilots changed seats in the helicopter, so that the aircraft commander sat in the left pilot's seat to act as the second pilot, and the other pilot, acting as the first pilot, sat in the right hand pilot's seat. The post of aircraft commander did not however change.

The flight engineer was changed, while the student flight engineer participated in both flights to study the work on board. The operator also participated in both flights.

The student rescue swimmer who took part in the first practice was replaced by another conscript student rescue swimmer. The rescue swimmer

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[1]) With the current barometric pressure, QNH, of 1003 hPa, the SSR-reported height is reduced by about 80 m to define the height related to mean sea level (MSL)

who was the normal member of the crew participated in both flights and served as the instructor for the younger student rescue swimmers.

The helicopter took off again from Säve at 18:32 with its five ordinary crew members, along with the student flight engineer and the conscript rescue swimmer, a total of seven men on board. The first pilot and the second pilot/aircraft commander sat in their usual places in the cockpit and the operator, flight engineer and student rescue swimmer sat in the cabin. The student flight engineer and the rescue swimmer sat in troop-carrying seats on the right side at the rear of the cabin.

Immediately after take-off from Säve the operator called ARCC on VHF channel 67 at 18:33:52 and reported *"Hotel 99 take-off Säve... east of Rörö, about 45 minutes"*.

The air traffic controller in Säve control tower called the helicopter at 18:37:20 and asked: *"Hotel 99... your present position?"*. The second pilot replied *"yes... location Kalven 200 feet"* after which the air traffic controller asked, *"do you have your transponder on?"* and the second pilot replied, *"coming... 5033"*.

After this, no further radio communication took place with the helicopter. If the helicopter sent any message later, this must have been on a frequency on which communication was not recorded.

The last radar return from the helicopter was at 18:40:51 and the SSR response gave the altitude as about 120 m STD, i.e. about 40 m above MSL.

The crew of the *Märta Collin*, which was located east of Rörö waiting for the helicopter to return, stated that they observed a faint glow in the sky ahead of the boat. The glow moved to their port (left). At that time the boat was holding a course of 200°, so the glow moved from west to east. The radar recording showed that the helicopter moved from a westerly position to an easterly position. The crew of the *Märta Collin* saw, a little later, through one of the wheelhouse windows, after the diffuse glow had disappeared, a white light descending at a steep angle from left to right, down towards the surface of the sea. As the light went out they heard a faint bang. At the same time an echo appeared on the boat radar, about 400 m ahead of the boat. The crew steered towards the radar echo, with their searchlight on, and about 100 m away saw a rescue swimmer in the water, close to a large piece of wreckage.

While approaching the rescue swimmer the crew called MRCC "Sweden Rescue" on VHF channel 16, at 18:44:18 and were asked by MRCC to switch to VHF channel 67.

At 18:45:08 *Märta Collin* called MRCC again on channel 67 and reported, *"Yes... we are here at position Lilla Barlind and helicopter Hotel 99 has crashed into the water here"*. Soon thereafter the *Märta Collin* picked up the surviving rescue swimmer, who was later transferred to Police boat 7050 for transport to an ambulance on the mainland.

During the evening and night an extensive search was carried out for the rest of the helicopter's crew, involving units from the SSRS, Coastguard, Police, civilian fishing boats and the Swedish Armed Forces. Within one hour of the accident, apart from the surviving rescue swimmer, the bodies of the first and second pilots, the student flight engineer and the student rescue swimmer had been found and recovered. The day after the accident the bodies of the operator and flight engineer had been found among the helicopter wreckage on the sea bed and recovered.

The accident occurred at about 18:42 in darkness at location 57°47.14′ N 11°41.05′ E (WGS84) 0 m above sea level.

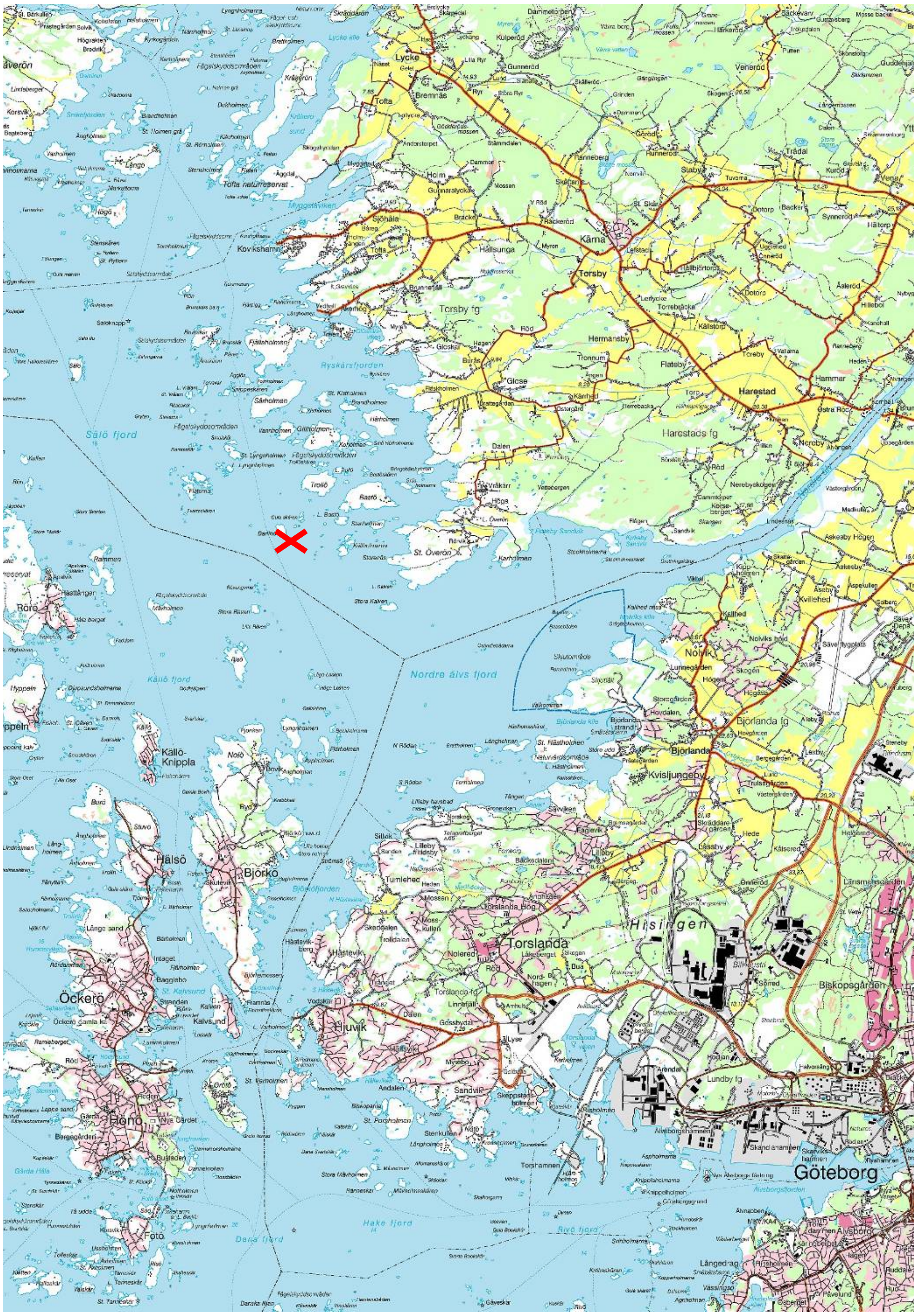

Fig. 1: *The accident location, marked by a red cross, was about 18 km northwest of Göteborg.*

1.1.1 Witnesses

There were four witnesses who made statements concerning what they saw or heard in connection with the accident: the rescue swimmer who was one of the helicopter crew, both crew members of the *Märta Collin,* and a witness who was on the northern part of Fjällsholmen, an island about 4 km north of Lilla Barlind. He did not see the helicopter but heard the sound of a helicopter. This witness is therefore called herein the "earwitness".

Rescue swimmer

The rescue swimmer was interviewed on three occasions. The first interview took place the day after the accident, in hospital, and the second one week later. The third interview was conducted about four months after the accident.

<u>*Interview in hospital the day after the accident*</u>
In the interview the day after the accident, the rescue swimmer related the following in connection with the second flight of the evening.

He was wearing an immersion suit and a flying helmet, and was not strapped into any seat. The weather had worsened. There was fog and a low cloud base. It was difficult to see the sea surface. He heard one of the pilots say that they had an engine surge. He felt shaking and banging, it was like an air pocket, and the flight engineer asked what was happening. The other pilot replied that it was a usual engine surge and they would have to change course. He also heard someone say that they were going left a little. Just before he heard the conversation about the surge he thought that they flew parallel to *Märta Collin*. He was almost sure that the helicopter was moving forward and that the *Märta Collin* was on the right of the helicopter. He assumed that they were quite close to winching. However the door was not open. He then could not remember any more until he was in the water. He thought that he had involuntarily escaped from the helicopter with the bang "down there". He also thought that what happened had something to do with the surging. He heard no screams.

He remembered that the autopilot "disconnected" but was not sure of which flight it was that this occurred, or if it happened on both flights.

On being asked if the spotlights were on he stated that he knew that they were illuminating when they took off, but after that he didn't know.

He had heard that a fuel pump was not working. Nor was the automatic level system working, so that they had to manually open and control the fuel valve by hand during refuelling.

<u>*The two further interviews*</u>
In the subsequent interviews he supplemented his information as follows.

At the time he noticed that the autopilot had disconnected, he sat and looked at the altimeter on the operator's panel, so he remembered that at its lowest the helicopter came down to 30 feet. He heard on the intercommunications equipment how the pilots counted the height down, 100, 80, 70, 60, 50, 40, 30 and that the helicopter began to climb again from 30 feet to 200, 250-300 feet. He thought he remembered that the flight engineer on the second flight asked what had happened and received the answer that the autopilot had disconnected. He was however still unsure whether this was on the first or second flight. He described the experience as it went quickly down and up again as like being on a roller-coaster.

Concerning the second flight that evening he stated the following. He sat furthest back in the helicopter. He could not remember whether the folding troop-carrying seat at the door was folded up, or whether it was already folded up at the beginning of the second flight. He thought that on the seat at the very rear was the bag that was usually placed there, so he sat on the seat that was second to the rear of the helicopter. He saw the *Märta Collin* obliquely to the right, in front of the helicopter when it was about 100 m behind the rescue vessel. They flew parallel to the rescue vessel for perhaps 10 seconds at the same height, when he heard them say that there was an engine surge and that they would have to change course. Then it went black.

He also had a picture in his memory that he found difficult to place, where he lay on a part, a piece of the helicopter wreckage, on the floor inside the helicopter. After that the rescue swimmer remembered nothing more until he was in the water among the wreckage. He remembered that he saw a boat's searchlight and a boat hook that was stretched out towards him, and someone asking him if he could hold on to it. He could not remember how he was lifted out of the water. While on board the *Märta Collin* after his rescue, the rescue swimmer stated that there had been a seven man crew on board the helicopter.

The flight engineer during the first flight of the evening
The flight engineer who was part of the crew during the first flight stated that he did not notice or hear the pilots talk about any engine surge during the first flight that evening.

The rescue swimmer during the first flight of the evening
The rescue swimmer who was part of the crew during the first flight did not remember noticing or hearing the pilots talk about any engine surge during the first flight that evening.

The crew of the Märta Collin
Both crew members of the *Märta Collin*, skipper and boatswain[2], were interviewed several times. One of these interviews took place on board the *Märta Collin* at the site of the accident. The crew gave the following witness statements concerning the event:

When the first winching had been completed the helicopter crew requested to return and carry out another winching after changing their crew. The crew of the *Märta Collin* replied that they would stay in the area and await the helicopter's return for a further winching. They went back to their starting point. They set a westerly course on the navigation equipment so that they had an aiming point, since the helicopter crew had said that they wanted to use a course a little more to the west.

The crew of the *Märta Collin* thought that it took a rather longer time than usual, so they made a tight circuit of Lilla Barlind. Then they positioned the vessel at about the centre of the navigation channel west of Barlind. They sat in the wheelhouse with the door closed and waited. The crew of H99 had not made contact with the *Märta Collin*. The skipper called the helicopter to report that the boat was in position, since he had started to wonder whether the pilots had meant that they should go even further to the west. However he received no answer from the helicopter when he called.

The crew could see that it was pitch black outside, and raining. They could just see the red light on the telecommunications mast at Rörö. As they lay and waited, a heavy mist came down. There was a southerly wind and the sea was "almost flat calm". They stated that the current was flowing at one and a half knots at about 300°.

The boat was stationary and the skipper tried to hold it in position. The boatswain said that he saw the helicopter's lights up in the cloud. The sky was lit up by these lights. The lights came towards them from a cloud, shone downwards and went from right to left in front of the boat. He expected that the helicopter pilots would soon contact them and ask them to set course. He no longer saw the helicopter and started almost to wonder where it was, then he saw a light, a light with a white beam, which moved rapidly downwards from left to right at a steep angle. He turned to the skipper and said that the helicopter had crashed. They heard a faint bang. An echo appeared on the radar screen about 400 m ahead of the boat. According to his estimate the echo coincided with the place where he had seen the light go into the water. On the VHF radio nothing could be heard on channels 6 or 16. When they heard the bang, the *Märta Collin's* crew called the helicopter crew on the radio, but received no reply. The boat steered towards the radar echo location, with its searchlight on. While approaching the location where the helicopter went down, they sent an alarm to the Maritime Rescue Coordination Centre. In the searchlight beam they saw a lot of wreckage, aviation fuel and the signal green suit of the rescue swimmer who stood or sat in amongst what they took to be rotor blade stumps. The boatswain took a boat hook and told the rescue swimmer to hold on to it. Once the rescue

[2] Boatswain – the second man aboard SSRS *Märta Collin*

swimmer had a grip on the boat hook, the part of the helicopter that they had seen sank. The boatswain pulled the rescue swimmer towards the stern of the boat and with the aid of the skipper got him on to the boat. Eventually the rescue swimmer was able to tell them that there had been seven men on board the helicopter.

The earwitness

Some time after the accident a witness was contacted who, according to the mass media, had heard the helicopter flying south of Fjällsholmen on that evening.

At the time of the accident this witness had been outdoors for about 10-15 minutes on the northern part of Fjällsholmen and had at that time heard a helicopter flying in the area south of Fjällsholmen. He had heard a faint bang, followed by a change in sound and the sound of an impact. It then went completely quiet, so he understood that something had happened to the helicopter. From his position he could not see anything since the visibility in the area that evening was very poor, one of the darkest evenings he had known.

Before the bang and the crashing sound he thought the helicopter noise was normal. He thought that the helicopter was either hovering or moving slowly, since the sound seemed to be coming from the same direction all the time and did not seem to alter in strength. In his profession as a sailor on board ferries, he had himself practised with helicopters before. The sounds he perceived as abnormal were the bang and the crashing sound he heard immediately before the sound from the helicopter stopped completely.

The witness left Fjällsholmen soon afterwards and heard news of the accident on the car radio as he was travelling home.

1.2 Injuries to persons

First Pilot

The forensic medical examination can be summarised as the pilot's death being caused by his body being subjected in connection with the accident to violent force, affecting among other things the circulatory organs and brain. The pilot also had injuries to hands, feet and the soft tissues of the face. In other respects there were no remarks from the forensic medical examination.

Second pilot/Aircraft commander

The forensic medical examination can be summarised as the pilot's death being caused by his body being subjected in connection with the accident to violent force, affecting the circulatory organs and brain. The pilot also had injuries to the soft tissues of the face. In other respects there were no remarks from the forensic medical examination.

Operator

The forensic medical examination can be summarised as the operator's death being caused by his body being subjected in connection with the accident to violent force. Among other things the operator had injuries to the circulatory organs and brain. In other respects there were no remarks from the forensic medical examination.

Flight engineer

The forensic medical examination can be summarised as the flight engineer's death being caused by his body being subjected in connection with the accident to violent force, affecting the skull and brain. In other respects there were no remarks from the forensic medical examination.

Rescue swimmer
The rescue swimmer survived the accident with only a minor fracture of the jaw, a minor injury to the right lower leg, minor spinal fractures and a loss of memory concerning part of the sequence of events.

Student flight engineer
The forensic medical examination can be summarised as the student flight engineer's death being caused by his body being subjected in connection with the accident to violent force. Among other things the student flight engineer had injuries to the brain, liver and spleen. In other respects there were no remarks from the forensic medical examination.

Student rescue swimmer
The forensic medical examination can be summarised as the student rescue swimmer's death being caused by his body being subjected in connection with the accident to violent force. Among other things he had injuries to the brain and multiple skeletal injuries. In other respects there were no remarks from the forensic medical examination.

1.3 Damage to aircraft

1.3.1 Fuselage

The fuselage was very extensively damaged. It had broken into two large pieces, with the front of the fuselage, engines, main rotor gearbox (MGB) and main rotor recovered from one salvage site (#1) and the rear of the fuselage with the intermediate gearbox (IGB), tail rotor gearbox (TGB) and tail rotor recovered from the second salvage site (#2). The distance between the two salvage sites on the sea bed was about 500 m. See Fig. 27.
The parts of the helicopter and its equipment that have not so far been recovered include the air intake screen for the left engine, the winch stretcher and parts of the left cabin door.

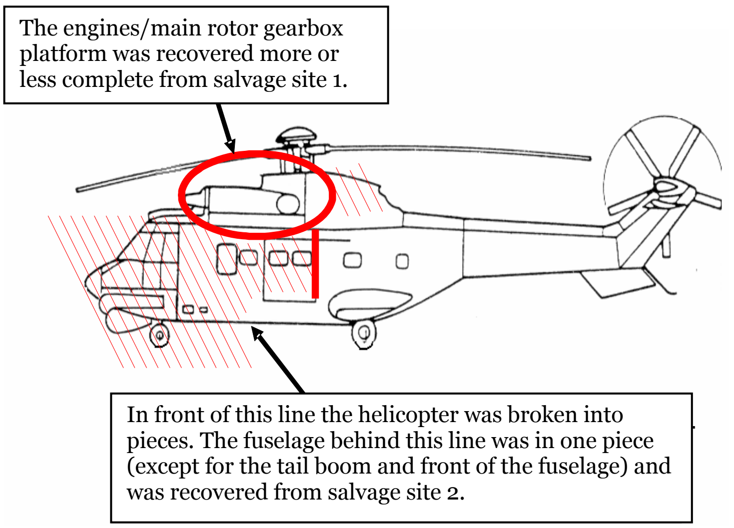

Fig. 2: *The helicopter's main division into the two major sections.*

The disintegration of the front of the fuselage was comprehensive. The roof, which provides a platform for the engines and rotor gearbox, along with the instrument panel and right side sliding door, made up the largest, most interconnected parts. The engine compartment hatches for the left and right engines were in place and latched. The remaining parts of the front fuselage could be retrieved by divers within a radius of 20 m from salvage site 1. See Fig. 23.

The rear of the fuselage was found upside down on the sea bed. The tail boom was turned through 180° forwards so that the tail rotor was level with the rear part of the left emergency floats. The tail boom was also twisted by 180° around its own axis. The tail boom was only attached to the rear fuselage by a small piece of skin plating, cabling, hydraulic pipes and the adjusting wires for the tail rotor.

Fig. 3: *The helicopter seen from the front. At the left are the engines, the MGB with the main rotor hub, and at the very front the casing with the air intake screen for the right hand engine. At the right are the front and rear fuselage parts.*

Fig. 4: *The sliding cowling for the gearbox that covers the area behind the main rotor gearbox. The cowling was split apart during the accident sequence.*

1.3.2 Rotor system

The helicopter's four main rotor blades and five tail rotor blades were found attached to their respective blade grips when the helicopter was raised.

The main rotor blades had disintegrated but most of their full lengths were recovered. The blade tips were missing from all the blades and two blades (red and black) did not have their balance weights. Some of the leading edge plates for the red and black blades were missing and have not been found.

One tail rotor blade (black) was broken at about halfway along its length.

Fig. 5: *The four main rotor blades of the helicopter.*

Fig. 6: *The five tail rotor blades of the helicopter.*

1.3.3 Engines

Both engines were found in their mountings, with the right hand engine displaced about 12 cm forwards. Both of the engine compressor blades of the first compressor stage showed diametric symmetrical damage. Both engines showed tangential damage in both the compressor and turbine stages.

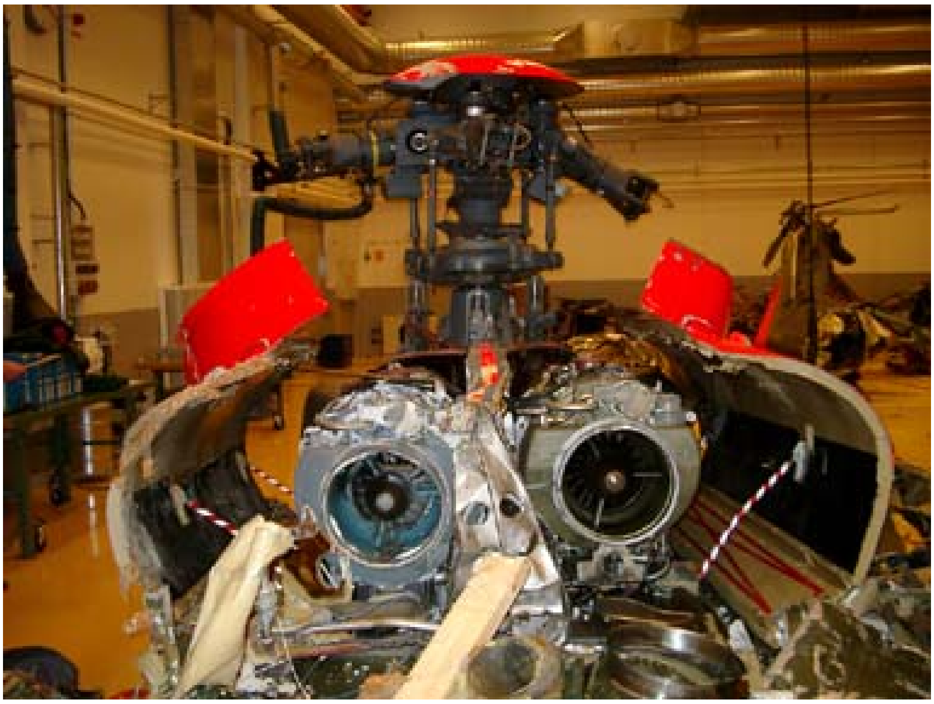

Fig. 7: *The helicopter's engines seen from the front (right hand engine, #2, at the left in the photograph).*

1.3.4 Other damage

Large amounts of wreckage were found afloat at the accident site. Several pieces of wreckage, found by the general public, were later handed in to SHK and the Swedish Armed Forces.

1.4 Environmental impact

The raised and recovered parts of the helicopter amounted to about 95% of its tare weight. At the accident site, about 1200 kg Aviation Kerosene 75 and 40 litres of oil (Gear oil 258, Pressure oil 023 and Aviation engine oil 860) leaked out.

1.5 Personnel information

The first pilot

First pilot, professional officer, served in 2nd helicopter battalion (2.hkpbat) as helicopter pilot and deputy commander of the squadron at Säve. He had started his flying service in the Navy and served as a helicopter pilot on the HKP2, HKP5 and HKP6 types. He later became an aircraft commander in the HKP 4 system, with both maritime operations and SAR service. He had also served as a flying instructor.

He attended an aircraft commander's course in transport aviation in 1992 and a squadron commander's course in 1999, and it was planned for him to attend a helicopter aircraft commander's course due to start the week after the accident.

During the period April 2002 — April 2003 he had converted on to the HKP10 system, a training course that was rather abbreviated because of his earlier long experience with the HKP4.

The pilot was approved, according to station orders (FljO Nr 57-65, 2003-03-20) as a pilot to be part of the SAR crew for the HKP10 from 1 April 2003 onwards.

His flying service had been as a pilot of aircraft types 61 (Beagle Bulldog) and 54 (Piper Chieftain), and helicopters HKP2 (Sud Aviation Alouette II), HKP4 (Boeing Vertol 107), HKP5 (Hughes 269A/Hughes 300C/Schweizer 300C), HKP6 (Agusta-Bell 206A) and HKP10 (Aérospatiale Super Puma).

Military flying hours		
previous	90 days	Total
All types	51.3	5180.9
This type	51.3	267.1

In 2003 the pilot had flown 81 hours as first pilot and 78 hours as second pilot, of which night flying accounted for 11 hours as first pilot and 11 hours as second pilot, totalling 22 hours of night flying. Of the total night flying time 8.2 hours had been performed during the autumn of 2003.

From Friday to Sunday inclusive before the accident he had been off duty and spent this free time with his family. The day before the accident he worked from 07:30 to 16:00. He flew from Säve to Såtenäs for a crew change and then back to Säve. In the evening he went to bed at the usual time and slept for about eight hours.

On the day of the accident the pilot started work at 07:30 and had been on duty for about 11 hours, including breaks, when the accident occurred. In the morning he had taken part in computer training. After a weather briefing at lunch time, he carried out between 14:40-15:20 instrument flying over the sea, descending towards lighthouses and a simulated boat, and practised winching over Säve airfield. The second pilot/aircraft commander also participated in this flying programme. A new weather briefing was given at 15:45 before the two evening flights.

During 2003 the pilot had accumulated 67 hours of overtime. This overtime was not associated with the week of the accident.

Second pilot/Aircraft commander

Second pilot, professional officer, served in 2.hkpbat as helicopter pilot and deputy commander of the SAR squadron at Såtenäs. At the time of the accident the pilot was the aircraft commander of the helicopter and was acting as the second pilot, seated in the left pilot's seat.

The pilot had begun his flying career in the Royal Swedish Air Force as a Viggen system pilot (AJ37) during 1977 - 1991. He retrained as a helicopter pilot in 1991. His conversion to the HKP10 was carried out in 1991-1992. After this he served in SAR as a helicopter pilot. He performed a maintenance flight test course on the HKP10 and a helicopter-oriented aircraft commander's course in 1994, squadron command course in 1998, simulator instructor's training and a flight safety officer's course in 2002 and aircraft commander's course in 2003. His flying service had been as a pilot of aircraft types 60 (Saab 105) and 37 (Viggen), and helicopters HKP5 (Hughes 269A/Hughes 300C/Schweizer 300C) and HKP10 Aérospatiale Super Puma).

Military flying hours		
previous	90 days	Total
All types	29.3	3308.9
This type	29.3	1826.9

In 2003 the pilot had flown 65 hours as first pilot and 56 hours as second pilot, of which night flying accounted for 8 hours as first pilot and 4 hours as second pilot, totalling 12 hours of night flying. Of the total night flying time 4.7 hours had been performed during the autumn of 2003.

During the period 1 January 2002 — 30 June 2003 the pilot served at the Helicopter tactical school at Linköping in a staff post with flying duties. During the period 15 May 2001 — 29 April 2002 he was grounded for medical reasons, and during the period 30 April 2002 — 24 August 2003 he had a dispensation with a permit to fly accompanied. When flying in a helicopter that is operated with a 2-pilot system, this restriction was not a hindrance. On the other hand, if the pilot was flying a single-pilot helicopter or other such aircraft, he would have had to be accompanied by a safety pilot. From 25 August 2003 he was allowed to fly without any limitation.

From Friday to Sunday inclusive before the accident he had been off duty and spent this free time with his family. The day before the accident he worked from 07:30 till 16:00. He started work at Såtenäs and flew to Säve.

On the day of the accident the pilot started work at 07:30 and had been on duty for about 11 hours, including breaks, when the accident occurred.

After a weather briefing at lunch time, between 14:40-15:20 he carried out instrument flying over the sea, descending towards lighthouses and a simulated boat, and practised winching over Säve airfield. This flying was carried out together with the first pilot. A new weather briefing was given at 15:45 before the two evening flights.

During 2003 the pilot had accumulated 28.5 hours of overtime. This overtime was not associated with the week of the accident.

Operator

The operator, a professional officer, had started his flying service in the Navy and served mainly in maritime operations as a tactical officer on the HKP4 from the 1980s onwards. During the period April 2001 — April 2003 he was converting on to the HKP10. From 1 April 2003 onwards he served as an operator on the HKP10 at Säve.

His flying service had been on the HKP4 (Boeing Vertol 107), HKP6 (Agusta-Bell 206A) and HKP10 (Aérospatiale Super Puma) helicopters.

Military flying hours		
previous	90 days	Total
All types	58.7	2447.4
This type	47.7	270.9

The week and weekend before the accident he had been off duty and spent this free time with his family. The day before the accident he worked from 07:30 till 16:00. He started work at Säve and served as an operator during a flight to Såtenäs and back.

On the day of the accident the pilot started work at 07:30 and had been on duty for about 11 hours, including breaks, when the accident occurred.

He served as an operator during the flight that was carried out from 14:40-15:20. A new briefing was given thereafter before the evening flying session.

During 2003 he had worked 22.5 hours overtime, but this overtime was not associated with the week of the accident.

Flight engineer

The flight engineer, a professional officer, had started his service in the Royal Swedish Air Force and served as a technician on Fpl37 (Viggen) since 1977. He had started his flying service in 1984 as a flight engineer on HKP2 (Sud Aviation Alouette II), converted on to the HKP10 (Aérospatiale Super Puma) in 1993, and thereafter flew at Såtenäs and Säve. He underwent a maintenance flight test course on the HKP10 in 1999. His flying service had been on the HKP2 (Sud Aviation Alouette II), HKP9 (MBB BO 105) and HKP10 (Aérospatiale Super Puma) helicopters.

Military flying hours		
previous	90 days	Total
All types	37.3	1738.6
This type	37.3	975

The day before the accident he worked from 07:00 to 16:30 after having been off duty over the weekend, which he spent with his family.

On the day of the accident the flight engineer started work at 07:00 and had been on duty for about 11 hours, including breaks, when the accident occurred. He served as a flight engineer during the flight that was carried out from 14:40-15:20.

The flight engineer had not worked any overtime during 2003.

Rescue swimmer

The rescue swimmer started his military basic training at F 17 Ronneby on 13 January 2003 and was then posted to 2.hkpbat at Säve for service on the HKP10. He was in the final stage of his conscription service and was due to be demobilised in December 2003.

He also participated in the flight that was carried out from 14:40-15:20.

Student flight engineer

The student flight engineer, a professional officer, had served as a flight engineer on the HKP4 and during 2003 had completed a technical course on the HKP10. He had started conversion to the HKP10 (GFSU - grundläggande flygslagsutbildning (basic flight tactical training) HKP10).

The student flight engineer accompanied the flight as an observer/student of the work on board, and did not actively participate in that work.

Military flying hours		
previous	90 days	Total
All types	6.9	2217.1
This type	5.5	6.1

He was off duty over the weekend. The day before the accident he worked from 07:00 to 16:30.

On the day of the accident the student flight engineer started work at 07:00 and had been on duty for about 11 hours when the accident occurred.

He also participated in the flight that was carried out from 14:40-15:20.

Student rescue swimmer

The student rescue swimmer started his military basic training at F 17 Ronneby on 21 July 2003. About two weeks before the accident he had been posted to 2.hkpbat at Säve for continuation training so that he could become part of the normal crew as a rescue swimmer on the HKP10. This was his first flight involving winching a stretcher on to a boat under way in darkness.

Crew readiness

The crew were ordered to be on SAR readiness during the evening until 22:00 for flying to be carried out from Linköping/Malmen. During readiness the aircraft commander intended to practice winching with a stretcher to/from a vessel while under way.

Crew co-operation
Nothing has emerged to indicate that before or during flying there was any problem in co-operation between the personnel who formed the crew. Nor has anything emerged to indicate that the second pilot trusted the skill of the first pilot so much that he set a lower priority on the supervision of the flying or that the first pilot did not obey instructions from the second pilot.

1.6 Aircraft

1.6.1 Technical Data

AIRCRAFT		
Manufacturer	Eurocopter, France	
Type	AS 332M1 Super Puma (HKP10)	
Serial number	409 (Manufacturer's construction number 2302)	
Year of manufacture	1991	
Gross mass	Max Structural Take Off Mass 9000 kg, actual 8316 kg	
Centre of gravity	4655 mm (max. forward cg 4510- max. rear-ward cg 4900 mm)	
Total operating hours	4143.45 hours at the time of the accident	
Operating hours at the most recent G-check	3997.10 hours (4 July 2003) ASTEC (Advanced software TEChnology)	
Operating hours at the most recent S-check	4098.15 hours (12 October 2003)	
Most recent preflight check	2003-11-18	
Fuel quantity at take-off	1500 kg	
ENGINES		
Manufacture	Turboméca, France	
Model	TAM 7A (Makila 1A1)	
Number of engines	2	
Engine/Individual no.	#1/2088	#2/2211
Total operating time, hrs	4162.21	4099.20

The helicopter was primarily intended to be used as a rescue helicopter. For this purpose it was equipped with, among other things:

- Navigational equipment suitable for this purpose.
- Search and rescue equipment which included breathing and ECG equipment, along with first aid bags which permitted expert resuscitation measures.
- A rescue hoist and spare hoist for winching up survivors.

The helicopter was equipped with an emergency transmitter (ELT) and a "homing pinger" transmitter.

The helicopter was not equipped with a flight data recorder (FDR) or cockpit voice recorder (CVR) despite the Swedish Armed Forces decision to introduce these after the accident to a HKP10 on 11 August 2000 at Kaskasapakte. The other HKP10s are now equipped with both FDR and CVR.

Nor was the helicopter equipped with any ground proximity warning system.

1.6.2 Aircraft documents

The helicopter was procured for search and rescue purposes and for its entire life was used for SAR within the Swedish Armed Forces.

From the aircraft documents seen by SHK it is apparent that the helicopter was delivered to the Swedish Armed Forces on 12 June 1991 with an operating time of 40.45 hours. The helicopter had thereafter undergone seven T checks and one G check. The helicopter had also received two technical modifications, “retrofits”. Retrofit 1 was implemented in 1995 and Retrofit 2 in 1997 at the F 21 helicopter workshop at Luleå and carried out by Eurocopter personnel.

The helicopter documentation revealed certain deficiencies, mainly concerning faults in the control and following card (Kf-kort) and DIDAS, where incorrect individual numbers were present for a number of units and apparatus. An example was the emergency transmitter (ELT), according to DIDAS, removed from a HKP5 on 27 October 2003 and placed in store 312 63.

All TRAB (teknisk rapport-arbetsbeställning – technical report/work order) written specifically for H99 since 31 March 2003 were scrutinised to check whether any major repairs had been carried out on the control systems, engines or transmission. No TRAB stated that any serious faults had occurred.

In DIDAS one of the TRAB (68 2399239) that was recorded referred to a list of post-servicing checks after a G check had been carried out. The list was documented in the Helicopter Wing documentation details where all posts were signed and issued, however the last posts that were implemented 100 hours after the G check were not reported by means of a measures taken report (ÅR).

The Certificate of Airworthiness was issued on 27 February 2002, with validity for a total flying time of 4500 hours, issued in accordance with RML V-5 with support from the Swedish Defence Material Administration type approval certificate 1/91 and maintenance reports 35810:50027, 2 February 2002.

Despite the discrepancies discovered in the aircraft documents, the helicopter was technically airworthy and maintained in accordance with applicable regulations.

1.6.3 Remaining remarks

In an interview with a flight engineer it emerged that one of two tank pumps was reported unserviceable and it was planned to be changed, but this had not been done by the time of the accident.

Also the tank panel, where the desired fuel amount is set, was unserviceable so that during refuelling the amount of fuel supplied had to be read off the fuel gauges in the cockpit.

1.6.4 Mass and balance

The mass and centre of gravity of the helicopter on take-off from Säve have been calculated as:

Total mass 8,316 kg.
Centre of gravity on the x axis: 4655 mm.
Centre of gravity on the y axis: approx. 1.6 mm right.

The permitted centre of gravity range on the x axis at a total mass of 8,400 kg is 4 510 – 4 900 mm. The permitted centre of gravity range on the y axis is 90 mm left and 80 mm right.

The calculations show that the helicopter’s centre of gravity location was within the permitted centre of gravity ranges.

The aids in the Flight Manual for calculation of the x axis location are adapted for a different cabin layout than usual. Centre of gravity calculations are not normally performed for the y axis, nor are there any aids for such calculations in the Flight Manual.

1.6.5 Flight instruments

This section contains descriptions of those flight instruments that were important for the investigation. The descriptions of the respective instruments consist of a review of the system function and then a summary of the results of interviews with experienced HKP10 pilots about human factors deficiencies they had encountered.

SHK has not examined which human factors verifications and validations were made of the Human-System interface in connection with the procurement of the HKP10.

Fig. 8: *Main instrument panel in the HKP10 cockpit. First pilot sitting at the right and the second pilot in the left pilot's seat.*

1.6.5.1 Electronic Flight Instrument System (EFIS)

The helicopter was equipped with the EFIS indicator system which consists, among other things, of two pairs of displays in the cockpit and one pair on the operator's panel in the cabin. The displays show the data that is normally shown on conventional instruments - ADI (Attitude Director Indicator) and HSI (Horizontal Situation Indicator). The system is divided into two identical systems, which work independently of each other. One system is operated by the first pilot and the other by the second pilot, and there is a possibility of transfer between the systems. The Operator's panel EFIS is slaved to the second pilot's EFIS and the operator is not able to select his/her own display modes.

The displays are on the instrument panel in front of each respective pilot. In addition, in front of each pilot are on/off switches and brightness controls for the displays.

Changes in the colour of the information on the displays are used to indicate that changes or faults have occurred. If the system detects that the radio altimeter is showing incorrect values the H.HT (Hover height) text changes colour from green to yellow, provided that the coupler is activated and that H.HT is selected.

Hover indication is one of several presentation modes that can be selected on the HSI. It is used during hovering and slow movement. The cross bars show current speed information longitudinally and sideways. The circles on the hovering indicator show the ground speed that the pilot has selected for the control automation and are presented in the interval of 0-30 knots.

The sensor for the hovering indicator is a doppler radar and measures speed over the surface (ground speed). In the case of winds less than 10 knots and flat calm water the doppler finds it difficult to detect the speed and often reverts to its memory. Memory operation is indicated by a yellow light called DOPMEM being lit, in which case the cross bars move to and stay at the centre. The HKP10 Flight Manual Part 2 Section IV states that the CALM SEA function must be selected in the case of winds equal to or less than 10 knots, when using any of the transition down (T.DWN), hovering (HOV) or ground speed (G.SPD) modes over water. When CALM SEA is selected, the DVLM (Doppler Valid Lock Monitor) function is switched on, which will detect if the doppler locks on to a false value. If a false lock is detected, the doppler indicates memory operation. If CALM SEA is not selected in the case of wind less than 10 knots, there is a great risk that the doppler gets a false reading which will not be indicated to the pilots. In the case of a false reading the cross bars often go to the centre and the yellow DOPMEM lights does not light. The presentation then is that the cross bars are in the centre and show that the helicopter is stationary, which may not be the case.

Fig. 9: *The HSI for the first pilot, with hovering indication. The presentation shows that the helicopter is stationary, providing the DOPMEM light is not lit. If the wind is less than 10 knots and CALM SEA has not been selected, exactly the same presentation can be shown as above, despite the fact that the helicopter may be moving in any direction.*

Pilot experience in respect of human factors deficiencies
When flying in darkness pilots often turn down the brightness of the displays to a minimum. It then becomes difficult to detect a yellow indication, or that an indication has changed from green to yellow. The presentation of the hovering indicator can also in these conditions be difficult to read, e.g. the trend circle.

In addition, pilots have experienced disorientation and felt that it was more difficult to suppress this when the instruments are small, e.g. EFIS.

In respect of the doppler function, pilots stated that there is a great risk of the doppler receiving a false reading that is not indicated, if the pilot has forgotten to select CALM SEA in light winds. The pilot may then lose track of the helicopter's speed and direction of movement.

1.6.5.2 Standby instruments

The helicopter is equipped with **one** standby attitude indicator, located on the instrument panel in front of the first pilot. At the top edge of the instrument is the bank angle pointer. The difference between the standby attitude indicator and the ADI in respect of how angle of bank is indicated is shown below.

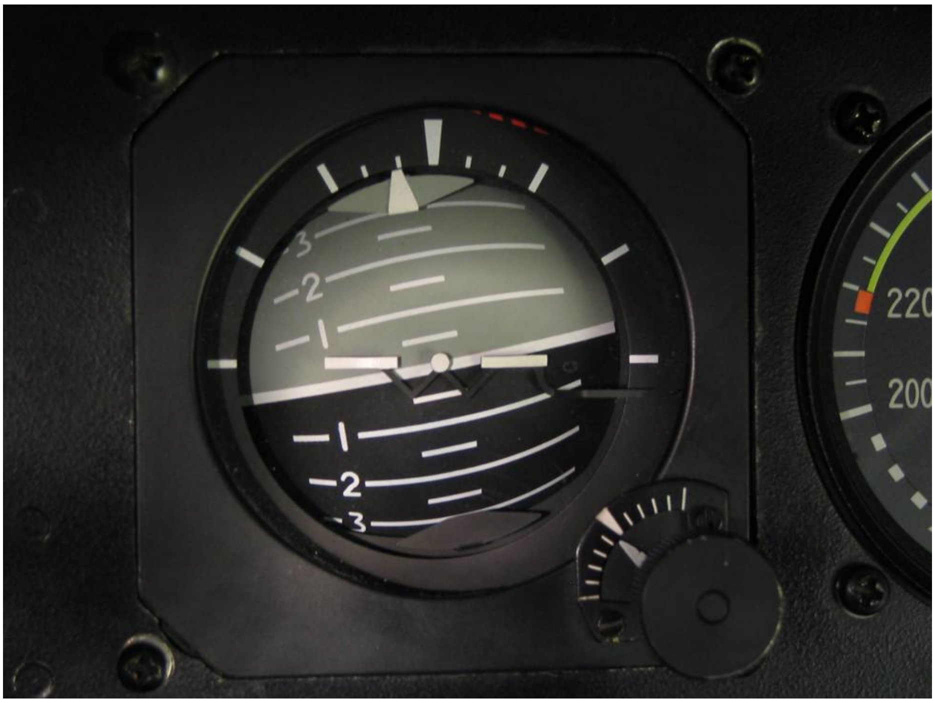

Fig. 10: Standby attitude indicator*, with the bank angle pointer at the top edge. Here the helicopter is banking about 10° to the right. The bank angle pointer is horizon-related.*

Fig. 11: *ADI, with the bank angle pointer at the top edge. Here the helicopter is banking about 10° to the right. The bank angle pointer is aircraft-related.*

<u>*Pilot experience in respect of human factors deficiencies*</u>
If the ADI is lost, the pilot can use the standby attitude indicator. The instruments in figures 10 and 11 both show an angle of bank of about 10° to the right. The different presentations of banking mean that there is a risk of misinterpretation when transferring from the ADI to the standby attitude indicator.

The helicopter's ADI is not considered to meet the needs of a helicopter pilot. For example the small format gives poor resolution of pitch and roll angles.

1.6.5.3 *Radio altimeter (RHM)*

The helicopter was equipped with dual, independent of each other, radio altimeters showing the helicopter's height above the underlying terrain. Height information is shown partly as an analogue on the circular pointer instrument (see fig. 12) and partly digital on the attitude direction instrument, ADI.

On each RHM a DH (Decision Height) can be set using the knob with a red light. When the helicopter during a descent passes the preset height, the system emits a warning of 4-5 audible beeps and also visually by illuminating the red light on the knob, and by showing DH on the ADI. The volume of the audible warning cannot be altered.

If both pilots have set the same decision height, the warnings will only be given once at the set height. If the helicopter remains below the decision height, no new warnings will be given. The knob for setting the decision height is located at 7 o'clock relative to the RHM.

Fig. 12: *The first pilot's RHM. The switch is set to OFF and the red/white flag indicates OFF. The Decision Height (DH) is selected by the knob with the red light at the instrument's 7 o'clock. The DH index marker is behind the red/white flag. On the photograph can be seen the non-sanctioned modification of a cable tie on the ON/OFF knob.*

Pilot experience in respect of human factors deficiencies

When flying in darkness, it has happened on several occasions that the pilot, when altering the decision height, has mistaken the controls and instead of turning the knob for setting the decision height has turned the ON/OFF knob that is located at 2 o'clock on the RHM. This has then switched off the RHM. The fact that pilots have had problems with this is shown by the ON/OFF switch having a white cable tie attached to it, as on the HKP10 that SHK inspected.

When the pilots are using earplugs, they usually increase the sound level for incoming audio. There is then a risk that the pilots do not hear warning sounds. HKV Flight safety section (FlygSäk) had therefore recommended that pilots do not use earplugs. Pilots have experienced that warning sounds in certain HKP10s had lower volume.

In addition it is said to have happened that pilots did not hear the warning sounds in stressful situations and that they forgot the activation of the audio warning after passing through the decision height.

According to pilots' experience the RHM should also have a better resolution in the area of heights that are of interest to helicopters and that the 0 feet marking should be located at 6 o'clock on the instrument rather than at 12 o'clock as it is now.

1.6.6 Autopilot (AP) and Coupler

The helicopter was equipped with an autopilot (AP) and a coupler FDC 155 (Flight Director Coupler). The coupler acts as a control unit between the RAMS 3000 navigation equipment and the AP in the helicopter's integrated navigation and control system.

The AP is normally always activated while flying, including hovering, and also while landing.

The coupler permits various control functions to be selected and ensures by means of co-operation with other installations in the system:

- Manoeuvring in pitch and roll in coupler mode or F/D (Flight Director in pitch and roll).
- Engagement of different modes (level flight, approach and SAR modes).
- The selection of hovering or level flight radar height.

The following selections are available on the control panel for the different modes (level flight, approach and SAR):

Level flight modes

A/S	Flying at a constant IAS (indicated air speed)
ALT	Holding at a constant barometric altitude
V/S	Flying at a selected climb or sink rate
HDG	Flying to follow a selected heading
NAV	Depending on the control panel selection, either - flying and tracking the preselected VOR radial - flying according to information from the navigation computer

Approach modes

These modes are not described here since they are not relevant to the current investigation.

SAR modes

H.HT	Holding at the selected radar height (40-300 ft) while hovering.
HOV	Automatic hovering.
G.SPD	Automatic hovering with a selected lateral and longitudinal speed.
T.DWN	Automatic descent transition to hovering at a selected radar height.
T.UP	Automatic transition from hovering to a selected radar height and 75 knots.
CR.HT	Holding at the selected radar height (100-2500 ft) while flying level in the cruise.
FLY UP	Automatic power increase if going below the selected safety radar height (RHM index). Only in the SAR mode.

Combinations of the different modes are available, e.g. CR.HT + NAV + A/S.

Hover height (H.HT)

Hover height can be selected within the range 40-300 ft and has an accuracy at the lower part of the range of ±5 ft. The height is maintained by using the two RHMs as sensors. When Hover height is selected, this is indicated by the H.HT light on the coupler panel showing green, and a green rectangle with green H.HT text is indicated on the upper EFIS indicator. The height hold can be quickly disconnected using the TRIM COLLECTIVE RELEASE that is located on the underside of the pilot’s collective lever. TRIM COLLECTIVE RELEASE has a dual function so that during manual flying it is possible to trim out the lever forces of the collective lever. This is why it is very easy to unwittingly disconnect H.HT if one chooses to trim out the lever forces. If such an inadvertent disconnection of the height hold takes place, this is indicated by two yellow flashing lights on the autopilot annunciator panel located above the upper EFIS indicator. If either of the two sensors gives incorrect values, this is indicated by the H.HT text being yellow instead of green.

In the case, among other things, of differences in engine torque and/or rpm (Ng), the H.HT is switched out. Disconnection is indicated by two yellow flashing lights on the autopilot annunciator panel. In addition, the

H.HT text on the EFIS indicator goes out. There is no acoustic warning of a disconnection of coupler modes.

If the coupler's internal monitoring system detects that height holding is outside the tolerances, this is indicated by two deviation arrows to the left and right of the H.HT text. If height holding varies by more than 5 ft or the rate of descent/climb varies by more than 200 ft/min the height holding function is faulty and is disconnected.

Pilot experience in respect of human factors deficiencies

Pilots have described the risks of disconnection and confusion between several controls due to the controls/buttons being similar and close to each other, and that some have a dual function, depending on the AP/coupler mode.

It can also be difficult to detect when the text H.HT on the EADI switches from green to yellow, particularly during night flying with dimmed instrument lighting.

1.6.7 Flying with high power output (Torque)

According to the HKP10 Flight Manual, Part 2, Section IV, PERFORMANCE, Engine and power transmission limitations, it is permitted for the power output, torque, with two engines to be greater than 81% (yellow values on the torque instrument) for a maximum of five minutes, including take-off and climbing. This should be interpreted as a maximum of five minutes continuous flying. This means that after operating with a torque of greater than 81%, flying must continue for an indefinite period with a torque of less than 81% before a new five minute period can begin. Flying with a torque of less than 81% is permitted without any time limit.

1.6.8 Compressor stall (Engine surge)

Turbojet engines can, in unfavourable operating conditions, be subject to compressor stall (also called engine surge). Surging can take place due to unfavourable air flows in the engine inlet, damage to the compressor, ice build-up or foreign objects (e.g. ingestion of birds).

Occasional surging does not normally affect the output power of an engine. The power loss due to such surging is very small, and may not even be noticed by the crew. It is also so brief that often no change in the engine instruments is visible. From a performance point of view, occasional surging is not "flight critical", nor is it necessary to call off a flight for this reason, i.e. to make a takeoff if surging occurs while hovering.

In the case of repeated or continuous surging, the engine power can be considerably reduced. Engine power from the surging engine reduces, which in turn means that the rotor revolutions decrease and the situation becomes "flight critical", and an take-off or emergency landing become necessary.

Apart from a loss of power, normally a loud noise (bang) occurs, that can be clearly heard on board the helicopter. In general it is only rarely that engine surging causes damage to an engine. In this type of engine the manufacturer Turboméca states that they have never seen damage to a compressor caused by surging.

If surging occurs it is normal to check that bleed offset is selected and then to assume a more favourable flight condition. This usually means that the helicopter's direction in relation to the wind direction and the incoming air flow to the engines must be altered.

The Flight Manual, Part 2, Section II Flying, and Section III, Emergency Instructions, do not describe any pilot actions in the case of an engine surge.

1.6.9 Bleed offset

The bleed offset function is used to avoid engine surging while hovering and moving backwards, sideways or with a tailwind. Bleed offset is selected by a switch located on the underside of each pilot's collective lever. The switch toggles, so that it alternately switches bleed offset on and off. This means that if bleed offset is switched off and both pilots decide to use bleed offset, and separately operate their switches at an interval of one second or more of each other, one pilot switches it on, while the other pilot inadvertently switches it off again.

When bleed offset is activated, this is indicated by two green lights labelled OFFSET being illuminated on the control panel (actually the subpanel) between the pilots.

When the engines are shut down (stopped) the bleed offset valves return to their de-energised positions, i.e. they close.

Pilot experience in respect of human factors deficiencies
Apart from pilots having inadvertently switched off bleed offset, as described in the paragraph above, it often happens that the bleed offset is in an incorrect position. Most often this is because a pilot has forgotten to reset the function. The location of the lights and their relatively discreet illumination means that they do not disturb pilots while flying with bleed offset selected. This however also means that it can be difficult to detect that bleed offset is selected when it should not be.

1.6.10 Communications system

The helicopter was equipped with four airborne radios:

- FR31 (AMR 345) VHF/UHF2.
- FR43 (SRA C-602) VHF FM.
- FR47 (Collins 9000) HF/SSB.
- FR48 (Collins ARC 182) VHF/UHF1.

FR31 is normally used for two-way speech communication with ATS (Air Traffic Services)(TWR (Tower; airfield control)/channel A and TMC (terminal control)/channel C2) or other aircraft.

FR43 is normally used for two-way speech communication with the police, rescue services, the SOS Alarm organisation and others.

FR47 is normally used for two-way speech communication with ground stations (ARCC/MRCC) or between helicopters.

FR48 is normally used for two-way speech communication with ground stations (ARCC/MRCC) or seaborne units. It can also be used for speech communication with ATS and other aircraft.

1.6.11 External lighting

Position light
The helicopter has five position lights:

- Two red position lights located on the left main landing gear, visible within a 110° sector from the front and along the left side of the helicopter's centreline.
- Two green position lights located on the right main landing gear, visible within a 110° sector from the front and along the right side of the helicopter's centreline.
- One white position light located at the extreme rear of the tail boom and visible within a 70° sector from the rear on either side of the helicopter's centreline.

Formation lights
The helicopter has two formation lights intended for formation flying in darkness, which provide a continuous blue beam. One of the light fittings is located at the top of the tail boom, and the other is behind the main rotor gearbox cover.

Life raft lighting
The helicopter has two external fixed lights which can be switched on to illuminate the area outside each of the cabin doors if the crew/passengers have to board rescue vessels in darkness. The lights are located behind the cabin doors.

Landing spotlights
The helicopter has two landing spotlights, which are used to illuminate the terrain below when landing in darkness. The spotlights are in fixed positions and are located in front of the stub wings. The spotlights can have their height adjusted when the helicopter is on the ground.

Winch spotlight
The helicopter has a fixed position spotlight located on the rear part of the left cabin footstep. This spotlight illuminates the area directly below the helicopter.

Tail rotor spotlight
To illuminate the tail rotor there is a fixed position spotlight located underneath the left supplementary fuel tank.

Search spotlights
The installation consists of three fold-away spotlights which can be moved vertically and horizontally. These are located underneath the cabin, one at the front on the right side, one at the front on the left side and one at the rear on the right side. Whether the first pilot or the second pilot manoeuvres the left, right or both the forward spotlights is determined by a 3-position switch in the cockpit. Usually the pilots only control the spotlights that are located on their “own” sides. The spotlights are directed by means of a 4-position switch on the respective collective levers. The third spotlight is directed by the hoist winch operator by means of a 4-position switch on the control handle which is used to operate the hoist winch.

When lit, it takes 10-20 seconds before the spotlights reach their maximum brightness. If a spotlight is switched off, it must be allowed to cool for 2-5 minutes before it can be switched on again. This is automatically achieved as soon as the correct operating temperature is reached.

In addition to the three spotlights there was a demountable SX-16 Nightsun spotlight, located behind the cargo hatch. The SX-16 is directed by means of a 4-position switch on the SX-16’s own control panel at the left of the main instrument panel, in front of the second pilot. The SX-16 takes about 3 seconds to light and provides maximum brightness immediately.

Pilot experience in respect of human factors deficiencies
The search spotlights for each pilot and the flight engineer have a long delay after being switched on until they provide maximum brightness This means that when flying in darkness the crew usually switch on the spotlights well before the estimated location where visual references can be obtained. In order that the spotlights when lit will not disturb/dazzle the pilots before references are obtained, they are usually directed straight out to the sides or straight down beneath the helicopter. When later the spotlights are needed, they are directed to the appropriate positions. This can be perceived as very disturbing in certain flight conditions.

Lighting and extinguishing of the spotlights is carried out by means of a rocker switch on the upper front part of each collective lever. It has happened that pilots have unintentionally activated the switch and switched off their spotlight. Switching back on can take longer than the normal lighting period. In addition, the Flight Manual (Part 1, description section) recommends waiting 2-5 minutes before switching back on. This recommendation cannot be followed in the case described above.

1.6.12 Audible warnings

An audible warning sounds and at the same time a warning light is illuninated when the following faults are detected:

- Fire in the main rotor gearbox and engine compartments.
- Excessively high or low rotor speed.
- The landing gear is not extended.

The warning for landing gear not extended is given at a speed of about 60 knots in the form of flashing L/G lights (the landing gear warning lights) on the main instrument panel. The warning can be acknowledged by pressing the L/G lights.

When the speed is <60 kt and the radar height <20 ft with retracted landing gear and an acknowledged warning, the L/G lights flash and the audible warning sounds for three seconds. The audible warning cannot be acknowledged.

The audible warning is controlled by a two-position AURAL WARNING ON-OFF switch on the sub-panel:

- In the ON position the audible warning is operative.
- In the OFF position the audible warning is inhibited and the yellow A. WARN light on the warning panel (α 32) is lit to remind the pilots of this.

The audible beeps that are generated when the helicopter descends below the preset decision height on the RHM are not affected by the position of the AURAL WARNING switch.

1.6.13 First aid equipment

In DIDAS there is no information concerning which individual helicopters carry first aid equipment, so that checks on this equipment were made more difficult. In addition, certain parts of the first aid equipment did not have individual numbers. One apparatus, the cardioscope, was not formally approved for flight in the case of the HKP10 (it had only been approved for flight in the HKP4 and HKP11).

1.7 Flight safety equipment for personnel

The investigation of items including the personal flight safety equipment is contained in a special appendix to the technical report.

The personal flight safety equipment worn by the crew at the time of the accident is listed below:

<u>*First pilot*</u>

- Flying helmet type 124 A, which suffered serious damage.
- Life preserver type 8E with manual inflation activation and a type 713MT personal emergency beacon. The flotation collar was open on the right side due to external influences related to the accident. The

life vest bladders had not been inflated. There was nothing to report concerning the emergency beacon.

- The helicopter type immersion suit had extensive damage to the back and right leg.
- Among the stipulated personal emergency equipment the aircrew knife and torch were not recovered.
- Civilian underwear and wool/towelling long thermal underwear.
- Aircrew watch
- Flying gloves of white leather that were no longer fit for flying use.

Second pilot/Aircraft commander

- Flying helmet type 120D that was damaged at the rear and neck.
- Life preserver type 8E with manual inflation activation and a type 713MT personal emergency beacon The collar was open on the right side due to external influences related to the accident. The life vest bladders had not been inflated. There was nothing to report concerning the emergency beacon.
- The helicopter type immersion suit had damage to the left side of the back and right leg.
- Among the stipulated personal emergency equipment the torch was not recovered.
- Aircrew scarf, orange.
- Stipulated underwear and socks, and non-stipulated combat shirt type M/90.
- Flying gloves type M/80.

Operator

- Flying helmet type 120C that was damaged at the rear and forehead. The helmet was over ten years old and the paint layer on the outer garment showed signs of many repairs. There is no specified life for flying helmets, but the manufacturer recommends a maximum of ten years if the helmet is not used regularly, and five years if it is used almost daily. Equivalent lifetime limits have not been specified for Swedish Armed Forces flying helmets.
- Life preserver type 8E with manual inflation and a type 713MT personal emergency beacon, with nothing to report.
- The helicopter immersion suit had small separate areas of damage on the arms.
- The stipulated personal emergency equipment.
- Civilian underwear, inner socks and complete wool/towelling long thermal underwear.

Flight engineer

- Flying helmet type 124A with damage on both sides. The helmet was partly (to about ⅓) noise- modified in accordance with TOMF FLYG 511-000180.
- Life preserver type 8E with manual inflation activation. The type 713MT personal emergency beacon had separated from its pocket in the flotation vest and the antenna was completely detached at its base.
- The helicopter type immersion suit had damage around the left arm, right hip and both legs.
- The stipulated personal emergency equipment.
- The stipulated underwear and socks.
- Aircrew watch
- Flying gloves type M/80 were recovered in the immersion suit.
- Support belt for the winch operator’s safety belt.

Rescue swimmer

- Flying helmet type 124 that was undamaged but had exceeded the date for inspection by 13 days.
- Life preserver type 8E with manual inflation activation and a type 713MT personal emergency beacon. The flotation collar was open on the right side due to external influences related to the accident. The life vest bladders had not been inflated. There was nothing to report concerning the emergency beacon.
- An immersion suit with damage to the right leg.
- A rescue swimmer harness
- The stipulated underwear and socks.

Student flight engineer

- Flying helmet type 124 that had impact marks on the right side of the rear and crushing damage to the right side.
- Life preserver type 8E with manual inflation activation and a type 713MT personal emergency beacon. The collar was completely open due to external influence during the accident. The inflation handle was pulled out of its channel, which was damaged. Both life vest bladders had cutting damage to the right side. The personal emergency beacon had minor damage.
- The helicopter immersion suit had damage to the right side.
- Among the stipulated emergency equipment the torch was not recovered.
- Stipulated underwear and non-stipulated combat shirt type M/90.

Student rescue swimmer

- Flying helmet type 124C that had scraping damage on the right and left sides. This helmet type was not in the applicable Material Maintenance Plan, TO UF FLYG 510-000102 J at the time of the accident. It has now been introduced.
- The rescue swimmer vest had cutting damage to the left side. The breathing tube was detached at the flotation bladder and pulled completely out. The type 169 transmitter/receiver had separated from the vest and was found hanging from the roof of the cabin. The type 713MT personal emergency beacon was not recovered.
- The immersion suit was damaged everywhere and the chemical light was missing.
- A rescue swimmer harness
- Stipulated underwear and non-stipulated combat shirt type M/90.

Other

In OSF (Ordnings- och säkerhetsföreskrifter för flygtjänsten – Procedural and safety instructions for flight operations) there is no requirement for personnel wearing immersion suits to carry the personal emergency equipment prescribed by OSF. Also, immersion suits do not have pockets to carry such equipment.

Fig. 13: *Flotation vest worn by all the crew except the student rescue swimmer.*

Illustration annotations:

Life vest bladders
(the life vest is not shown in the illustration)

Pocket for the life vest inflation unit

Life vest inflation activation handle

Pocket for 713MT personal
emergency beacon

Personal emergency beacon
activation handle

1.8 Meteorological information

On 18 November a warm front with rain had moved in over the West coast. Earlier in the day it had also rained from a previous warm front.

The temperature was +8° to +9° and the relative humidity was >95 % at ground level.

At the weather briefing, at 15:45, the crew received from the meteorologist the following forecast for the evening up to 22:00:

- visibility 2-6 km,
- light rain,
- complete cloud cover at 90 m, temporarily broken cloud cover at 30 m,
- southerly wind 5 m/s veering to southwest 10 m/s,
- ice formation in cloud above 2000 m and
- no engine icing risk and a surface temperature of +8°.

The weather forecast for Malmen met the requirements for an alternative landing airfield.

In connection with the request for take-off clearance at 18:29 the crew received from Säve air traffic control the following weather information for the airfield "*Wind 200 °- 8 knots… and for your information I have visibility between 2 km and 3700 m and broken at 200 feet… QNH 1003 hPa.*"

There were no meteorological observations from the area of the accident. The closest observation stations, apart from Säve airfield, are Måseskär approx. 40 km north-north-west, Skagen approx. 65 km west and Nidingen approx. 55 km south of the accident location.

According to available observations from these stations the weather developed in accordance with the stated forecasts during the period of both flights. This was visibility 3-5 km in rain with a cloud base of 30-120 m and some broken cloud cover. The wind was south-south-west at approx. 5 m/s.

The crew of the *Märta Collin* estimated visibility as just over 2 NM, i.e. approx. 4 km and the wind 3-4 m/s, and the sea state was described as *"almost flat calm"* but not completely calm.

The risk of engine icing for the HKP10 lies, according to meteorological criteria, at temperatures <+5°C and a relative humidity of >75%.

According to the HKP10 Flight Manual the risk of helicopter and air intake icing is present when the indicated ambient air temperature is ≤+5°C and in damp weather conditions (rain, fog and snowfall), when hovering over water or flying in cloud. The conditions that evening were not conducive to engine icing. since the temperature was too high.

According to the witnesses on the participating rescue vessels, there was a north-westerly current of 1.5-2 knots. By north-westerly current is meant that the water was flowing towards the north-west. Objects on the surface are also affected by the wind, and this is confirmed by, among other things, the navigation equipment on the *Märta Collin*.

No lightning discharge that could have affected the helicopter was recorded. The only lightning discharge recorded in Sweden occurred in northern Poland, about 20 hours before the accident.

1.9 Aids to navigation

The helicopter was equipped with a navigational computer called the RAMS 3000 (Racal Avionics Management System), the information in which could not be evaluated, since the computer lost its memory contents due to the long period it spent under water. The information in the RAMS is processed with the aid of a GPS receiver and inertial navigation system (INS).

1.10 Radio and radar information

1.10.1 Recorded radio communications

Radio communication between the air traffic controller at Säve and the helicopter only took place in connection with the take-off and departure from Säve. After take-off at 18:32 the operator contacted ARCC on VHF channel 67 and reported the intention of the crew to exercise with the *Märta Collin*.

The last transmission took place about 4 minutes before the accident, when the crew, at the request of the air traffic controller at Säve, reported their position and switched on the helicopter's transponder (SSR).

No radio communication was recorded between the helicopter and the *Märta Collin* during the final flight.

1.10.2 Recorded radar information

The helicopter was tracked on radar by the Navy Sea Surveillance Centre in Göteborg. Radar tracking took place using the *STRIMA* combat control system which also has a replay function, enabling that particular flight to be displayed afterwards. The computer clock in the combat control system obtains real time from the Swedish Armed forces IP (Internet Protocol) network, which means that the time displayed by the system is probably very close to standard Swedish time.

The helicopter was tracked on radar by two military primary radar stations and the Swedish Civil Aviation Administration secondary radar station, *Landvetter MSSR*. Landvetter MSSR displayed the identity and flying altitude as received from the helicopter transponder, the SSR response. The first SSR response during the final flight was obtained at 18:37:19 and the last at 18:40:51. During this period 35 genuine SSR returns were made, along with three with corrupt values[3]. On the occasions that corrupt SSR responses were received, the primary radar echo was able to record the correct position. The radar printouts are based on screen dumps from the *STRIMA* replay.

The radar pictures have been analysed by the *EC-Gruppen* at Svängsta, which is the subcontractor for the Sea Surveillance Centres. Radar returns from both radar stations were recorded and stored in a common file, so that the recordings are displayed together. Double returns mean that the recordings of the helicopter by the radar stations were not exactly coincident and that the accuracy of their position detections varied a little.

The flying altitudes displayed in the SSR responses are given in standard metres (STD = 1013.2 hPa) so that the true heights were approx. 80 m lower, since the actual barometric pressure, QNH,[4] = 1003 hPa at the time of the accident.

1 hPa = approx. 8 m height difference, i.e. 1013 minus 1003 hPa = 10 hPa giving about 80 m difference.

Figures 14 and 15 show the recorded radar returns during the first flight that evening.

Figures 16 to 21 show the recorded radar returns during the second flight that evening, which ended with the accident.

The evening's first flight

From the recorded radar information it can be seen that the helicopter crew, during the first flight that evening, which began at 17:25 and ended at 18:11, aborted a direct approach to the *Märta Collin*, accelerated away and circled to the position for winching to the vessel. After winching had been completed they returned to Säve and landed.

The locations of the *Märta Collin* could not be observed on radar at any time during the evening.

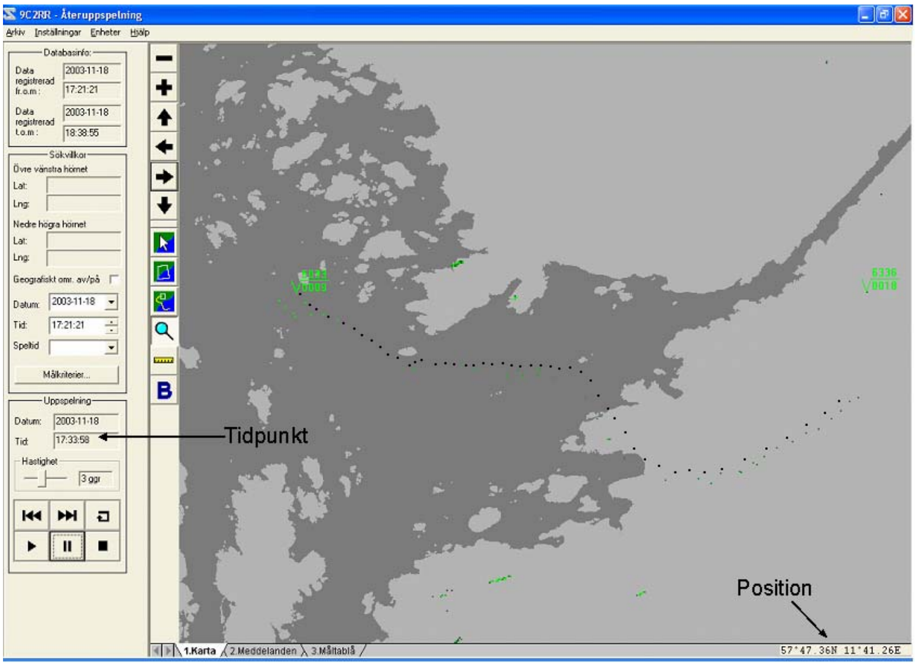

Fig. 14: *The primary and secondary radar picture shows the position of H99 at 17:33:58 and the SSR response gives the flying altitude as approx. 90 m STD, i.e. approx. 10 m AMSL in the vicinity of Märta Collin's location south-west of Lilla Barlind island. The green radar responses indicate double returns.*
Illustration annotations: *Time (Tidpunkt).*

3 A corrupt value refers to an incorrect position return from the transponder (SSR).
4 QNH = Actual barometric pressure reduced to that at mean sea level (MSL)

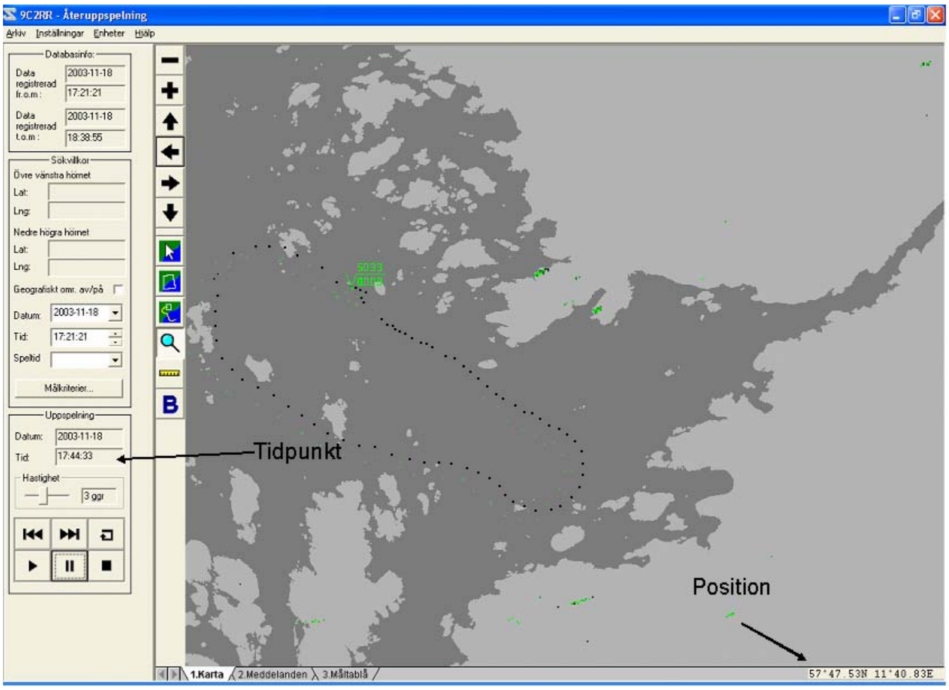

Fig. 15: *The primary and secondary radar picture shows the position of H99 at 17:44:33 and the SSR response gives the flying altitude as approx. 90 m STD, i.e. approx. 10 m AMSL during the second approach to Märta Collin, after which winching took place. The image shows recordings from both the radar stations which could track the helicopter. The green radar responses indicate double returns. <u>Illustration annotations:</u> Time (Tidpunkt.)*

<u>The evening's second flight</u>

After refuelling and a crew member change another take-off began at 18:32 from Säve towards *Märta Collin* in the same exercise area. The radar picture shows that the helicopter crew did not switch on the transponder. On request from the Säve air traffic controller the transponder was activated as the helicopter passed the *Lilla Kalven* lighthouse.

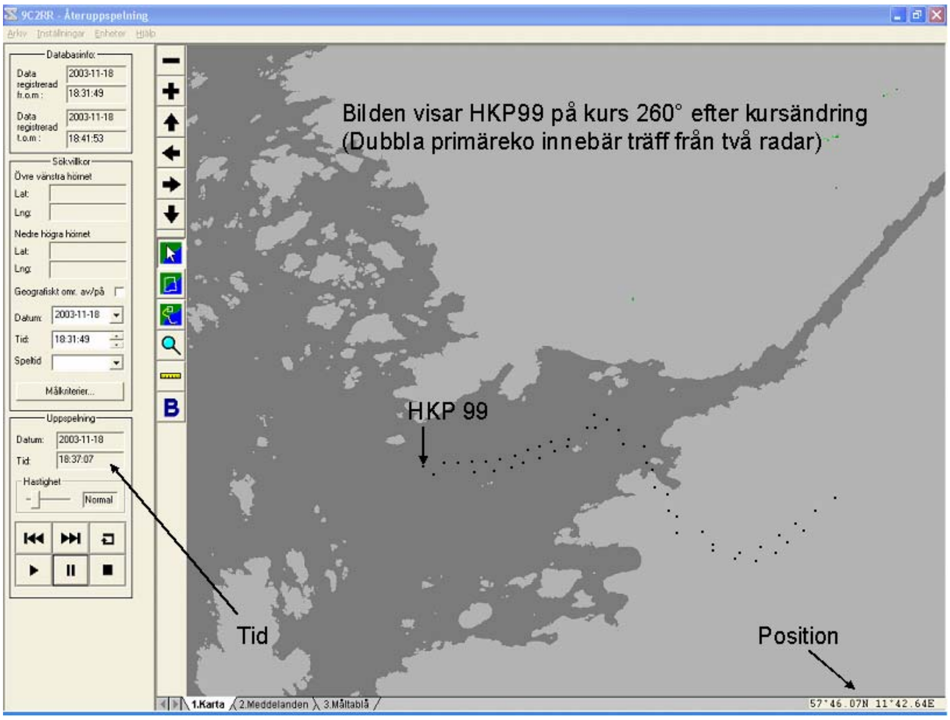

Fig. 16: *The primary radar picture shows the position of H99 at 18:37:07 while approaching the Märta Collin. As no SSR response from the helicopter is shown, it can be seen that the helicopter crew had not switched on the transponder, so that its identity and height were not known by observation of the radar picture.*
<u>Illustration annotations:</u> Time (Tidpunkt).The image shows HKP99 on a track of 260° after changing direction (Double primary radar echo means returns from two radars)

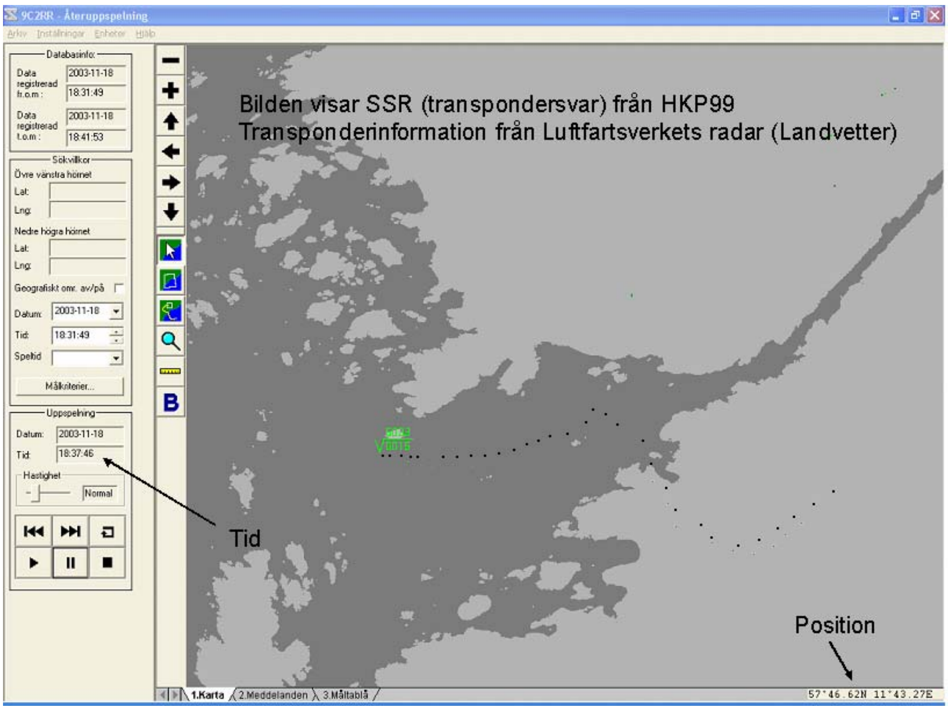

Fig. 17: *The primary and secondary radar picture shows the position of H99 at 18:37:46 and the SSR response gives the flying altitude as approx. 150 m STD, i.e. approx. 70 m AMSL after the helicopter crew switched on the transponder at the Lilla Kalven lighthouse.*
<u>Illustration annotations:</u>The image shows the SSR (transponder response) from HKP99. Transponder information from the Swedish Civil Aviation Authority radar (at Landvetter airport).Time.

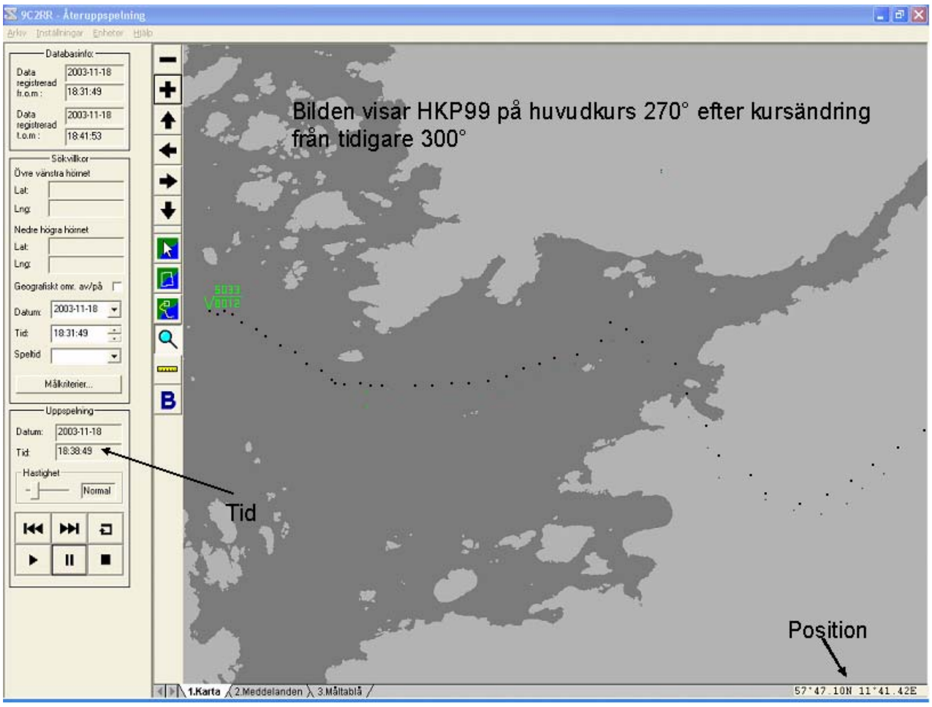

Fig. 18: *The primary and secondary radar picture shows the position of H99 at 18:38:49 and the SSR response gives the flying altitude as approx. 120 m STD, i.e. approx. 40 m AMSL directly south of Lilla Barlind island and south of the position of Märta Collin. The green radar responses indicate double returns.*
Illustration annotations: The image shows HKP99 on its main track of 270° after changing course from the previous track of 300°. Time.

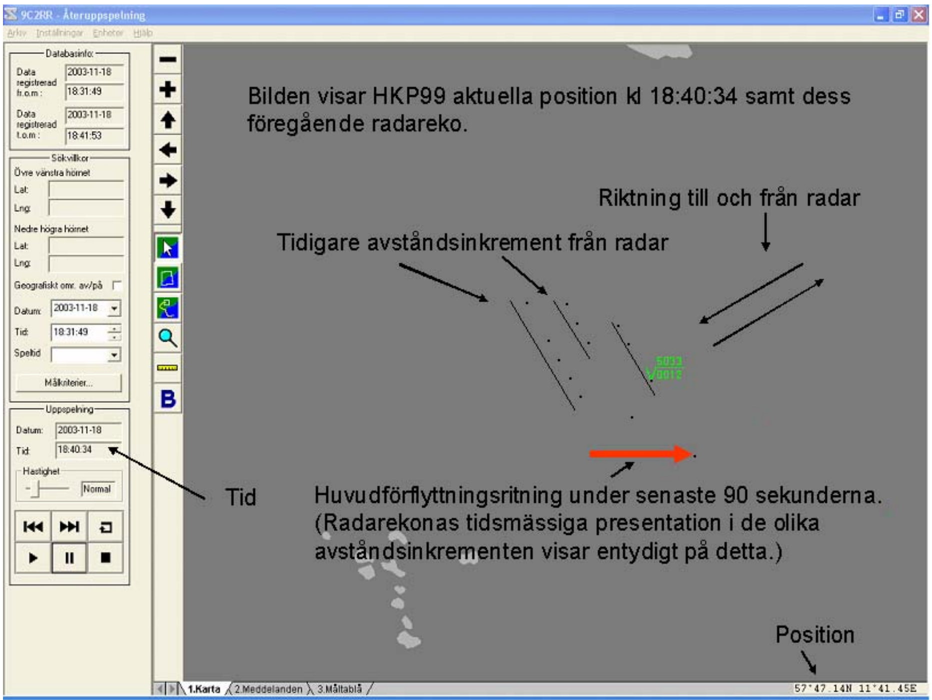

Fig. 19: *The primary and secondary radar picture shows the position of H99 at 18:40:34 and the SSR response gives the flying altitude as approx. 120 m STD, i.e. approx. 40 m AMSL south-west of Lilla Barlind island. The recordings of the final 90 seconds of the flight clearly show that the helicopter moved at low speed, hovering towards the east.*
Illustration annotations: The image shows the actual position at 18:40:34 and the previous radar echo. Direction to and from radar. Earlier distance increments from the radar. Main direction of flight during the previous 90 seconds. (The time presentation of the radar echoes at the various distance increments clearly show this.)Time.

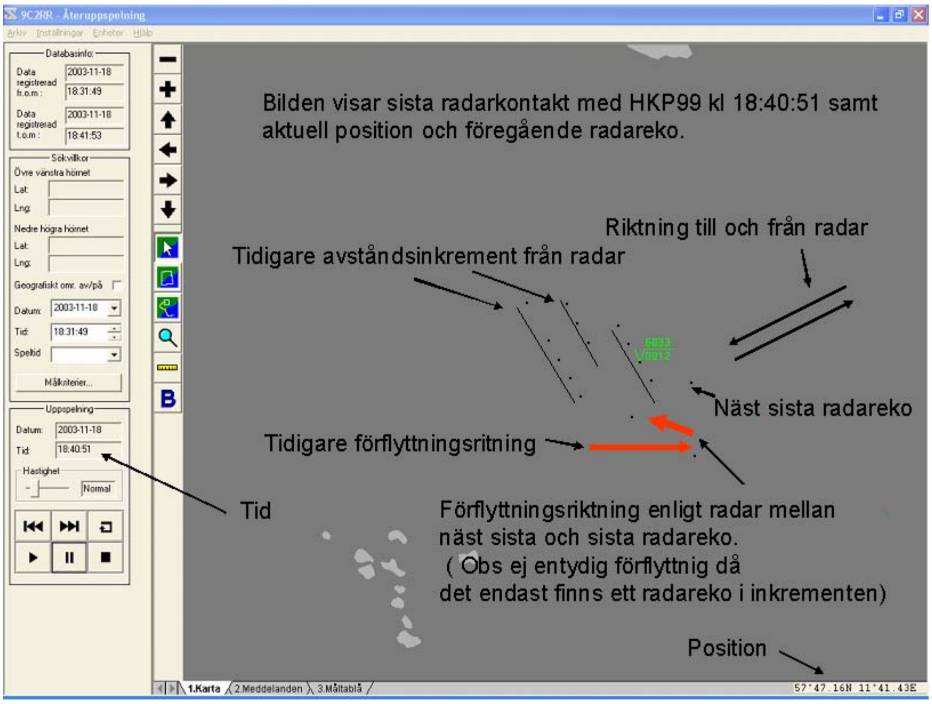

Fig. 20: *The primary and secondary radar picture shows the* **last** *recorded position of H99 at 18:40:51 and the SSR response gives the flying altitude as approx. 120 m STD, i.e. approx. 40 m AMSL. Flying thereafter may have taken place at a height where the radar stations were technically unable to see the helicopter due to terrain masking or the curvature of the earth.*
<u>Illustration annotations:</u> The image shows the last radar contact with HKP99 at 18:40:51, the actual position and the previous radar echo. Direction to and from radar. Earlier distance increments from the radar. Penultimate radar echo. Earlier direction of movement. Direction of movement according to radar between the penultimate and final radar echoes. (Note that the movement is not completely clear as there is only one radar echo in the increment).Time.

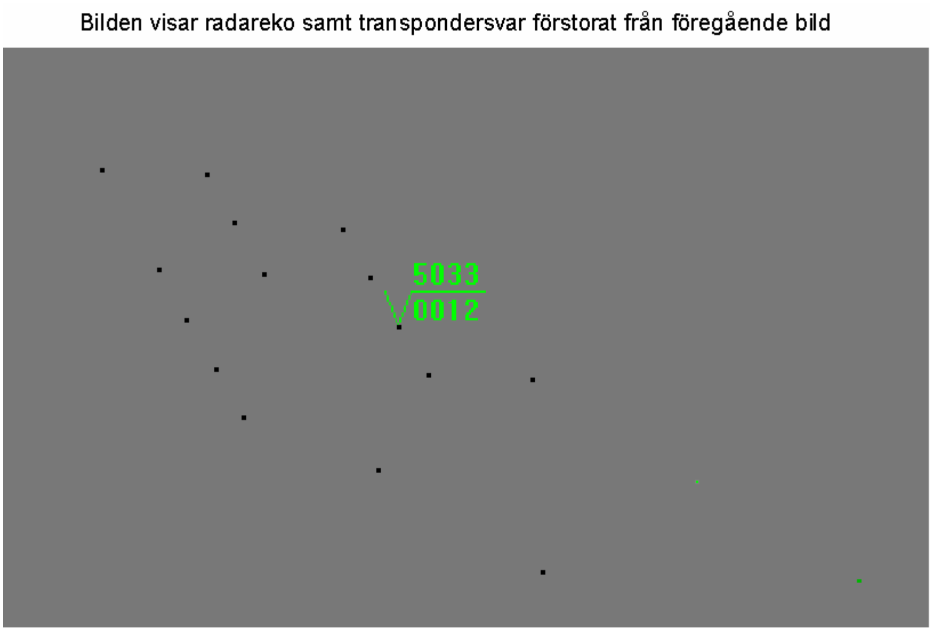

Fig. 21: *The primary and secondary radar picture shows the* **last** *recorded position of H99 at 18:40:51 and the SSR response gives the flying altitude as approx. 120 m STD, i.e. approx. 40 m AMSL south-west of Lilla Barlind. The displayed position of the helicopter is at the tip of the “tick” symbol.*
<u>Illustration annotations:</u> The image shows radar echo and response from the transponder enlarged from the previus picture.

1.11 Aerodrome information

The status of Säve was in accordance with MIL AIP and the airfield was not subject to any restrictions or limitations.

1.12 Flight recorders

1.12.1 Flight Data Recorder (FDR)

At the time of the accident the helicopter was not equipped with a flight data recorder (FDR).

1.12.2 Cockpit Voice Recorder (CVR)

At the time of the accident the helicopter was not equipped with a cockpit voice recorder (CVR).

1.13 Technical investigations

1.13.1 General

In connection with the recovered helicopter being placed in a hangar at the Försvarsmaktens Tekniska Skola (FMTS – Swedish Armed Forces Technical School) at Halmstad an initial inspection and documentation were carried out on the fuselage, engines, rotors and other systems.

After this a large number of investigations were carried out on the various helicopter systems. At various stages of the SHK examination of the helicopter at Halmstad, representatives of Eurocopter, Turboméca, Astec Helicopter Services, Volvo Aero, and the then CSM Materialteknik, later known as Bodycote CSM, and now Bodycote Materials Testing AB, followed the investigations.

External expertise provided support to SHK and carried out the following investigations:

Investigation of	**Carried out by**
Engines	Turboméca, Bodycote CSM, Peter Allen, Astec Helicopter Services och Volvo Aero
Main rotor gearbox and hub. Operating cylinders	Eurocopter
Tail rotor and gearbox	Eurocopter
Fuel and oils	CSM Materialteknik
ELT och homing pinger transmitter	AerotechTelub (now known as Saab Aerotech)
Fuselage structure and main rotor blades	Eurocopter and Bodycote CSM
Instrument panel and flying instruments	Bodycote CSM, AerotechTelub (now known as Saab Aerotech)
Documentation	Swedish armed forces fleet management office
Emergency and safety equipment	Bodycote CSM
Tape recorder with recorded radio communications	Magnic AB

There follows a summary of the results from the investigations of the various sub-systems.

1.13.2 Fuselage

The damage to the front of the helicopter's fuselage mainly indicates that the collision forces were from the front, slightly to the left, and slightly underneath. The damage also indicated that at the time of the collision the helicopter had some forward speed, clearly exceeding hovering speed. The damage to parts inside the helicopter also showed that water had entered the cabin at high speed. Despite the fuselage being subjected to forces that were mainly from the front, individual components such as the engines and their platform showed that they had been subjected to forces from underneath. Due to evidence of paint scraping it can be concluded that several main rotor blades had made contact with the top of the structure of the left cockpit door, the engine housings and the area close to the left engine air intake screen.

The rear of the fuselage was recovered from about 500 m away from the collision site. The tail boom was broken/cut off immediately in front of the ventral fin. The reason for the tail boom breaking off was that it was struck repeatedly by the main rotor blades. There were indentation marks from the collision with the water on the front part of the floor in the rear of the fuselage. The landing gear was retracted and the emergency flotation gear was not activated. The nose wheel was bent to the right, which shows that during the collision the helicopter was moving or leaning to the left.

The two fold-down engine covers were in place and correctly latched. After inspection of the fuselage wreckage and making calculations with the aid of a simulation program, Eurocopter concluded that the helicopter was travelling at about 80 knots, had a sink rate of >10 m/s and was in a "nose down" attitude and a negative flight path vector at the time of the collision.

1.13.3 Engines

The engines, gearboxes, drive shafts and rotors were examined by the manufacturers Eurocopter and Turboméca at their factories in France. The parts were accompanied to France by people assigned as technical experts by SHK, who also participated in and monitored the inspections.

Representatives of the manufacturers Eurocopter and Turboméca and the maintenance suppliers Astec Helicopter Services, Volvo Aero and Bodycote CSM participated in the examinations of the helicopter in December 2003 and May 2005 at Halmstad.

Both engines showed similar tangential damage in both the compressor and turbine stages. Both of the engine compressor blades of the first compressor stage showed symmetrical damage diametrically.

The damage observed to the engines was, after careful and comprehensive examination adjudged to have occurred due to the vertical forces that arose when the helicopter collided with the water. There were no indications that the damage to the first compressor stage blades occurred before colliding with the water.

It was not possible to ascertain whether the bleed offset was activated at the time of the collision with the water.

During the technical examination of the engines there were no indications that the engines were not operating normally.

Fig. 22: *The first compressor stages of the right engine (#2, left-hand picture) and left engine (#1, right-hand picture) photographed from the front. The symmetrical locations of the damage to the compressor blades can be seen in the pictures.*

1.13.4 Power transmission

The power transmission system was examined in Sweden and by the manufacturer. There were no indications that the power transmission did not operate normally.

1.13.5 Main and tail rotors, including hubs and rotor blades

The results of the examinations that were carried out in Sweden and by the manufacturer showed no damage or faults in the system before colliding with the water.

It was revealed by the examination that the main rotor hub had been subjected to large forces, showing that the drive from the engines was transmitting power, at the time the main rotor blades struck the water and the helicopter. The extensive damage to the main rotor blades confirms this.

Examination of the tail rotor showed that it was operating until the moment that the tail boom and drive shafts broke. Only one blade was broken off, which supports the fact that the tail rotor stopped due to losing its drive and not because it collided with any fixed object during normal operation.

1.13.6 Hydraulic system

The helicopter's hydraulic system was examined and no deviations or faults were identified. The damage was due to impact with the water.

1.13.7 Flight control system including Autopilot/Flight Director Coupler

The basic flight control system had only one damaged area which was due to overload failure associated with the impact with the water. All the hydraulic actuators in the control system were examined and there was nothing to report.

All six channel selection buttons on the AP panel were in the depressed position. In respect of the two lane selection buttons it could not be established whether they had been activated, as the buttons have return springs.

The coupler panel function pushbuttons/switches have return springs so it could not be established which function was activated.

On the HKP10 system there were a number of operational reports (DA - driftstörningsanmälningar) in respect of disconnection of the coupler modes.

However, the particular apparatus installed in the crashed helicopter did not show any abnormal fault functions.

The examination could not reveal any faults in the AP/Coupler.

1.13.8 Electrical system

No damage or faults apart from the impact damage could be identified.

1.13.9 Flight instruments

The instruments in the helicopter's instrument panel have been examined at Bodycote CSM at Linköping. There were no indentations on the dial gauges to indicate values representative of the instant of impact. The engine instruments however showed values that were representative of the condition they were in when electrical current to the instruments was interrupted. They indicated normal engine values (Ng), higher than normal exhaust temperature (T4) for one engine and a high but acceptable torque indication. The triple needle instrument showing the rotor and free turbine rotation speeds (Nr+Nf), showed normal values. The high exhaust temperature can perhaps be explained by different power outputs between the engines at the instant of impact. The examination showed that all the engine values, as far as they could be analysed, were normal at this stage of flight and for the actual flying weight.

Some of the instruments depend on air pressure. In connection with the water impact they lost this information.

The EFIS instrument lost its information when the electrical current flow stopped in connection with the impact.

On the HKP10 system there were a number of operational reports (DA - driftstörningsanmälningar) in respect of the attitude director indicator, ADI, extinguishing during flight. A review of the technical reports written for the individual apparatus in the system showed that faults had been found. One individual apparatus (the display control panel) in the crashed helicopter showed a higher fault rate than normal. In all there were nine faults reported for this unit, but only two faults had been reported in the most recent four years before the accident.

The standby attitude indicator showed a value of over 20° left bank and a few degrees nose down. The gyro was locked due to impurities when salt water entered the gyro ball bearings. Examination did not reveal any mechanical locking that could lead to impact with the water.

The needle on the first pilot's RHM was at about 30 feet and that of the second pilot was at about 20 feet. Both RHMs were set for a decision height of 30 feet.

As a result of the EFIS extinguishing in HKP10 that had occurred, the Armed Forces Headquarters Air Force Flight safety department (HKV GRO FV Flygsäkerhetsavdelning) issued an operational order (3 February 2005, Diary no. 02 810:61911) to the Helicopter Wing. Because of this order the Helicopter Wing (chief of the standardisation group and HKP10 chief pilot) issued a flight instruction (flyganvisning – FA no. 05-02), on 3 March 2005 that described the emergency procedure/measures to be taken if the EFIS extinguished.

1.13.10 Warning and indication lights

The light bulbs on the instrument panel (main warnings, warning panel and other indication lights) along with the light bulbs in the coupler, autopilot panel and RADAR-RAMS were examined by Bodycote CSM with the intention of determining the state of the lights at the time of the accident. Altogether 227 warning and indication light bulbs from the accident and ten or so reference light bulbs were examined.

The mechanical shock generated in a light bulb filament due to acceleration in connection with an accident can cause deformation and fracture with a characteristic appearance depending on whether the filament is hot or cold when the deformation takes place.

In a light bulb that is subjected to severe acceleration the filament coil straightens out. The extent of this depends on the age of the light bulb, the amount of force and whether the filament is hot or cold. If the filament has also broken, the break can reveal whether this took place while it was hot (with voltage applied) or in a cold condition. If the filament is subjected to voltage at the instant of breakage pearls of melted filament form at the place of breakage, or the filament material becomes soft. In a cold condition the fracture is brittle, with transverse flat fracture surfaces.

As criteria for the on condition during examination, the degree of deformation/stretching of the filament coil is used, and possibly the character of the fracture.

The most definitive, clear proof that a light bulb was on when the filament broke is that there are melted pearls at the ends of the fracture.

If a light bulb filament is brittle and the filament coil has not straightened out, or only to a small extent, it is probable that the light bulb was not on. A complicating factor is however that a cold, almost new light bulb filament coil can be stretched without breaking.

The filament in a light bulb that is on cools down very quickly when the current is switched off and can therefore appear as a brittle fracture when subjected to G forces in a cold condition after the light bulb has extinguished.

For each light bulb that was examined the filament stretch and fracture were documented. Any fracture surfaces were studied at high magnification with a scanning electron microscope.

The examination found that the filaments in the following light bulbs had no, light or medium stretching:

- main warning light bulbs
- light bulbs in the warning panel (α 32),
- other indication light bulbs on the instrument panel, left and right side DOPMEM, left and right side annunciator panel AP, left and right side L/G, POWER 1 and POWER 2, RAMS CKPT-CABIN and RADAR CKPT-CABIN,
- the coupler panel,
- the operating and indication panel RAMS, Radar and EFIS at the operator's table and
- eight of the 21 light bulbs on the AP panel.

The following light bulbs had severely stretched filaments:

- 13 of the 21 light bulbs on the AP panel.

The indicator light bulbs for the bleed offset function were not recovered.

Out of all the examined warning and indication light bulbs, only the light bulbs in the AP panel had severely stretched filaments and thereby clearly showed that they were on while being subjected to powerful deformation.

1.13.11 Communications system

All the in-flight radio apparatus (FR) was examined to try to determine if they were switched on and which frequencies or channels were selected. The examination was unable to determine which frequencies were set on the FR31, FR43 or FR47.

The examination was able to determine that the left knob on the FR48 was set to manual (MAN), which means that the operator selected the frequency himself instead of any of the 30 preselected frequencies. The knob at the right was set to OFF, which indicates that the radio was switched off.

From the recorded radio communication with ARCC it was determined that the operator had radio contact with ARCC, on VHF channel 67, and reported the crew's intention to practise with *Märta Collin*. It was not possible to determine which radio apparatus was used for this.

1.13.12 Spotlights

It was not possible to determine which spotlights were lit at the time of the accident since several of them were not recovered or they were damaged on impact with the water.

1.13.13 Fuel and oils

Analysis of fuel and oil samples from all the helicopter's components was performed by Bodycote CSM and the test results were normal. All magnetic plugs were checked and found normal.

1.13.14 Other

On examining the sub-panel it was found that the AURAL WARNING switch was in the OFF position.

On examining the emergency transmitter (ELT) at AerotechTelub, it was found that the battery was discharged. The discharged battery could indicate that either it was discharged due to the ELT being activated, or that it was discharged due to the length of time it was in salt water, providing a current path between the battery terminals. The design of the ELT means that it is not possible to determine whether the transmitter was activated in the accident. The damage to the bracket indicates however that the ELT was subjected to sufficiently high G forces to activate the transmitter (>5 G).

The transmitter did not operate when tested with a new battery.

The pinger transmitter was examined at AerotechTelub, by reference to UFA Flyg 280 4081C. The carrier frequency, pulse repetition frequency and battery voltage were within the stated values. The pinger transmitter water-activated switch operated normally. This means that was very probably activated while it was in the water.

On the helicopter wreckage that was recovered there were no signs of fire or explosion.

All four first aid bags in the cabin had separated from their frames without damage to the frames, securing straps or bag contents.

1.14 Operational flight conditions

1.14.1 Airborne search and rescue standby (Flygräddningsberedskap – FRÄD)

During the evening the crew had the task of SAR standby for flights being carried out from the airfield at Linköping (Malmen). All aircraft commanders who are on SAR standby have a permanent Decision on flying (BOF) from the Flight Operations commander or Flying Squadron commander to respond to real search and rescue missions on receiving a callout alarm from ARCC. According to the BOF, they are also able to exercise the crew, e.g. by winching to a vessel, as was planned for that evening.

1.14.2 The evening's flights

During the evening, two flights were planned with the *Märta Collin* in the coastal waters east of Rörö. A flight engineer, who was not on duty that evening but was present at the briefing at 15:45, stated that the aircraft commander was somewhat dubious about flying, due to the weather conditions, since it was the conscript's first opportunity to winch with a stretcher in darkness. The aircraft commander proposed that the exercise should be carried out over the airfield. The rest of the crew thought it was a good opportunity to practice in the prevailing weather conditions and pointed out that it would be a good exercise for the whole crew. In addition the crew of the *Märta Collin* were already apprised and had agreed to take part in the exercise.

The prevailing weather met the OSF requirements for performing such a flight. After discussion with the rest of the crew, the aircraft commander decided to carry out both flights in accordance with the original plan, and gave the crew the air mission briefing (OFFG) after the weather briefing from the meteorologist. SHK has not been able to determine how detailed the aircraft commander's verbal briefing was for the flights in question at the OFFG.

According to the written flight programme for that evening's flight operations, only the winching exercise off Rörö was due to be flown. The programme did not give any details of the exercise, route or heights.

GFSU for an HKP10 crew is to carried out in accordance with the UHU training instructions for the HKP10. These instructions also apply to fully trained crews where applicable.

According to UHU HKP10 Part 2 the following flying exercises can be valid for the planned exercise with water contact and contact with the *Märta Collin* (winching target):

- 21:4 = Automatic descent to water contact <u>with</u> coupler.
- 21:5 = Instrument flying procedure for descent to water contact <u>without</u> coupler.
- 21:6 = Instrument approach to vessel with the aid of radar.

For the winching itself to the vessel there is the following exercise in UHU HKP10:

- 50:3 = Hoisting of a survivor from a vessel..

The above exercises can be generally described as follows:

Take-off and approach to the vessel are carried out by the first pilot by flying on instruments and steered by the operator. The second pilot monitors the flying and assists the first pilot as requested. Flying is carried out above obstacle height (>500 ft) over land, over the highest obstacles. After reaching water, the operator informs the pilot that it is clear to reduce height. The operator localises and steers the pilot towards the vessel with the aid of radar, among other things. The helicopter flies in over the vessel and "gets ready". Then there is a descent, transition down, with or without the aid of the AP/Coupler. Flying out is normally at 500 ft/100 kt and there must be a check that the emergency flotation equipment is armed. There is then a turn back towards the vessel and a descent is started at about 500 ft/min at a speed of 70 kt. When the helicopter has reached the selected hovering height (150-40 ft) the speed is reduced to hovering speed, <40 kt.

The second pilot tries to get a visual reference, e.g. the water surface or the vessel. Only when the second pilot has visual contact is this reported to the first pilot, who then transfers to visual flying.

The first pilot can then gradually approach the vessel to carry out the planned winching.

An alternative procedure is for the operator, with the aid of radar, to steer the helicopter straight towards the preliminary position for final approach and a hovering point, that enables further movement for winching. This method is mainly used when the position of the vessel is known, and the exercise is intended to be carried out several times.

The setting of decision height (DH) on the RHM is not regulated by the HKP10 Flight Manual.

In UHU HKP10 there is advice for how DH is to be utilised when flying to water contact. In exercise 21:4 “Automatic descent to water contact with coupler” it states that on the approach the first pilot is to set his DH to 30 ft and the second pilot is to set his DH at half the flying height. During the descent the second pilot is to change his DH to 30 ft.

In exercise 21:5 “Instrument flying procedure for descent to water contact over the sea without coupler” it states that on the approach the first pilot is to set his DH to 50 ft and the second pilot is to set his DH at half the flying height. During the descent it states that the second pilot is to change his DH to 30 ft. In the illustration for exercise 21:5 it shows however that the second pilot, during the descent, must set his DH to **50** ft.

In interviews with flying personnel it emerged that the second pilot usually sets his DH to half the flying height, unless the first pilot decides otherwise. Just before, or at the commencement of, the final descent, the second pilot sets his DH to 30 ft, i.e. 10 ft below the intended hovering height. This is to avoid “fly up” when flying with an activated AP/coupler, or to avoid the acoustic warning from the DH when flying manually.

1.14.3 *Normal take-off*

According to the HKP10 Flight Manual Part 2, Section II, page 16, a normal take-off is performed as follows:

1. Hover at 15 ft into wind
2. Read the blade angle
3. Lower the nose 5-10° and increase the blade angle approx. 1°
4. Increase speed to 40 kt/100 ft
5. Continue accelerating to 70 kt/300 ft

During take-off the first pilot controls the helicopter and the second pilot assists by monitoring the flying, ready to immediately take control if necessary.

1.14.4 *Take-off on instruments*

According to the HKP10 Flight Manual Part 2, Section II, page 16, an instrument take-off is performed as follows:

1.	CPL and F/D	ON
2.	Set the take-off course using the HDG bug	
3.	Set the variometer index	DESIRED POSITION
4.	TRIM COLL REL	DESIRED POSITION
5.	Hover up and trim at 15 ft	
6.	Instruments check	
7.	Lower the nose 5-10° and increase the blade angle approx. 1°	
8.	Increase speed to 40 kt/100 ft	
9.	Continue accelerating to 70 kt/300 ft	
10.	HDG	ON (as necessary) (See remarks)
11.	ALT or V/S	ON (as necessary) (See remarks)

Remarks: To be switched in at IAS >40 kt in the case of 4-axis flying and at IAS >70 kt in the case of 3-axis flying.

During an instrument take-off the first pilot monitors the flight path situation with the aid of the flight instruments and the second pilot assists by monitoring the flight path, ready to immediately take control if necessary.

When flying in darkness the second pilot, during the take-off also moves the SX-16 spotlight to the position desired by the first pilot.

1.14.5 Emergency landing

According to the HKP10 Flight Manual Part 2, Section III, pages 37-38, an emergency landing is performed as follows:

Failure of one engine during hovering out of ground effect:

1.	Take a nose-down attitude	15-20°
2.	Blade angle	approx. 14°

…over terrain suitable for landing (water). Without single-engine performance:

3. (Release the emergency floats)
4. Do not exceed 40 kt
5. Raise the nose to max. 10° at 20 ft
6. Reduce the rate of descent with the collective lever
7. Apply braking when the nose wheel is on the ground

…over terrain unsuitable for landing:

3.	At 30 kt gradually reduce the attitude	
4.	Climb at 45 kt to 2000 ft	
5.	Landing gear	IN
6.	Continue climbing while accelerating to 70 kt	
7.	Reduce power to 30 minutes rated power output	
8.	Abort the task	

Single-engine performance means that with just one engine operating the helicopter can continue to hover and thereafter perform a take-off without losing height.

1.15 Accident site

The accident site was in the sea about 4.2 km ENE of Rörö.

At the position 57°47.14′ N 11°41.05′ E (salvage site 1) were found the front fuselage of the helicopter, the engines and MGB with the main rotor.

At the position 57°47.33′ N 11°40.60′ E (salvage site 2) were found the rear fuselage with the tail rotor.

The water depth at both locations was about 12 m.

1.16 Medical information

All the crew members had undergone the prescribed medical examinations in accordance with OSF, without remarks.

No unauthorised substances were found in the crew.

During the period 15 May 2001 — 29 April 2002 the second pilot had been grounded due to a heart complaint. After this, during the period 30 April 2002 — 24 August 2003 he had a dispensation with a permit to fly accompanied. At the time of the accident he had regained flight status without restrictions.

1.17 Fire

No traces of fire were found.

1.18 Actions by the rescue services

1.18.1 Rescue services in the case of aircraft accidents

Search and rescue duty[5] is a national obligation. Airborne search and rescue searches for and locates missing aircraft. When an aircraft comes down into the sea, airborne search and rescue also has the responsibility for relief and rescue efforts.

For every rescue task there is a rescue leader to lead and co-ordinate the efforts. A government or local district authority shall, at the rescue leader's request, participate with suitable resources in a rescue effort.

The government authority and local district rescue services also have a specific responsibility to co-operate and co-ordinate the work they do with each other and with others involved.

1.18.2 Flygräddningstjänsten, Airborne SAR (Search And Rescue)

Swedish airborne search and rescue is planned and organised in accordance with internationally agreed principles. The airborne search and rescue service is controlled, in addition to Swedish legislation, by international conventions laid down by the ICAO (International Civil Aviation Organization).

In respect of Sweden, the airborne search and rescue service is managed by the Swedish Civil Aviation Administration[6] Aeronautical Rescue Co-ordination Centre (ARCC) in Göteborg with the radio call sign "Sweden Air Rescue". The Search and Rescue centre is co-located with the Maritime Rescue Co-ordination Centre (MRCC), the Coastguard regional management west and the Swedish Armed Forces maritime surveillance centre west. In the rest of this document the co-located centres are called the Rescue centre. For staff work during a rescue, the rescue leader has access to staff from the co-located authorities. In connection with the helicopter accident various tasks were distributed among the centres, and staff briefings were held for directives and briefing on the current situation. Off-duty personnel also helped with necessary tasks in the severely stretched centres and were later responsible for relieving the personnel on assigned duty.

The rescue leader leads the efforts from the ARCC, regardless of where in the country the search area or accident site may be located. The Swedish Civil Aviation Authority does not have resources of its own, but uses those of the co-operating authorities and organisations, such as the Swedish Maritime Administration, the Police, the Coastguard and the Swedish Armed Forces. There are agreements that secure helicopter readiness for the airborne search and rescue tasks. With reference to the search and rescue legislation, suitable units can be utilised during a rescue.

When a co-ordinated function is needed in the area of the rescue efforts, the rescue leader can, via ARCC, assign a suitable person or unit to the OSC (On Scene Co-ordinator) and an ACO (Aircraft Co-ordinator). The OSC shall act as the extended arm of the rescue leader and co-ordinate the rescue efforts on site. The ACO is a function for co-ordinating several in-flight units during the rescue efforts.

1.18.3 Co-operating authorities and organisations

Maritime rescue

The Swedish Maritime Administration's Maritime Rescue Co-ordination Centre, MRCC, with the radio call sign "Swedish Rescue", leads maritime rescue efforts in the search and rescue of people in distress at sea.

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[5] There is a requirement for airborne search and rescue services in the rescue services legislation (1986:1102) and from 1 January 2004 in the legislation (2003:778) concerning prevention of accidents

[6] The Swedish Civil Aviation Authority from March 2005 onwards

The MRCC uses the Swedish Maritime Administration's own resources, and those of the Police and other national and local districts. Further resources are trading vessels, fishing vessels and leisure craft.

Other resources
Coastguard resources that are on standby also participate as needed in rescue tasks.

Sjöräddningssällskapet (SSRS - the Swedish Sea Rescue Society) is a voluntary society which has over 100 vessels at various maritime rescue stations along the coast of Sweden. As a rule, the closest maritime rescue station is called out for maritime rescue tasks.

As support for the general public, the Swedish Armed Forces can contribute resources in connection with major disasters. At the time of the accident the Älvsborg amphibious regiment (Amf4) was stationed at Göteborg. Amphibious regiments operate with vessels and personnel in the transition between sea and land.

SOS Alarm Sverige AB (SOS Alarm) has by means of an agreement with the state the task, among other things, of responding to the common alarm telephone number 112. This task also involves co-operation with the Airborne and Maritime Rescue centres.

The SOS centre in Göteborg is co-located with the Greater Göteborg Rescue service. From here the rescue service units and resources from the ambulance service in Göteborg are called out and directed. In addition to ambulance road vehicles there is an ambulance vessel, and an ambulance helicopter based at Säve airfield.

1.18.4 Sequence of events from the search and rescue perspective

Incoming and outgoing alarms
The Rescue centre received a call on VHF channel 16 at 18:44 (reference time[7] +0 min). It was a call from *Märta Collin*. The call was transferred to VHF channel 67 and the *Märta Collin* reported at 18:45 (+1 min) that helicopter H99 had impacted the water at Lilla Barlind. The message reported that *Märta Collin* was at the accident site and that one person from the helicopter had been seen in the water together with a lot of wreckage.

At 18:46 (+2 min) the Rescue centre sent an alarm to the rescue vessel *PO Hanson* at the SSRS station in Hovås. At the same time, the Rescue centre broadcast a general call on VHF channel 16. Maritime rescue units were sought in the area of Barlind east of Rörö. At the time of the accident ARCC had methods for handling alarms to sea-going rescue units via MRCC. At the same time there was no specified action plan for aircraft accident rescue.

Police boat *7050* was located just north of Varholmen when they heard the call from *Märta Collin* to the Rescue centre. When the police boat contacted the *Märta Collin* it was reported that there were people in the water and the police boat was asked to come as quickly as possible. The police boat arrived at the *Märta Collin* at 18:57 (+13 min). The Coastguard vessel *KBV050* answered the general call from the Rescue centre immediately and reported that they were at Björkö, east of Knippla. *KBV050* had launched R.I.B. boat *KBV483* and arrived at the accident area at 19:04 (+20 min). At 18:46 (+2 min) the Rescue centre sent an alarm to the Swedish Armed Forces search and rescue helicopter H96 at Ronneby. The helicopter, which was equipped and manned with a winch and rescue swimmer, was airborne at the time and went directly towards Säve. The flying time with that type of helicopter from Ronneby to Säve is 1.5 hours. The rescue leader decided at 19:21 (+37 min) that the helicopter should be recalled to Ronneby. The reason given for this was that the search area was judged to be very limited and

[7] 18:44 is the reference time for time comparison with later events

that there were many sea-going units that had reported in. The crew of H96 asked if they could continue to fly towards Säve but were ordered by ARCC to return to Ronneby. At the same time it was made clear that the Swedish Armed Forces had no helicopter at Säve that could participate in the rescue.

The Swedish Maritime Administration's VTS[8] at Marstrand had noted that there was a helicopter accident in the vicinity and called the Rescue centre at 18:47 (+3 min). It was decided that pilot boat *742* should go to the accident site. The pilot boat arrived in the area of Barlind at 19:24:00 (+40 min).

At 18:49 (+5 min) the Rescue centre notified SOS Alarm in Göteborg and requested the assistance of the ambulance helicopter based at Säve. The crew of the ambulance helicopter reported that they could not fly due to the bad weather conditions. SOS Alarm informed the Rescue centre at 19:01 (+17 min) that two ambulances and an accident ambulance (OLA[9]) were on the way to Lilla Varholmen. There was a suitable quay at that location specified by the rescue leader for bringing injured people ashore.

At 18:50 (+6 min) the Swedish Armed Forces vessel *HMS Grundsund* which had deep-sea divers on board and was lying at Marstrand was given the alarm.

The fishing boat *Falken* reported to *Märta Collin* at 18:50 (+6 min) that they were nearby and would go to the accident site. The fishing boat had powerful lights. The *Märta Collin* was called by the fishing boat *Rebecca* at 18:54 (+10 min). Similar to the *Falken* the *Rebecca* carried powerful lighting amounting altogether to 10 000 W. *Rebecca* arrived in the area at about 19:00 (+16 min). A third fishing boat, the *Astrid*, arrived at about the same time at the accident site.

The *KBV303* reported at 18:53 (+9 min) that they had information about the helicopter accident and were on the way from Rönnäng towards Barlind. *KBV303* did not however understand that it was the island of Barlind east of Rörö that had been reported. Therefore *KBV303* first went to the island of Barrlind west of Tjörnekalv. By 19:28 (+44 min) the vessel was however at the accident site and reported this to the *Märta Collin*.

A second police boat, *7060*, went from Nya Varvet in Göteborg to the accident site at 19:09 (+25 min).

At 19:16 (+32 min) the Rescue centre checked whether the police helicopter at Säve could perform an ambulance task. The personnel were at readiness at Säve but could not fly due to the weather. At this stage the police helicopter personnel had not been given the information that this concerned a helicopter accident off Rörö.

The Swedish Armed Forces maritime transport centre at Amf4 had received the information about the accident via news reports to the general public. They reported to the Rescue centre at 19:35 (+51 min) that assault boat *930* was available as a resource for the rescue. The boat reported that it had arrived in the area at 20:08 (+1 hour 24 min.).

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[8] VTS: Vessel Traffic Service, traffic information centre
[9] OLA: Accident ambulance with specially trained paramedical personnel

Units which participated in the rescue between 18:42 – 02:10:

Time	Unit	Rescue centre alarm	VHF alarm	Received an alarm in another way	Arrived at
18:42	*H99* crashed				
18:42	*Märta Collin*			Saw H99 crash	
18:44	MRCC, Sweden Rescue			Alarm from the *Märta Collin*	
18:46	*PO Hansson*	X			19:30
18:46	Units in the vicinity	X	X		
18:46	*Police boat 7050*			Heard the alarm from the *Märta Collin*	18:57
18:46	*KBV050* including R.I.B boat *KBV483*		X		19:04
18:46	*H96*, SAR helicopter	X			Recalled at 19:21
18:47	*Pilot boat 742*			From VTS Marstrand	19:24
18:49	SOS Alarm	X			
18:51	Ambulance helicopter			SOS Alarm	Unable to fly due to weather
18:50	*Grundsund*	X			20:02
18:50	*Falken*, fishing boat		X		19:00
18:53	*KBV303*		X		19:28
18:54	*Rebecca*, fishing boat		X		19:00
18:54	*Astrid*, fishing boat		X		19:00
19:07	Divers from Greater Göteborg Rescue service			SOS Alarm/Rescue service alarm centre	19:51
19:07 -	Ambulances and doctor team			SOS Alarm	19:17 - 19:37 Meeting place Lilla Varholmen
19:09	*Police boat 7060*			Police control centre	19:35
19:16	*Police helicopter 942*	Request for ambulance task			Unable to fly due to weather
19:35	*Assault boat 930*			General public news report	20:08
20:11	Survey vessel *Ping*	X			22:20
20:23	*Police helicopter 942* takes off from Säve				20:30 *Police helicopter 942* aborts due to weather
01:10	*Police helicopter 942* takes off from Säve and flies towards the area				02:10 *Police helicopter 942* lands at Säve

<u>Organisation and implementation of the rescue efforts at the accident site</u>
The *Märta Collin* naturally became the unit on which the Rescue centre concentrated the co-ordination at the outset of the rescue efforts. The Rescue centre was in contact with the *Märta Collin* among others at 19:01 (+17 min). It was decided that the rescue swimmer who had been rescued should be taken to Lilla Varholmen by police boat *7050*. Ambulances should go there since the ambulance helicopter, due to the poor weather conditions, could not fly to Rörö as previously stated. From the *Märta Collin* it was reported that the rescued person had pain in his eyes due to the fuel from the helicopter.

The fishing boats *Falken, Rebecca* and *Astrid* arrived in the area by 19:00 and started to search for people in the water. According to the skipper of the *Rebecca* the current was flowing at 315° at a speed of about 1 knot.

At 19:04 (+20 min) the *Rebecca* found the body of the student flight engineer. The position of the find was at 57°47.50′ N 11°40.49′ E (fig. 23). It was difficult for the crew to see him. The most visible were his boots, which were light gray. He had no helmet and lay face down in the water when found. Police boat *7050* arrived at the location and helped to lift his body on to the deck of the police boat.

At 19:06 (+22 min) the rescue leader gave police boat *7050* the task of transporting the injured rescue swimmer from the *Märta Collin* to meet the waiting ambulances at Lilla Varholmen.

At 19:08 (+24 min) the *KBV483* picked up the body of the student rescue swimmer. He was floating on his stomach with head down and helmet on. The reflectors on the immersion suit were seen first, with the aid of a handheld spotlight at a distance of about 50 m. The position where he was found was estimated at 57°47.44′ N 11°40.64′ E (fig. 23). The body of the student rescue swimmer was taken by *KBV483* in to Lilla Varholmen, where the ambulances were to wait.

KBV050 declined at 19:12 (+28 min) the request from the Rescue centre to co-ordinate the efforts and take on the role of OSC as at the time there were too few on board for the task.

The rescue leader stated at 19:26 (+42 min) that one boat should remain at the accident site. The *Märta Collin* returned and stayed in that position. The *Rebecca* found the body of the second pilot/aircraft commander between 19:04 and 19:29. He lay face down in the water with helmet on and was first seen at an estimated distance of 10-15 m. No exact time or position were given. His body was transferred to the rescue vessel *Astra* at 19:29 (+45 min). The *Astra* had been called out from the *Märta Collin*.

The *Rebecca* found the body of the first pilot at 19:34 (+50 min). The position of the find was at 57°47.50′ N 11°40.49′ E (fig. 23). The *Rebecca* had arrived at what was perceived as the same single flotation vest several times. On the last occasion it was realised that it was the body of a person wearing a flotation vest and without a helmet.

The bodies of the two pilots which had been taken on board the *Astra* were transported by police boat *7050* to Lilla Varholmen. Within 50 minutes of the alarm that the helicopter had crashed, five of the crew members had been found. Three of these were found by the crew of the *Rebecca*.

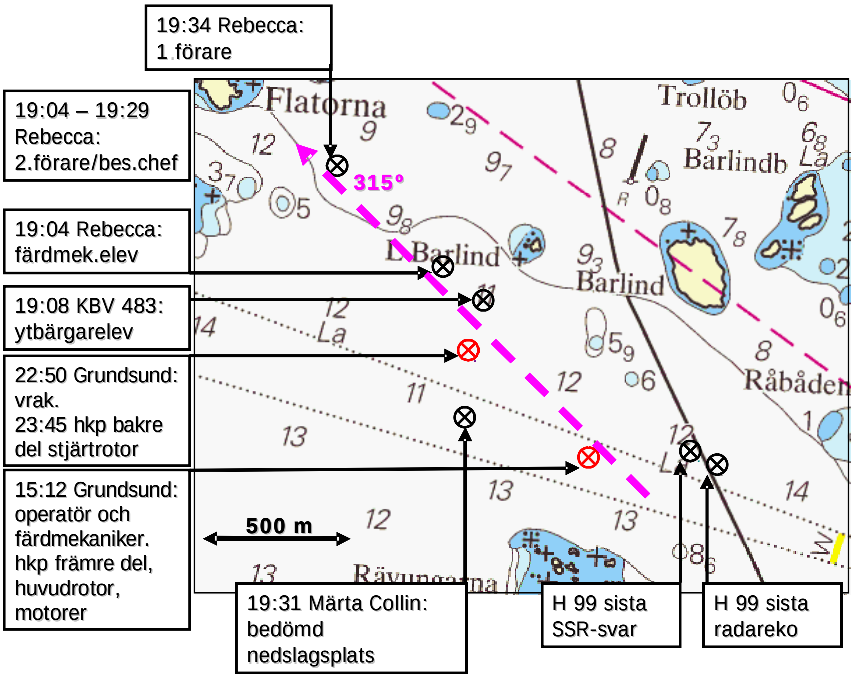

Fig. 23: *Positions where the helicopter and its crew were found by the respective rescue units, with the actual times stated. The position where the body of the second pilot was found was not logged by the Rebecca.*

Illustration annotations:

19:34 Rebecca: First pilot

19:04-19:29 Rebecca: Second pilot/aircraft commander

19:04 Rebecca: Student flight engineer

19:08 KBV 483 Student rescue swimmer

22:50 Grundsund: wreckage
23:45 helicopter rear fuselage, tail rotor

15:12 Grundsund: Operator and flight engineer. Helicopter front fuselage, main rotor, engines

19:31 Märta Collin: estimated impact point

H99 last SSR response

H99 last radar echo

The crew of the *Rebecca* were never certain of who was the leader of the rescue efforts. They did not have anyone giving them direct orders.

The rescue leader did not provide any general directions for the efforts in the form of a general decision (beslut i stort - BIS).

The *Märta Collin* reported at 19:43 (+59 min) to the rescue leader that five people had been found. It was then decided that two people were still missing.

The *Märta Collin* reported at 19:31 and 19:39 (+47 and +55 min respectively) that the estimated position of the impact was 57°47.2′ N 11°40.6′ E (fig. 23).

Police boat *7050* reported to the rescue leader at 19:51 (+1 hour 7 min.) that it had left two people at Lilla Varholmen and was on the way back with divers from the local district Rescue services. The police boat crew asked if an OSC had been assigned. The rescue leader replied that no OSC had been assigned. Co-ordination was carried out by the rescue leader in conjunction with the *Märta Collin*.

PO Hanson arrived in the area of the accident at 19:30 (+44 min). At 20:00 (+1 hour 16 min.) the rescue leader gave *PO Hanson* the task of taking on the role of OSC and organising a trawl with boats in line abreast. All units that were able to participate in a trawl were to gather south-west of the accident site, half a nautical mile[10] from the Kalven lighthouse. The search course was given as 300°, speed four knots and distance between the vessels half a cable[11].

In addition to the *PO Hanson*, police boat *7060*, pilot boat *742*, assault boat *930* and *KBV050* along with *KBV303* took part in the trawl. The search began at about 20:25 (+1 hour 41 min.) (fig. 24). The fishing boats *Astrid, Falken* and *Rebecca* did not take part, as they jointly decided to search among the wreckage in the direction of the current, which in their opinion offered the greatest chance of finding more people from the helicopter.

The *Grundsund* arrived in the area at 20:02:00 (+1 hour 18 min.). *Grundsund* would act as the diving vessel and be responsible for diving at the impact location. The Coastguard and Rescue services divers assembled on the *Grundsund*.

The police helicopter took off from Säve at 20:23 (+1 hour 39 min.) but had to land again at 20:30 due to bad flying weather.

The *PO Hanson* reported at 20:49 (+2 hours 5 min.) to the rescue leader that the trawling boats had arrived at Lyngnholmen (fig. 24). It was decided that trawling should continue on a reverse course back, and much further east. The rescue vessel *Astra* and fishing boat *Astrid* then pointed out that the search should continue on a bearing of 300° with the current to the north-west. The *PO Hanson* then changed the course of the trawl so that it continued north-west towards both the illuminating fishing boats in the area.

A great deal of wreckage was found but was not recovered, as the search was for people in the water. Searches were also conducted around and on the islands to check for equipment that had floated ashore.

The *PO Hanson* reported at 21:29 (+2 hours 45 min.) that the northern limit for the divided trawl was the latitude through Grytan (fig. 24).

Grundsund reported at 21:46 (+3 hours 2 min.) that diving had been carried out in a 30 metre circle around a position given by *Astrid*. Only paint scrapings had been found. The rescue leader ordered *Grundsund* to lead and co-ordinate efforts with *Astrid* which would search with sonar and possibly supplementary diving from *Grundsund*. In addition the survey vessel *Ping* would join in with special underwater search equipment. *Grundsund* felt that the Sjöugglan (underwater search vehicle) that was requisitioned would get in the way of the work in progress and proposed that it should be held in readiness for the time being. The rescue leader decided to delay using the Sjöugglan.

The *PO Hanson* reported at 22:07 (+3 hours 23 min.) to the rescue leader that the trawling boats were at Sälöknapp (fig. 24). They then returned south to the impact location. The *PO Hanson* reported at 22:39 (+3 hours 55 min.) that the trawling boats would pause and their crews would gather on board the *Astra*. Further orders were awaited from the rescue leader. The rescue leader did not carry out a systematic follow-up of how the trawl had been implemented and which islands and beaches had been searched.

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[10] Minute of distance/Nautical mile (Nm): 1 852 metres
[11] Cable length: 185 metres (1/10 Nm)

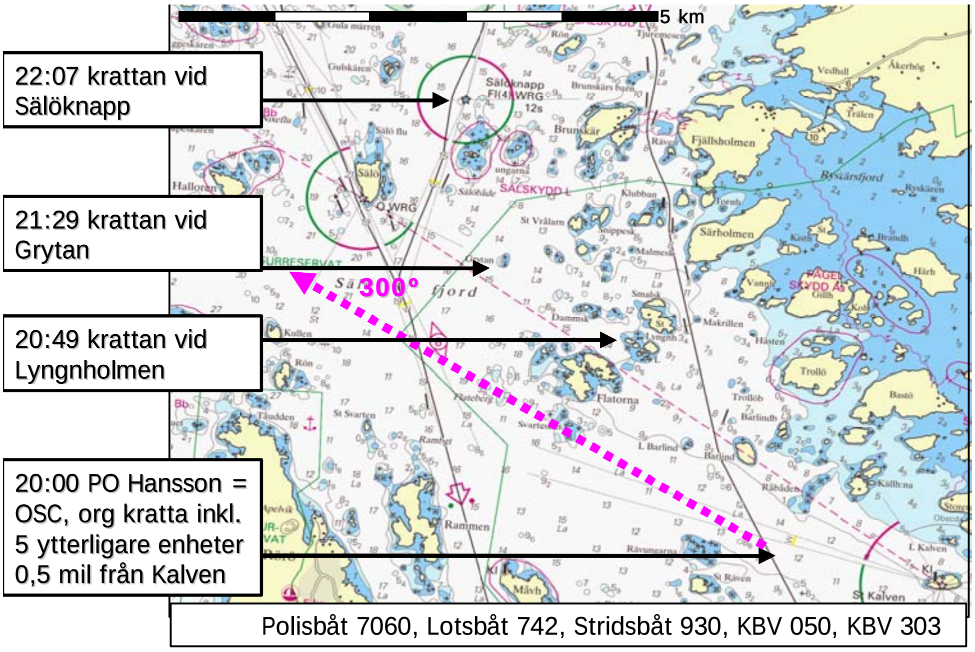

Fig. 24: *Searching was carried out using the trawling method.*

Illustration annotations:

22:07 trawling at Sälöknapp

21:29 trawling at Grytan

20:49 trawling at Lyngholmen

20:00 PO Hansson = OSC, organising trawling icluding 5 further units 5 km from Kalven

The survey vessel *Ping* arrived at the *Grundsund* at 22:20 (+3 hours 36 min.). The *Ping* reported at 22:28 (+3 hours 44 min.) the position of a wreck at 57°47.33′ N 11°40.60′ E. The *Grundsund* reported to the rescue leader at 22:50 (+4 hours 6 min.) that a wreck had been found that was heavily damaged. New divers would go down, equipped among other things with a camera. The *Grundsund* reported at 23:45 (+5 hours 1 min.) that the helicopter was broken into two large parts. The rear lay in the position reported by *Ping* (fig. 23). There were no bodies there. In reply to a question from the rescue leader the *Grundsund* reported at 22:59 that the water temperature was 7 – 8°C.

At the Rescue centre a new rescue leader took over at 23:05 (+4 hours 21 min.). At 23:06 (+4 hours 22 min.) the rescue leader ordered the *PO Hanson* to search at the Barlind islands and south and east thereof, and at Rävungarna. The rescue leader was relieved after 21 minutes.

Police helicopter *942,* that was equipped with a thermal imaging camera, took off from Säve at 01:10 and searched in the area around Barlind island with no results. The helicopter landed at Säve at 02:10.

The *PO Hanson* reported at 01:13 that the wind was westerly, about 10 – 12 m/s with seas of about 1 metre.

Between 01:00 – 02:00 several units abandoned searching in the area. The *PO Hanson* reported at 02:03 that the search was being broken off due to the increasing wind strength. It was blowing at 20 m/s in the gusts. Units that could, were to report to the MRCC at dawn for directives concerning the next day's search.

ARCC decided at 02:49 to terminate the airborne search and rescue, and the Police, Swedish Armed Forces and MRCC were notified.

The *PO Hanson*, which had changed crew, continued the search on its own through the night.

A large number of craft joined in on the morning of 19 November to continue the search for the two who were missing. There were vessels from the Coastguard, the Swedish Sea Rescue Society including the *Märta Collin*, the Swedish Maritime Administration, the Swedish Armed Forces, the Police authorities, and also Coastguard aircraft. *KBV050* took over at 08:20 as OSC and all units were informed of this. The OSC documented which beaches would be searched from vessels or by foot patrols, and which water areas would be searched. The search was implemented during the day in a more organised way than the previous evening.

Police helicopter *942* took off from Säve at 08:29 and proceeded to the assigned search area.

The *Grundsund* reported at 10:54 that the helicopter's cockpit had not been located. The place where the rear lay had been marked out. Searching with an ROV[12] was planned for the afternoon. New dives were started from the *Grundsund* at 11:18. However the divers found nothing.

The search area for the vessels was extended at 11:35 towards the northwest as a result of the finds that had been made. The Rescue centre put out a general call that all units should log all items found and state the time and location of the finds.

Police helicopter *942* reported at 12:44 that they had sighted an oil slick that looked as if it was bubbling up from under water. *KBV 050* went to the location and received a strong echo from the bottom. At the same time they placed a buoy at the location. *Grundsund* reported at 15:12 that divers had found the front part of the wreck and both missing persons, the operator and the flight engineer, at position 57°47.14′ N 11°41.05′ E (fig. 23). According to divers from the *Grundsund* the platform with the engines and main rotor gearbox was lying on its side. Towards the rear, 2.5 – 3 m from the rotor was found the operator, secured by a securing harness to the operator's seat. He was wearing a flotation vest and a helmet. The flight engineer was trapped in the wreckage by his left arm. He had no helmet but was wearing a flotation vest and a winch operator's safety belt.

The rescue was declared terminated by the Rescue centre at 16:35. Salvage operations then began. The two missing persons had been picked up at 17:22 and transferred to police boat *7050* for transport in to land.

The Rescue centre terminated the mission at 21:44.

1.19 Survival aspects

Damage to the helicopter and injuries to the deceased crew were so extensive that there was no possibility of survival. The same conclusions were reached in a report from Eurocopter. Of the six deceased crew, two, the flight engineer and the student rescue swimmer, were not strapped in. The flight engineer was however wearing a winch operator's safety belt with a support line attached to the cabin roof.

The surviving rescue swimmer was not secured by either securing straps or a safety belt. He received only a minor injury when he separated from the helicopter. The crew of the *Märta Collins* stated that they immediately saw the rescue swimmer in the water, as he was wearing a bright green immersion suit with reflective material.

During the search the participating vessels found it very difficult to locate the two pilots and the student flight engineer in the water as they all wore dark green immersion suits without reflectors, intended for helicopter flying duty.

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[12] ROV: Remotely Operated Vehicle

1.20 Tests and research

1.20.1 *Reference flights*

In order to establish the accuracy of the recorded radar returns, three reference flights were carried out in the area of the accident. From these completed reference flights SHK has been able to establish that the accuracy in positioning at the radar stations involved for a stationary or hovering helicopter can vary by up to 100-150 m. This means that a helicopter can be stationary and hovering, while the radar echoes indicate irregular movement within a limited area. The completed reference flights strengthen the opinion that the radar recordings taken during the 90 seconds before the accident indicate hovering or movement at low speed within a limited area. During the reference flights radar contact with the helicopter was lost when flying at a height of 10 m or less. At the time of the accident, radar recordings showed the lowest stated height as about 120 m STD, i.e. about 40 m AMSL before impact with the water. How the helicopter moved after the final recorded radar echo could not be determined, as the radar stations then lost contact with the helicopter.

The presented flying altitude in the radar recordings changes at intervals of 30 metres, so it is not possible to determine the exact height of the helicopter for each radar echo (every 6th second).

1.20.2 *Flying altitude presented as an SSR response*

The radar station altitude responses from the helicopter's transponder present the altitude information as metric standard heights (STD= 1013.2 hPa). The transponder reported flying altitude changes at intervals of 100 feet = 30 m. The transitions from the presented flying altitude to the next higher or lower flying altitude take place at irregular intervals, so that, from the SSR responses, the exact altitude of the helicopter could not be determined on each specific occasion.

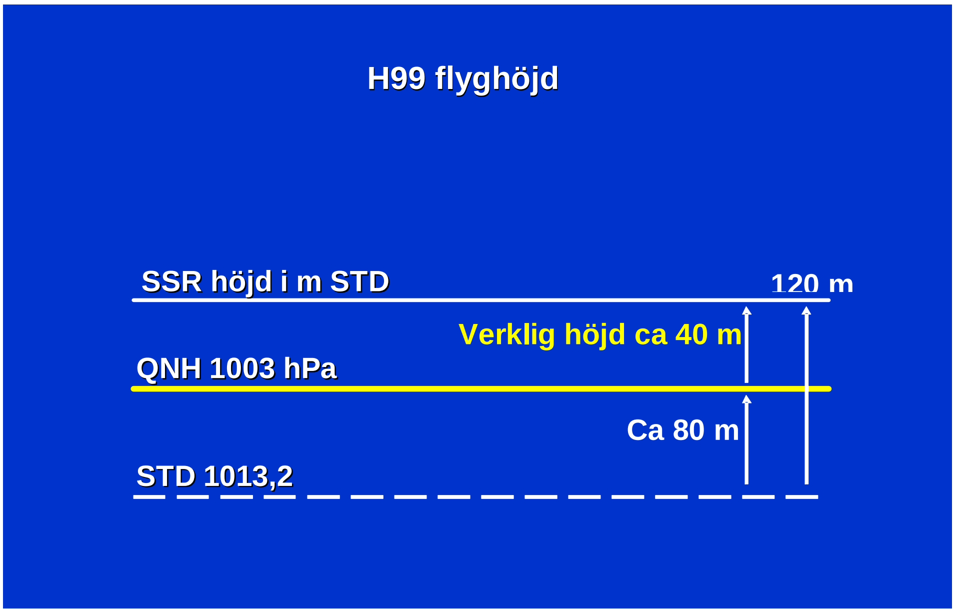

Fig. 25: *The helicopter's transponder (SSR) sends altitudes in standard metres (STD = 1013.2 hPa). To calculate flying height above mean sea level (AMSL) corrections must be made for the actual barometric pressure, QNH = 1003 hPa at the time of the accident, subtracted from the stated SSR altitude (1 hPa = approx. 8 m).*
Illustration annotations: *H99 flying altitude. SSR altitude in metres, STD. Actual height approx. 40 m. Approx. 80 m*

1.20.3 Simulator testing

In connection with flying in a syntetic training device tests were carried out to document the order of sink rate achieved when performing a take-off from hovering, on the basis of the stated conditions. In both cases the tests were from hovering at about 100 ft height. In one case it was a normal take-off with two engines, but with a considerable nose-down attitude that generated a sink rate. In the other case the collective lever was rapidly lowered to its lowest position.

In both cases a sink rate developed of the order of just over 5 m/s.

1.21 Organisational and management information

1.21.1 Organisation of the Helicopter Wing

After a defence decision in 1996 the Helicopter Wing was set up in 1998 to gather all helicopter operations from the various branches of Swedish Armed Forces defence into a joint Wing staff located at Linköping. The new organisation was expected to offer substantial operational, personnel and financial benefits.

As shown in fig. 26 frequent organisational changes were made in connection with and after the Wing system came into operation. The changes brought both mergers and relocation of helicopter operations.

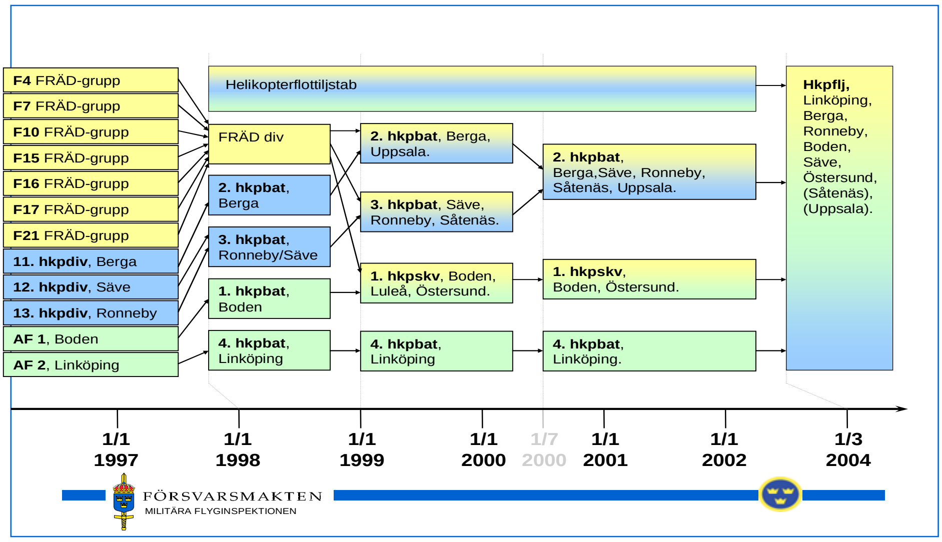

Fig. 26 *The Swedish Armed Forces helicopter operations. Organisational changes from 1997 to 2004. The Swedish Armed Forces helicopter operations are shown in yellow, the Navy's in blue and the Army's in green.*

At the time of the accident the Helicopter Wing had three operational sections, which based their work at eight locations: 1.hkpskv – Boden and Östersund, 2.hkpbat – Berga, Säve, Såtenäs, Ronneby and Uppsala, and 4.hkpbat – Linköping. The Wing staff at Linköping was not, in RML parlance counted as an operator or provider. The operational units were autonomous. The Helicopter Wing was a staff with a co-ordinating role.

The operational units had interim authorisation to carry out flight operations. They had not yet been granted full authorisation and therefore did not fulfil all the applicable requirements of RML. The authorisation process that was in progress with the three operational units had been suspended. Transfer to operational authorisation for the complete Helicopter Wing was planned to take place from 1 January 2003 onwards. This timing was however postponed several times. It was first in connection with the implemented reorganisation in 2004 that the Helicopter Wing obtained an interim operational authorisation.

Merging of the Säve squadron and the Såtenäs SAR squadron was in progress in 2003. At the time of the accident it was apparent that the commander of the Säve squadron would become commander of the entire operations and that the commander of the SAR squadron would become his deputy. The merger was implemented at the turn of the year 2003/2004.

The Battalion commander and Flight Operations commander for 2.hkpbat were located at Berga. Due to the organisational changes their areas of responsibility had successively increased by several helicopter types and one aircraft type, more aviation products and more operational locations with associated personnel. This increase in areas of responsibility does not seem to have been accompanied by an increase in resources. It has become apparent that it was difficult for the Flight Operations commander to follow up the operations at each of the five sites in person. Nor was he authorised to fly the HKP10. During 2003, for various reasons, several different officers held the post of Flight Operations commander at 2.hkpbat.

The Air station commander had the work environment responsibility for personnel at all the outstations. Responsibility for the work environment means being responsible for inspecting, implementing and following up the operations in such a way that ill health and accidents are prevented and that a satisfactory work environment is maintained. The work environment tasks were delegated to directly subordinate commanders. SHK has limited the investigation of the work environment to a study of how the organisational changes were managed prior to and at the time of the accident.

The Swedish Armed Forces have not been able to show that any documented risk assessment was carried out either before the merging of the defence force branches helicopter operations or before the subsequent organisational changes, with the purpose of taking measures to minimise the risks. Nor was there any evaluation performed after the changes. There were no documented procedures for managing organisational changes.

1.21.2 *How personnel perceived the work situation*

The following emerged from interviews with personnel involved in the helicopter operations at Säve and Såtenäs.

The many organisational changes and the question of where the merged helicopter operations for Säve and Såtenäs should be located created a sense of insecurity among the personnel. According to those who were interviewed, there were many indications that the operations would be based at Säve. Some thought however that a base at Säve would be short-lived and that operations would then be moved to Såtenäs. Some said that they felt unsure about their own futures, where they would work and whether they should leave their jobs or not.

Several expressed uncertainty about the organisation's goals and continued direction. There were some expressions of a lack of faith in the Helicopter Wing management. There was also uncertainty about how commanders at lower levels in the organisation were thinking, and the leadership was perceived as being unclear.

In addition, several of the personnel felt that problem resolution was not managed efficiently. Problems that were brought up concerned the fact that there was no prescribed terminology for callouts and standardised procedures with checklists[13] in the HKP10 system. Misunderstandings had occurred during flight, between crew members from different defence branches, operating bases and helicopter systems, for example terms were used that meant different things. Other crew members than the pilots said that they had their own meetings, so-called “confessionals”, to discuss their

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[13] Checklists for how various training exercises should be carried out.

experiences of misunderstandings and lack of standardisation, and to push for development in a positive direction. Debriefing after flying and discussions were however not thought likely to lead to long-lasting improvements. Among the interviewed pilots and commanders the feeling was that decisions on questions dealing with common terminology and standard procedures had to be taken at higher levels in the organisation. They thought that such questions should be taken up in the work on the Flight Operations Manual (FOM).

Several persons said that there was a lot of turbulence at the workplace as a consequence of the organisational changes, unsolved issues and unfulfilled plans. Some said that many tasks that had nothing to do with flying operations had been added, and that they feared that these tasks would take the upper hand. There was a consciousness of the need, before and after each flight, to have a "flying window"[14], while it was perceived as being difficult to get the separation and time needed for such pauses.

There were fears that airborne search and rescue did not get the training time required to be able to maintain sufficient skill. One question that had been discussed concerned the provision of resources in the form of helicopters and flying time. Certain changes had, according to the squadron commander, recently taken place, by borrowing helicopters from other bases, but the situation was not seen as being satisfactory.

On 10 November 2003 the aircraft commander had handed in the following questions before a flight safety officers' meeting (FSO-möte) that was planned to take place in December 2003.

- The noise problem in the HKP10 and what applies in respect of earplugs. How many shall have more problems if nothing happens soon? What is happening?
- The organisational problems that in turn create uncertainty about where we shall carry out our flying duties (Såtenäs or Säve).
- Helicopter availability to be able to operate an efficient flight service. Not knowing from week to week how many flying hours and how many helicopters would be available for use for flying on FFSU and GFSU tasks.
- We are unable to plan properly! Is this really how we should be operating?

In respect of the crew that were involved in the accident, it emerged from an interview with, among others, a colleague, that the aircraft commander had expressed the thought of leaving the unit to work in a different place within the Swedish Armed Forces. It also emerged that the flight engineer had decided to work with other tasks within the Swedish Armed Forces, closer to where he lived, to avoid commuting.

1.21.3 Manuals and procedures

The HKP10 Flight Manual does not cover prescribed standard procedures and checklists with clear directives for the pilots' co-operation and communication with "callouts" during different phases of a flight, including standard phraseology. An Flight Operations Manual with flight operations procedures had not been produced at the time of the accident.

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[14] The Swedish Armed Forces has in its flight safety provisions introduced the term *flying window*. The flying window is to be seen as a period of time before and after each flight. The flying window is intended to allow each pilot and crew, in a peaceful and undisturbed environment, to be able to prepare and concentrate before flying, and to evaluate the mission afterwards.

1.21.4 Training

The helicopter training instructions for the HKP10, UHU HKP10, contain instructions for the training of crews on this type of helicopter. The UHU is divided into different stages – type training (TIS) - basic flight tactical training (GFSU) for pilots who have already had flight tactical training in a different helicopter (GFSU:Ä) and periodic flight training for pilots (PFT).

The HKP10 UHU states in detail which theoretical and practical flying exercises that a GFSU for pilots is to include and how they are to be implemented.

In addition the UHU contains basic flight tactical training for operators, flight engineers and rescue swimmers, with descriptions of the scope and implementation of the exercises.

According to the UHU, basic training is to be similar, in order to ensure that crew members can be usefully employed regardless of where they are based. The training must lead to the student obtaining such knowledge as to meet the goals stated in Bestämmelser för flygutbildning (BUF – Regulations for flying training) for helicopter units at SAR readiness. The HKP10 UHU at the time of the accident had not been ratified by the Flygvapnets Flygbefälskola (FBS – the Air Force Flying Commanders School).

In order to maintain authorised flying status, PFT is implemented by training for emergencies in helicopters as first pilot and training for emergencies in simulators as first pilot and second pilot.

PFT in helicopters covers the following flying exercises:

- Engine failure during hovering and during take-off and landing.
- Loss of the left hydraulic system and tail rotor control failure.
- Autorotation and faults in the engine control system, along with single-engine flying.

PFT in the simulator was increased in 2003, in accordance with a Helicopter Wing decision, from one to two practice sessions per year. Flying in a simulator covers training in dealing with emergency situations.

Simulator training is normally carried out in a simulator at Stavanger. This is however not equipped with Swedish-type equipment and instrumentation, so that task training with an autopilot/coupler could not be practised. General emergency training on the helicopter type could however be carried out.

A simulator in Switzerland has also been used for simulator PFT.

During simulator training a record is kept of who has performed which exercises and when. There was no documented assessment of pilot performance during the exercise.

At the time of the accident there were no detailed regulations concerning refresher training after a long period of absence from flying duty. After the accident, limitations for helicopter crews, taking into account their current flying performance after a long period of absence from flying, were introduced into the Flight Operations Manual Part A.

The conversion of the first pilot to the HKP10

A training table, stating which flying exercises the pilot had carried out during conversion to the HKP10, was found in his computer. However the exercise table did not show when particular exercises had been carried out. Whether the exercise table was up to date could not be determined, but the pilot had probably been ordered to document completed flying himself. It cannot be ruled out that the pilot carried out flying sessions without documenting them. From the exercise table it appeared that the pilot substantially completed the flying exercises covered by GFSU:Ä. Taking into account his previous long experience on the HKP4, there were some practice flights which were not noted as completed in the table. According to the squadron command, these could have been carried out in connection with other flying, which would mean a certain reduction in flying time.

Concerning the simulator flying for the first pilot, there was documentation for flying since 2002 up to and including the autumn of 2003. The simulator exercises included in the training had been carried out by the pilot at the then Helicopter service at Stavanger. He had performed simulator flying on two occasions during 2003.

A staff meeting with the GFSU instructors concerned had been held before authorisation was granted. However there was no documentary record of the meeting, but according to information received there were no remarks to the disadvantage of the pilot.

Taking into account the flying time spent on the HKP10 by the first pilot since conversion began, it can be assumed that all important phases were completed in accordance with the training schedule for GFSU:Ä.

Second pilot/Aircraft commander

The aircraft commander had completed GFSU at the beginning of the 1990s. No exercise table from that time had been saved. According to information received he had completed a full GFSU HKP10 and had been flying the HKP10 for over 10 years. He was well versed in the flight profiles used by the system. The pilot had also acted as a flying instructor for other colleagues during GFSU and had participated in the training of the first pilot.

In respect of the aircraft commander's simulator training there was documentation for flying since 1992 up to and including the autumn of 2003. He had performed simulator flying on two occasions during 2003.

CRM training

As SHK mentioned in Report RM 2005:01, crew co-operation is of decisive importance to flight safety, which was already noted in civil aviation in the 1970s. Within civil aviation it is required by the authorities that there is regular training in Crew Resource Management (CRM). Within military aviation there was no equivalent requirement at the time of the accident. Training in CRM is now regulated by Flight Operations Manual Part A (Joint) 5.2.1.10.

CRM concerns the non-technical knowledge, skill and attitudes required for safe and efficient flying.

Starting in 1994, FBS has held courses in crew co-operation.

In the aircraft commanders course that the aircraft commander attended in 2003 there was a part that among other things dealt with CRM, stressing team dynamics, leadership, crew co-operation and decision-making, along with crisis management.

1.21.5 Safety follow-up

In January 2003 HKV (Headquarters) assumed a new organisational structure. In connection with this the Helicopter Wing was subordinated to the Air Force Inspector (FVI). FVI then took over responsibility as the central operations executive with operational responsibility (Directive 26 May 2003, 09 860:68045) for subordinate units, except for units subordinated to Joint Forces Command (C OPIL) in the case of operations, exercises and overseas forces, where C OPIL had responsibility (Commander-in-Chief (ÖB) decision 20 December 2002, HKV Communication no. 25420:74168).

FVI as the central operator is to lead the operational safety work by, among other things:

- Elaborating the utilisation of a system for operational safety.
- Following up operations by subordinate units in respect of operational safety.
- Reviewing and co-ordinating plans and operational tasks from the operational safety viewpoint.
- Deciding on measures and limitations for operations.

According to an interview with FVI this means in practice, among other things, assigning personnel to those posts pointed out in RML, e.g. flight commanders, to engage in dialogues with operational units concerning production and taking the responsibility for achieving balance between resources and tasks, following up operations and deciding on limitations.

FVI stated that his resources for following up operational safety within helicopter operations were the Flight safety department (FlygSäk), the central Flight Operations commander, central technical manager and to some extent FBS. FlygSäk mainly worked on following up reported deviations and had regular meetings with the Helicopter Wing to discuss flight safety questions.

SHK has obtained the minutes of a meeting between the Air Force Command, the Helicopter Wing and FBS. The meeting took place some months before the accident. FlygSäk had called the meeting to discuss a number of flight safety questions that they considered were serious and wished to have aired. The meeting dealt with, among other things, questions and goals within operations in general, training instructions, exercise goals, assignment of command personnel and technical services. There was an item concerning CRM on the agenda, but this was not taken up due to lack of time.

The FVI expressed his concern over the flight safety events that had occurred in the Helicopter Wing. He saw a connection between those events and the current organisation. The meeting did not deal expressly with the development of the organisation, but he stressed that opinions that had been aired must be taken into account within the new developments in the organisation. Further, he wanted clarity in the command of flying duties and technical services in the new organisation.

According to the FVI, an operational authorisation for the Helicopter Wing is, in accordance with the RML requirements, a condition for securing the safety management of its operations.

During 2003 the Swedish Armed Forces published as usual a Flight Safety analysis. In this, FlygSäk analysed and commented on some of the 2002 reports on operational malfunctions, which were categorised as "Human error".

The basis for the analyses of the helicopter systems was pilot-related operating problems and experience from the FlygSäk visits to units.

There were differences in the reporting frequencies of operational disturbances between helicopter systems. The differences were assessed as being to some extent explained by the fact that in helicopter systems employing the two-pilot concept, i.e. HKP4, 10 and 11, misapplied controls and forgetfulness were caught by the crew so that possible incidents were avoided. Experience from the visits by FlygSäk to units also indicated that the differences were due to a lack of willingness to report, above all in the HKP10 system.

In addition it was mentioned that failure to communicate, associated with differences in terminology had occurred. Within crews, personnel had not always "spoken the same language". Certain pilots had limited flying time and most had at some time during the year been subject to lowered flying capability. Reports of confusion between controls and accidental settings indicated poor design of controls and switches. FlygSäk also concluded after visiting units that the unit goals were unclear and that squadron commanders perceived that they had insufficient time to spend on their core task of flying duty.

The 2002 flight safety analysis of helicopter systems noted above all the reduction in flight time allotted to the helicopter units in order to adapt operations to a constantly new and restricted financial framework. It was emphasised that reduced flight time allocation can result in a deterioration in flight safety, with the risk of one or more accidents.

Since 2003 FlygSäk has reduced its number of posts by about 30 %. Also, FlygSäk is no longer organised under FVI.

From the time when FVI became the central operations executive with responsibility for operations, among other things a requirement for certain central executives was introduced by Headquarters Basic Organisation Command Air Force department (HKV GRO Flygvapenavdelning). There was thus at Headquarters a central Flight Operations commander flying and a central technical manager. In interviews carried out at Headquarters in 2004 it emerged that there were no descriptions of responsibilities and tasks for these executives , and for this reason their roles in the flight safety process were unclear.

According to the FVI, the FBS “took the temperature” of the flight duties command. This expression indicates that it is part of the job of FBS to follow up the flight duties command within the Swedish Armed Forces and to express opinions on how their tasks are fulfilled by the units. These opinions were in the first place provided to those concerned, i.e. Flying squadron commanders and Flight Operations commanders. If the observations concerned such matters as attitudes and safety principles, FlygSäk would also be informed.

Follow-up of flight duties also took place by staff at FBS taking part in the daily operations, such as flying, briefings and debriefings. This meant that the follow-up was usually in connection with flying in the aircraft/helicopter types that these personnel were trained to fly. At FBS there was normally one person with helicopter competence. He/she would normally be authorised to fly one of the helicopter types in the Swedish Armed Forces. During 2003 one of the people working at FBS was authorised to fly the HKP5. This person was relieved in October 2003 by another, who was authorised to fly the HKP4. Of the others at FBS five were rated on the JAS39 and one on transport aircraft.

The FVI stated that he felt greater confidence in the HKP10 system in respect of flight safety than in other helicopter systems. The background to this was that he felt that flight safety thinking in that system was more like the safety thinking that he was used to in the Air Force.

1.21.6 *Supervision functions*

In interviews with the the Inspectorate of Military Flight Safety (FLYGI - Militära flyginspektion) in 2004 it was stated that about 65% of its work concerned the certification of personnel and products, such as new helicopter systems and the JAS39 for export and flying units. Industries that worked with military aviation were also included in this operational area. FLYGI assessed that the Inspectorate dealt more with matters outside the Swedish Armed Forces than internally with the Swedish Armed Forces Wings. During 2003 there was within FLYGI an officer with helicopter competence.

In the interview it was also said that FLYGI reviews operational systems and follows up on these. According to received information, FLYGI did not have the resources to go down to a lower detail level in its reviews or to inspect the daily operations. To follow up on standards, values and attitudes while reviewing was not perceived as part of the FLYGI task. According to the interviews this was where FlygSäk had a clearer role.

At the time of the interviews in 2004 there was a requirement from Headquarters command for 30% savings in the Safety Inspectorate, which would also affect FLYGI.

1.21.7 Other investigations

The SHK investigation (RM 2002:1) of a helicopter accident in August 2000 at Kaskasapakte showed that in helicopter operations there existed resource, reorganisation and leadership problems, which typically involve risks to flight safety. SHK investigations of helicopter accidents occurring in 2003 before the one in the Göteborg archipelago showed that reorganisation and leadership problems continued. The investigation into the accident to an HKP11 (Z34) on 25 March 2003 (RM 2005:01) drew attention to several reorganisations having been carried out, which created much turbulence and unclear command relationships within the Helicopter Wing. In addition SHK found that cultural differences, among the merged helicopter units from the Army, Navy and Air Force, meant that there were sometimes different conceptions of how the operational tasks should be carried out, and this contributed to friction and conflicts. Finally it was remarked that there was sometimes a lack of faith in the Wing management. The Wing management was seen as finding it difficult to bring the operational units to a joint point of view.

SHK recommended that the Swedish Armed Forces should investigate the alleged deficiencies in command and control of the helicopter operations. In its report on 20 December 2005 to SHK concerning which measures the Swedish Armed Forces had taken, it was mentioned that an investigation into the above-mentioned measures had been carried out (Headquarters document 02 810:79336). The investigator found that certain deficiencies remained in 2005. These were:

- Fragmented and diffuse division of responsibility in respect of the roles of the Swedish Armed Forces as an aviation authority and as a flight operator.
- Limited capability of the Headquarters flight safety function to carry out preventive flight safety work.
- Organisation changes had been implemented without, in respect of consequences affecting flight safety, performing a prior systematic risk analysis, followed up during implementation and evaluated afterwards.
- A deficiency of relevant helicopter-specific competence at Headquarters.
- A lack of common basic values and perspective within the Helicopter Wing.
- An imbalance between tasks and resources within Helicopter Wing operations.
- Implementation of RML in the Helicopter Wing was not prioritised relative to other unit tasks.

The investigator mentioned that it was in his view a lack of common basic values and perspective within the Helicopter Wing that was the single largest contributory factor to the worsened flight safety situation within the unit.

In conclusion the investigator proposed several measures to eliminate the deficiencies. In the Swedish Armed Forces reply to the SHK recommendations the work situation was reviewed in respect of these proposals for measures. Concerning the recommendation to introduce systematic procedures for the management of organisational changes, the Swedish Armed Forces replied that the proposals were complex and that they had not so far been analysed within Headquarters.

1.22 Regulations

1.22.1 Rules of Military Aviation (RML)

The Rules of Military Aviation (RML) are the rules to be applied within the Swedish Armed Forces for military aviation. RML has been developed in stages.

The first part to be prepared, RML-G (Grunder - Basic), was followed by RML-V1 (Verksamheter - Operations) which regulate the management of operations. These were then followed by V6 (Aviation Maintenance) and V2 (Air Operations)

Several parts of the RML are still not ready and issued, which means that flight operations of the Swedish Armed Forces are still regulated by a mixture of new and old regulations.

The rules contain a number of requirements. Operators and providers shall in their documented management systems show how they meet these. RML-V-2 requires that operational units operating flight duties shall show their fulfilment of requirements in a Flight Operations Manual (FOM). This Manual must be integrated into the operational description.

U-RML (Utvecklingsplan för RML – Development plan for RML) was determined on 1 April 2001 by the then C FLYGI and forms the basis of development, maintenance, review and revision of RML. According to planning, the main part of the development of RML was to take place in 2001-2004. At the time of the accident eight of the originally planned parts remained to be issued, including those dealing with personnel, aviation training and operating regulations.

The authorisation process for operational units in military aviation has been lengthy and worked in such a way that the respective operating units have sent documentation to FLYGI in stages for checking. While waiting for authorisation reviewing and final approval from FSI the operational units have obtained interim operational authority, applicable for a limited time period. The operational authorisation regulates how operations shall be organised and which posts shall be filled. Operational authorisation also defines division of responsibility and powers assigned to the respective named commanders.

RML V1 (Command) contains regulations and general advice which is also directed at condition makers. By condition makers is meant, amongst others, staff within Headquarters who manage or respectively play a part in the processes that determine conditions and external restrictions for military aviation. These are the Joint Organisations Command (Operations- och insatsledningen - OPIL), the Joint Organisation and Procurement (KRI), the Joint Training Command (GRO), the Plans and Policy Staff (PLAN) and Personnel Staff (PERS). Condition makers are not required to describe how they deal with the applicable requirement elements in RML. FLYGI decides in his checks to which extent the requirements of the regulations are being fulfilled.

The role of the FVI as a central operational executive with operational responsibility and the posts of central Flight Operations commander and central technical manager are not described in RML, but are seen as an application of the requirements on those influencing operations in accordance with RML V-1.

In connection with the SHK investigation into a serious incident to a transport aircraft that occurred on 11 December 2003 ((M-12/03), interviews were held with FVI, FSI and other personnel at Headquarters, among others, at the wing level. In these interviews it was stated that implementation of RML was slow. Several conditions were judged to have influenced the introduction, such as the presence of a strong verbal tradition, that people were not used to documenting their work and procedures, and that there was a lack of understanding of the importance of RML as a common set of regulations. There were several indications that it had been difficult to communicate the motive and create understanding of the importance of documented procedures and quality management. In addition it was stated that implementation took place at a stage when the Swedish Armed Forces was undergoing considerable changes, including reduction of resources. According to the interviews, no additional assignment of resources had taken place to speed up implementation at the wing level.

1.22.2 Rules and regulations in respect of flight operations

For units on SAR readiness there was a permanent Decision on flying (BOF) for real SAR tasking and training, issued by the Flight Operations commander or the Flying squadron commander. On receipt of an alarm from ARCC the aircraft commander, on condition that the external circumstances such as weather were met, could decide to fly and issue air mission briefings (OFFG). The aircraft commander could also decide not to fly if the external conditions did not meet the stipulated requirements.

OSF/RML D1 Section 5 – Flying traffic and Combat command regulations, define which weather conditions permit flying.

OSF 5.2.2.2 defines the visibility conditions for flight and the distance from cloud that aircraft pilots must maintain in order to be able to fly with visual flight rules (VFR). In the case of helicopters exceptions to these rules are permitted since they can be flown at such low speeds that obstacles can be seen in time to avoid collision. In daylight flight visibility may not be less than 500 m. In darkness flight visibility may not be less than 3 km.

These limitations may however be reduced in the case of rescue missions or training for such missions.

OSF 5.2.3.2.3 states: When a helicopter is flying over the sea in cloud or outside cloud with the water in sight, with flight visibility of less than the VFR requirements, it must fly at not less than 300 ft in height.

During rescue flying, or where required for tactical reasons, helicopters must have equipment for accurate position definition and height measurement.

- Flying over land at no less than 500 ft height above the highest obstacle within 5 km/3 NM.
- Flying level over water at no less than 150 ft height within 5 km/3 NM from fixed obstacles. During rescue operations, or training for them, while taking into account the risk of moving obstacles, level flight down to 60 ft.

Helicopters equipped as above and with radar may, above the water surface (at least 4 km/2 NM long and 1 km/0.6 NM wide in the direction of flight) descend to/fly at no lower than 60 ft height and reduce speed to hovering. If in addition the helicopter has suitable automatic guidance, descent to hovering above the water surface is permitted.

The minimum distance to obstacles in the direction of flight is 1000 m/0.6 NM. In the case of slow hovering next to an obstacle, the minimum distance is to be equal to the minimum resolution distance of the radar.

The HKP10 meets the requirements for operating to the above-mentioned lowest values.

RML-V-2B 2.29 contains the requirement for the air operator to prepare a Flight Operations Manual (FOM). This is to contain all the instructions and the information that is necessary for all personnel on flying duty to be able to perform their tasks. The FOM shall have the following main structure:

Part A: General/Basic (All non-type related Air operational policies, instructions and procedures)
Part B: Aircraft operating matters – type related
Part C: Area, route, aerodrome and war base instructions and aeronautical information
Part D: Training (All training instructions for personnel required for a safe air operation)

Detailed requirements are set for the contents of the various parts. Among other things the FOM shall contain flight operational procedures with in-flight procedures, standard phraseology and checklists.

The transition to RML-V2 was guided by interim rules, which expired on 31 October 2002. Thereafter RML-V2 applied completely. Under the management of FSI the work of preparing the FOM had been in progress since 2001. Initially the FOM work had focused on operations with helicopters, transport and special flying. The final date for preparation was moved in stages. Limited resources at Headquarters were cited as the reason for the work being delayed.

During the autumn of 2004 work was resumed again on all parts of the FOM, on the basis that the Air Force should be regarded as an "aviation company" and that the Air Force Inspector was responsible, after receiving FSI approval, for determining the FOM. A FOM Part A for the Swedish Armed Forces was prepared and ratified on 1 October 2006 (Headquarters reference 02 800:61680).

1.22.3 Provisions and general recommendations on changes in operations

The RML includes rules concerning the handling of changes in operations. RML-V-1B 1.23.3 states the following:
"During the planning of development or dismantling of war units and when developing new functions within the military aviation system, critical flight safety related changes should be identified and analysed, and decisions should be taken about the introduction of risk-minimising measures. The effect of such measures should be monitored and recorded. *Records shall be maintained and shall on request be made available for the Authority."*

RML-V-1C 1.41 places the following requirements on an operational unit.
"Each operator or provider within the military aviation system shall establish documented procedures covering preventive measures related to planned changes to the operations as well as corrective actions when deviations occur. The deviation control shall cover handling of the particular case and the reporting according to 1.40.1 as well as initiative regarding preventive actions related to product characteristics and investigation about the operational aspects."

RML-V-1C 1.42 contains requirements for checking the operational conditions as follows:
"There shall be a documented procedure covering systematic review of prerequisites before an operational change within the military aviation system takes place in order to prevent the introduction of dangerous activities or working methods."

When changes to the activity are being planned, the employer in accordance with the Swedish Work Environment Authority Provisions (2001:1,§8) on Systematic Work Environment Management shall assess whether the changes entail risks of ill-health or accidents which may need to be remedied. The risk assessment shall be documented in writing. The risk assessment shall indicate which risks are present and whether or not they are serious. The General Recommendations to the section state that personnel can sometimes suffer as a result of reorganisational measures, especially where there are cutbacks and closures involved. It is important to identify the risks early on, so that negative consequences of the adjustment process can be averted.

1.22.4. *Civilian regulations in respect of SAR operations*

In JAR-OPS3, which applies to commercial air transport with helicopters, ambulance helicopter operations are described under the heading of Helicopter Emergency Medical Service (HEMS). The differences between Ambulance flights, HEMS and SAR are described in supplement ACJ-1 to JAR-OPS 3.005d.

There are no international civil safety regulations for SAR operations. It is up to each national authority to draw these up if they consider them necessary. When operations are carried out by civilians in Sweden, it is done in accordance with the operator's FOM, approved by the Swedish Civil Aviation Authority.

1.23 Other

1.23.1 *Spatial disorientation*

The pilot's (crew's) *"spatial orientation"* is a part of the pilot's (crew's) situation awareness (SA) and can be defined as a correct perception of the aircraft's position, motion and attitude relativ to ground or another aircraft.

Spatial orientation is derived from sensory information from vision, muscles and vestibular (balance) organs, along with information provided by flight instruments.

In case of spatial disorientation (SD) one is unable to properly assess the aircraft's position and/or movement and/or attitude in relation to the ground or another aircraft. If the pilot only relies on the sensory information there is a very great risk of SD, especially if the visual cues from the ground/water, horizon and cloud formations are inconclusive. In flight, vision is dominant in relation to the vestibular organs and especially that part of vision which stands for comprehension of spatial orientation and movement (peripheral vision) which is important to avoid SD.

SD is normally divided into three types:

- Type I: Incidents which one does not experience as SD *(unrecognized)* because the cognitive process is not including the sensory or instrument information that exists *(central error)*.
- Type II: Incidents which are detected as disorientation *(recognized)* and it takes a certain amount of time to sort this out.
- Type III: Disorientation is experienced which in addition has a strong effect on the pilot *(incapacitating)* and brings about severe anxiety and fear.

SD types II and III are also usually termed *"input errors"* since one is receiving incorrect signals from the sensory organs to the higher cognitive centres in the brain.

SD type I is the most common problem in today's aircraft and helicopters, due to the amount of complex information that need to be handled, while at the same time as a pilot one has to correctly assess aircraft attitude and speed.

Examples of human factors that contribute to the generation of *"central errors"* can be:

- faulty mental focusing,
- stress,

- complacency and
- oxygen deficiency or G effects.

Other human factors that may contribute:

- flying experience (both total and current),
- instrument flying training,
- physical and psychological health,
- the influence of/after-effects of alcohol and drugs, and
- general cognitive factors.

Examples of factors in aircraft and flight situations that often affect the predisposal for disorientation:

- transition between IFR and VFR flying, weather factors,
- poor visibility, isolated single lights,
- great height or decreased dynamic light flow on the peripheral visual system,
- terrain without contours or water without texture (flat calm, undisturbed snow surface),
- sustained acceleration and *"below the threshold"* acceleration changes,
- small and poorly located flight instruments, instrument symbols that are difficult to interpret and
- high manoeuvrability of the aircraft.

Possible conditions for SD to arise in this accident:

- instrument flying conditions in darkness, rain, low cloud, calm sea tendency and probably very few visual orientation cues,
- hovering taking place with poor or limited external visual references,
- instrument design with relatively small instruments and in some cases doubtful symbols, and
- spotlight manoeuvring/light conditions in cloud.

Within the Swedish Armed Forces very limited aviation medicine training concerning disorientation has been provided for personnel subject to flight duty.

After the accident to a HKP10 at Kaskasapakte, the Swedish Armed Forces planned a study to review, develop and guarantee flight medicine training of personnel subject to flight duty. The main purpose was to educate and train personnel subject to flight duty in spatial orientation and situation awareness. This was one of the measures that the Swedish Armed Forces promised in its response to the SHK report RM 2002:01 (24 October 2002, 02 810:71894). This study did not however take place due to lack of resources, which the Swedish Armed Forces reported to SHK on 22 January 2004 (02 810:61312).

1.23.2 The effect of stress on perception of the flight path

The effects of stress on pilots' judgement and decision-making have been studied in a simulator by Wickens *et al* (The effects of stress on pilot judgment in a MIDIS simulator, in Svenson & Maule Eds. Time pressure and stress in human judgment and decision making, Plenum Press, New York, 1993). The study showed that stress had a negative effect on judgment and decision making in scenarios with high spatial demands. By spatial demands is meant the need to visualise the aircraft's position in the air in relation to the ground, weather information, traffic, etc. and to mentally transfer and rotate an aircraft representation.

1.23.3 Flight safety in the case of organisational changes

Organisational changes can, if they are not well managed, lead to a reduction in safety. Many risks can be avoided if measures are taken before the changes are introduced. Ensuring that there are sufficient trained staff in all areas is obviously important for safety, as are clearly defined procedures, roles, responsibilities, contact interfaces and resources. Maintaining the commitment of personnel and a positive safety culture are central to the work of change. The management of organisational changes is therefore a part of an organisation's safety management system (see for example Management of Operational Safety in Nuclear Power Plants, INSAG 13, IAEA 1999).

Uncertainty is a fundamental source of stress in connection with changes. The fear of losing one's job, the risk of being moved and loss of identity, status and prestige are common stress factors in connection with mergers and cutbacks. This means that measures to reduce uncertainty are particularly important in the rearrangement processes and organisational changes. Participation in the changes contributes to providing control over what is happening. Openness and information contribute to increased confidence in the management's handling of the situation. (See for example Cartwright & Cooper, Managing Mergers, Acquisitions and Strategic Alliances: Integrating People and Cultures, Oxford: Butterworth-Heinemann 1996).

Mergers appear to involve particularly demanding rearrangement processes. Rosness *et al* (Flysikkerhet under omstillingsprocesser (Aviation safety during processes of change), Sintef 2005) have gathered experiences of mergers and among other things point out that it is very important to monitor the quality of co-operation and communication in turbulent periods, e.g. conformity to the operational CRM concept. It is also suggested that the inspection authority may need to tighten its inspections during processes of change and focus more sharply on organisational aspects. Another lesson is that lack of continuity in the business leadership during a merger can make follow-up of the business more difficult. In addition, subcultures may survive for years among the staff of different companies after a merger.

Flight Safety Digest, March-April 2003, contains the results of a survey intended to study developments within commercial aviation and assessing what possible effects these could have on flight safety. In the survey, mergers of different company cultures were discussed. Among other things were discussed what the differences in different companies' CRM philosophies and flight operations procedures could mean in terms of increasing risks within merging companies.

One conclusion from the survey was that there is a belief among airlines that CRM, standardised procedures and the professional culture would mitigate the risks. The study indicates that these measures do not provide a complete solution. Other measures may be needed. One of several recommendations is to produce guidelines for managing organisational changes. Another recommendation is to develop an audit process to identify latent deficiencies in companies where changes have already taken place. In addition it is recommended that the content of the CRM training that is provided is reviewed. Also mentioned is that inspection authorities should review their inspection work and procedures, to ensure that they match the risks that can arise in connection with organisational changes.

In a psychological thesis at the University of Lund in 2005 a comparative study was carried out of organisational climate, safety culture and the working environment of a helicopter unit and a fighter aircraft unit. The purpose of the study was to gather information that could give a picture of the situation in the Swedish Armed Forces helicopter organisation in light of the changes that the organisation had undergone since 1998 and the serious accidents that occurred thereafter.

The study took the form of a questionnaire to pilots, technicians, observers/navigators and operators/rescue swimmers at a helicopter unit at Ronneby and a fighter aircraft unit at Luleå, a total of 125 personnel. The response frequency was high – 90%.

One of the main results of the study was that pilots of the helicopter unit tended to perceive the organisational climate and psycho-social working environment more negatively than pilots of the fighter aircraft unit. In addition, the results indicated a worse safety culture in the helicopter unit for the same group.

In the thesis the results were analysed on the basis of the differences between the units in respect of organisation, management and flying hours utilised. In the helicopter operations there had been extensive and repeated organisational changes, with consequent effects in the form of stress. The operations had a less unified organisational culture after the merging of the helicopter operations of the three defence branches. This was assessed as being liable to affect co-ordination and co-operation. The number of flying hours were halved for helicopter pilots, which reduced the opportunity for training on the main tasks. This was adjudged to involve a risk of less strongly expressed professional identity as pilots, with an effect on self-esteem. In the helicopter organisation, commanders at a higher level were located further away from the operational work, which was assessed as making communication, inspection, participation, co-ordination and feedback more difficult.

The Norwegian Accident Investigation Board (HSLB) was commissioned by the Samferdselsdepartementet (the Norwegian Ministry of Transport and Communications) to investige how flight safety was managed in authorities and companies during the on-going reorganisation of Norwegian aviation (Report SL RAP 35/2005).

HSLB found that research and experience from other countries showed that possible negative flight safety consequences seldom materialised as accidents until several years after the changes were implemented. Therefore other kinds of indicators were used in order to be able to assess the level of safety.

HSLB examined how the major players in Norwegian aviation managed safety during the process of change. The main conclusion was that a number of large and small changes were not sufficiently assessed in terms of their consequences in respect of flight safety – neither separately nor jointly. When such investigations into the consequences were carried out, it was often thought that there were deficiencies in their following-up.

The survey came out with several recommendations, of which the following are thought to be of interest in this investigation. One recommendation to the inspection authorities was to evaluate whether greater weight should be placed on system-oriented and risk-based inspections, and to train/recruit staff with associated competence to follow up the safety-related consequences of rearrangement measures for the object under inspection. One of the recommendations to airlines was to map out cultural differences before a merger and to integrate the courses of the original companies so that a new company culture could be established in a way that would be obvious to all those affected. Another recommendation was to develop follow-up and guidance routines so as to systematically include flight safety in rearrangements and changes, and to recruit/develop further the necessary competence for this.

1.24 Salvaging the aircraft

The preparations for salvage already began on the evening of 18 November 2003. For location of the wreckage *HMS Grundsund* and as diving ship and work platform *HMS Loke* were utilised. Initially there was some difficulty in locating the wreckage as buoys that had been laid had been dragged by the current. The helicopter was equipped with a pinger transmitter, but the equipment for tracking this was never used, as the wreckage was located with the aid of the Navy's ROV (Remotely Operated Vehicle).

On 23 November salvage was carried out at *salvage site 1* of the front part of the helicopter fuselage along with the engines, gearboxes and main rotor complete with latched covers. The front part of the cabin, up to the principal frame, was crushed and severely deformed. At the site, on the sea floor, was found a large amount of debris belonging to the helicopter.

Some parts had also been found by the general public and handed in to the Swedish Armed Forces which forwarded them to SHK.

On 25 November salvage was carried out at *salvage site 2* of the rear part of the helicopter fuselage along with the tail boom and tail rotor. At the site, on the sea floor, virtually no loose parts belonging to the helicopter were found. Salvage sites 1 and 2 were about 500 m apart. After salvage at these two sites, the sea floor was trawled to try to find the missing parts.

Mapping of the sea bottom was thereafter carried out in two stages with help from the Marin Mätteknik company of Göteborg.

During the autumn of 2005 supplementary diving and salvage were carried out with the aid of *Grundsund* at the locations identified by Marin Mätteknik. Among other things the following items from the helicopter, despite extensive searches of the sea bottom, have still not been found:

- the hoist winch stretcher,
- the air intake screen for the left engine,
- front edge plating from the rotor blades,
- the folding centre seat from the cockpit,
- a 12 kg powder fire extinguisher and
- the control panel for the SX16 spotlight.

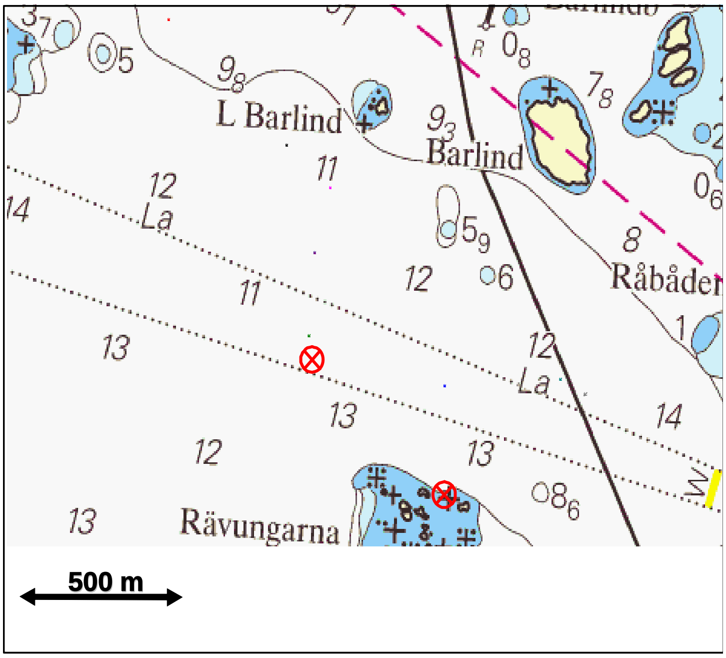

Fig. 27: *The two locations where the helicopter wreckage was found. The south-eastern location was called salvage site 1 (57°47.14′ N 11°41.05′ E) and the north-west location was called salvage site 2 (57°47.33′ N 11°40.60′ E).*

1.25 Equality of opportunity

SHK in its investigation did not identify any questions of equality of opportunity character.

2 ANALYSIS

2.1 The accident site

At *salvage site 1* were found the heaviest parts of the helicopter, such as the engines, main gearbox, main rotor hub with main rotors and forward part of the fuselage. In addition many small parts from the forward part of the fuselage of the helicopter were found spread out within a 20 m radius. At the same location, the day after the accident, two of the deceased were found, the operator and the flight engineer.

At *salvage site 2* were found the helicopter's rear fuselage with the tail boom, tail rotor gearbox and tail rotor.

Both salvage locations were in a north-westerly line. The crew member picked up on the evening of the accident was found on a parallel line.

Very probably the helicopter impacted at salvage site 1. It broke apart and most of the parts sank to the bottom. The rear fuselage drifted with the north-westerly current and sank to the bottom about 500 m further away.

With a current of 2 knots, this means that it took about 8 minutes for an object to drift about 500 m.

2.2 Technical faults or deficiencies

In the technical investigation of the recovered parts of the helicopter no technical faults or deficiencies were found that could explain the accident.

Extensive examinations were made of the various systems in the helicopter. The helicopter lacked both an FDR and a CVR which contributed to the complexity of the investigation.

2.2.1 Fuselage and rotor system

During the technical investigation nothing was found to indicate that anything had broken before impact with the water, so the earwitness's information about a bang and impact noises are assumed to have come from the impact with the water.

2.2.2 Engines

The surviving conscript rescue swimmer stated that he heard both pilots mention that they had an engine surge. In the technical investigation it could not be determined whether surging occurred in one of the engines. Nor could the instrument values that were seen on some of the engine instruments confirm a surge on either engine. Surging is usually so brief that often no change is visible on the engine instruments . The power loss due to a single surge is very small, and may not even be noticed by the crew. Repeated or consistent surging can cause loss of power but is unusual in the HKP10. If one engine suffers consistent surging this is often due to vital parts of the engine being damaged, e.g. by a bird or other foreign object being sucked into the engine. Such damage had not been found in the examined engines.

The symmetrical damage to the 1st compressor stage in both engines was, after detailed examination, deemed to have arisen in connection with water impact. The fact that both engine compressors should have been damaged to a similar and symmetrical extent by foreign objects or other disturbances must be ruled out. The compressors were also examined with respect to aerodynamic flutter. No reason could be found that would cause flutter in both engines simultaneously.

2.2.3 Flight instruments

All the helicopter instruments were found mounted in the instrument panel and were examined by the then Bodycote CSM (now Bodycote Materials Testing) company at Linköping.

As far as it was possible to trace the values on the instruments from the instant of impact, these were normal for that instant of flying.

In this event it was not possible to determine whether either EFIS indicator blanked out during the later phase of the flight.

2.2.4 Warning and indication lights

Conclusions could not be drawn from the light bulbs where examination results showed that they either did not have, or only had a small amount or medium stretching of the filament, as there were light bulbs that very probably should have been lit, but did not show any filament stretching at all.

This is shown by the fact that half of the eight light bulbs located in the two RADAR and RAMS holders on the main instrument panel, and that belong to the selector CKPT/CABIN, should be lit while flying, but the examination showed that there was no filament stretching in any of these eight light bulbs. It was therefore deemed by the examiner that they were cold (not lit) at the time they were broken.

Even the opposite conditions could apply. Namely that light bulbs that were extinguished could have lit up during the break-up due to short-circuiting or for other reasons and then had a powerfully stretched filament during continued retardation.

This is shown by the fact that the thirteen light bulbs in the AP panel, with highly stretched filaments, represent illogical combinations of both correct indications and fault warning indications. There is thus no conceivable fault function in the AP that could give this combination of lit light bulbs on the AP panel.

2.2.5 Autopilot/Flight Director Coupler

Despite the above light bulb analysis there were indications that the AP was activated on impact with the water, which is normal for the exercise. Partly because all except three lights, of those which should be lit when the AP is activated, had filaments that were highly stretched. Out of those lights which normally would be extinguished when the AP is activated, all except one showed little or medium stretch in their filaments.
In addition all six channel selection buttons were depressed (ON position).

In respect of the two lane selection buttons it could not be established whether they had been activated, as the buttons have return springs.

In respect of the reported operational disturbances referring to disconnection of coupler modes, SHK considers it to be a deficiency in that there is no acoustic warning in the case of disconnection of selected modes.

Regarding the coupler, it was not possible to determine if any mode was active during the final stage of the flight.

2.2.6 Hydraulic system

All the hydraulic cylinders in the flight control system were examined and there were no indications of damage or faults.

The probability of a total loss of hydraulic pressure is very small, since the system consists of two completely independent systems. In addition scrutiny of the written TRABs showed a low occurrence of faults, without any increasing trends in the systems and their component individual parts.

2.2.7 *Electrical system*

The radar information showed transponder responses from the helicopter assessed up to just before impact with the water. The crew of the *Märta Collin* saw a white light from the helicopter when it passed at a steep angle down into the water and impacted.

Against this background and considering that the electrical system consists of two completely independent alternators and three batteries, one of which is an emergency battery, a total loss of electrical power is improbable.

2.2.8 *Eurocopter's simulation of collision forces*

According to Eurocopter the simulation program that was used was designed to simulate the behaviour of a helicopter when colliding with water. It was also stated in the Eurocopter report that the model had been validated for the usual certification conditions and among other things these were for a forward speed of up to 15 m/s (approx. 30 knots) and a descent rate of up to 2 m/s (approx. 400 ft/min). Eurocopter had carried out two computer simulations which, together with the observations made, were the basis for their standpoint. The low speed scenario was at a forward speed of 80 knots and a descent rate of 15 m/s. In the high speed scenario the forward speed was 140 knots and the descent rate 1.5 m/s. Both scenarios included assumptions that were outside those for which the model had been validated.

SHK supports the Eurocopter results in respect of forward speed, the "nose down" attitude and a negative angle of bank. In its report Eurocopter also assessed that the descent rate must have been >10 m/s. It was however emphasised that the use of a simulation program in this actual case had to be taken cautiously and that the output data could only provide indications.

Against the background of the above uncertainty and the simulator tests that SHK had performed, where the achieved descent rate reached just over 5 m/s, SHK assesses that the actual sink rate could have been less than that stated by Eurocopter.

2.2.9 *Other*

No reports from the helicopter crew concerning disturbances or problems during the flight were received by air traffic control at Säve, the SAR centre or the *Märta Collin*.

There were no signs of fire or explosion.

2.2.10 *Conclusions*

When the helicopter's remains were salvaged all the parts and systems vital for propulsion and manoeuvring were found. The results of the examinations of all the helicopter parts that were recovered showed that they were probably working before the accident.

2.3. External influences

2.3.1 *Weather*

According to the witnesses the weather for the second flight compared with the first had deteriorated to some extent in the exercise area. From the weather information received from Måseskär, Skagen and Nidingen it is not possible to be sure of the weather conditions at the accident site at the time of the accident, but it is estimated that the differences between the first and second flights were as follows:

- The wind veered from about 220° to about 190° with more or less unchanged speed of about 5 m/s.
- Visibility deteriorated from 4-6 km to 2-4 km.
- The low cloud thickened, from being spread out at about 60 m and broken at 150-200 m to broken at 30-60 m.

2.3.2 *Ice build-up and engine icing*

In dry air the temperature falls by 1°/100 m. With a surface temperature of +8-9°C the temperature, as an absolute minimum, should have been +5°C at 300 m (1000 ft). The adiabatic saturation (wet bulb) temperature decrease at +8°C is 0.7°/100 m and at the time of the accident the probable temperature decrease would have been 0.8°/100 m. This gives a probable lowest temperature of +5.6°C.

At these temperatures there is no risk of ice accumulation on a helicopter, according to SFI.

There is a risk of engine icing on a HKP10 at temperatures <+5°C and relative humidity exceeding 75 %. On take-off from Säve the temperature was all the time well over +5°C but on departure, which was at less than 1000 ft, the helicopter could, if it climbed to the maximum permitted height, have been close to but not have passed the limit for this interval. Hence the conditions that evening were not conducive to engine icing, since the temperature was too high.

Nor has anything come to light that indicates there was icing on the airframe or in the engines of the helicopter during the first flight that evening.

Icing on the airframe or engine ice is therefore not likely at the air temperatures prevailing at the time of the accident.

2.3.3 *Bird strike*

No evidence or indications that the helicopter collided with a bird were found among the recovered parts of the helicopter. If a bird had been sucked into an engine, bird remains would very probably have been found in it.

2.3.4 *Conclusions*

From the completed investigation there was no sign that an external influence – ice formation or a bird collision – contributed to the accident.

2.4 Radar information

The recorded radar returns, from the two radar stations that were able to track the route of the helicopter during the evening, were analysed by experts from the EC group. The presence of double radar returns is due to the fact that the pulses from the radar stations did not strike and be reflected from the helicopter exactly simultaneously, and that the accuracy in position registration can differ by up to 100-150 m from the true position. From the radar recordings, and completed reference flights, it could be determined that during the final 90 seconds of flight the helicopter clearly moved in the hover at about 40 m height above sea level eastwards from a position that was south of the location of the *Märta Collin*. The two final recorded radar responses, with a westerly movement, were however not clear, according to the EC group, as there were too few returns.

There was no radar registration of the position of the *Märta Collin* because the radar stations in use cannot normally see objects on the sea surface or at minimum height, due to terrain masking.

The recorded change in flying altitude from about 200 m down to about 90 m STD, i.e. approx. 120 m down to about 10 m AMSL during the first flight, could have been the crew's attempt to get direct visual contact with the *Märta Collin* without needing to carry out a circuit procedure.

During the second flight (in which the accident occurred) there was no radar recording with stated SSR height down to about 10 m AMSL (30 ft) with subsequent climb to a higher flying height, so the *"roller-coaster"* height change down to 30 ft experienced by the rescue swimmer probably occurred during the first of the two flights.

2.5 Injuries to persons

First pilot
From the injuries to the first pilot it was considered that he had been strapped in to the right hand pilot's seat with shoulder and waist belts. He had injuries to both hands and feet, so it is assumed that he was holding and manoeuvring both the collective pitch and cyclic stick controls and had both feet on the tail rotor control pedals at the moment of collision.

The injuries to the left side of the face of the first pilot indicated that at the moment of collision his head was turned some way to the right as if flying using visual references. It is not possible with any degree of certainty to tell whether the pilot was monitoring the flying instruments. Turning the head could be a reflex movement immediately before the instant of impact.

The pilot was killed by severe trauma to the body, received from forwards and below.

Second pilot
From the injuries to the second pilot it was considered that he had been strapped in to the left hand pilot's seat with shoulder and waist belts. He did not have injuries to either hands and feet equivalent to those of the first pilot, so it is assumed that he was not actively holding or moving any guidance control or foot pedal at the instant of impact.

The injuries to the right side of the face of the second pilot indicated that at the moment of collision his head was turned some way to the left. This could possibly indicate that he was operating the controls for the SX-16 spotlight. It could also be could be a reflex movement of the head immediately before the instant of impact.

The pilot was killed by severe trauma to the body, received from forwards and below.

Operator
From the injuries to the operator it was considered that he had been strapped in to the operator's seat with shoulder and waist belts. His right leg was in the gangway outside the operator's panel.

The operator was killed by severe trauma to the body, caused by striking the operator's panel.

Flight engineer
From the injuries to the flight mechanic it was considered that he had not been strapped in to any seat.

The flight engineer was killed by severe trauma to the body from the front, caused by striking the structure of the helicopter.

Rescue swimmer
From the injuries to the rescue swimmer it was considered that he had not been strapped in to any seat at the instant of impact. He stated himself that he had not been strapped in. He suffered a minor back injury, a minor injury to the right lower leg and a loss of memory of the accident event itself.

Student flight engineer

From the injuries to the student flight engineer it was considered that he had been secured by a three-point belt in one of the troop-carrying seats on the right side of the helicopter.

The student flight engineer was killed by severe trauma to the body from the front, caused by striking the structure of the helicopter.

Student rescue swimmer

From the injuries to the student rescue swimmer it was considered that he had not been strapped in to any seat at the moment of collision.

The student rescue swimmer was killed by severe trauma to the body from the front, caused by striking the structure of the helicopter.

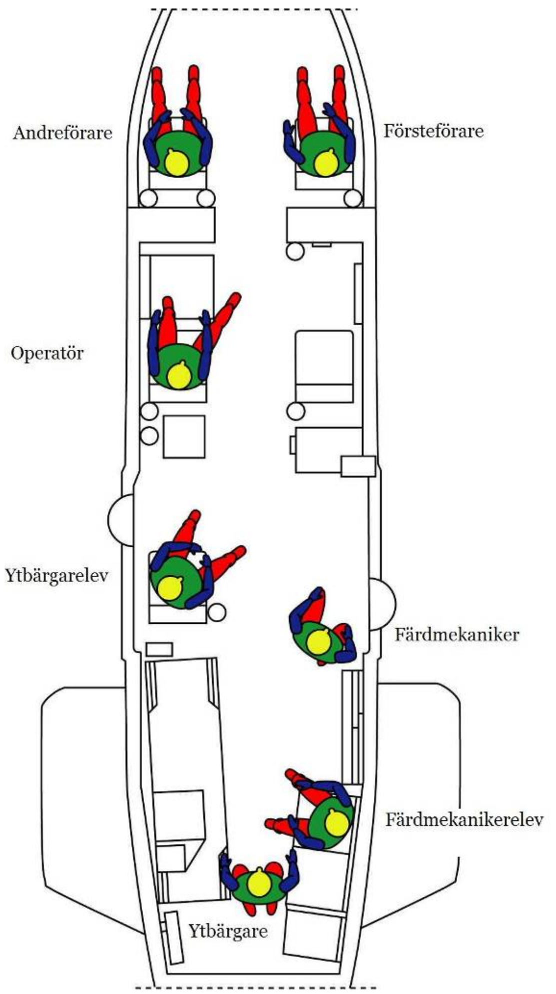

Fig. 28: *The probable locations of the crew at the instant of impact. The flight engineer was wearing the winch operator's safety belt and could not therefore sit in his normal place, due to the length of the support line and it being secured to the roof. The rescue swimmer and student rescue swimmer were not secured in their seats by securing straps at the instant of collision.*

Illustration annotations:

Second pilot — *First pilot*

Operator

Student rescue swimmer — *Flight engineer*

Student flight engineer

Rescue swimmer

Other
Examinations of the crew showed that no illegal substances were present. No health condition that could have influenced the accident was recorded either.

2.6 The flight sequence

2.6.1 Flight that ended with the accident

Crew change
After carrying out winching with the *Märta Collin* the crew returned and landed at Säve. The flight engineer and conscript rescue swimmer were replaced by new crew members. In connection with the crew change nothing has emerged to indicate that the crew had experienced any technical or other problems during the previous session or during the crew change.

One of the helicopter's two fuel tank pumps had earlier been reported as unserviceable. Flying is permitted with one pump unserviceable.

During the crew change, the crew may have been under a certain amount of pressure since the crew of the *Märta Collin* were hove to and waiting for the next flying session.

Take-off from Säve
In connection with the request to take off the air traffic controller reported to the helicopter crew the deterioration in visibility at the airfield that had occurred. On the basis of data available, the take-off and radio communication were performed in the normal manner.

Departure flight
After take-off and while departing to the exercise area and the *Märta Collin* the helicopter was called by the air traffic controller at Säve who could not see the helicopter on radar, since the crew had forgotten to switch on the transponder. When the helicopter crew were made aware of this the transponder was switched on and the air traffic controller could observe the position of the helicopter at Kalven. Communications were normal and no problem was mentioned. After this no further radio transmissions were heard from the helicopter.

Passing Kalven
After the helicopter had passed Kalven the radar recordings showed a normal approach to the *Märta Collin* on a westerly course. The helicopter then hovered for more than 90 seconds in the area south of the *Märta Collin*.

From the flying exercises described in section 1.14.2 it seems probable that the crew performed one of 21:4, 21:5 or a combination of these exercises, with direct flying towards a point south of the *Märta Collin*, i.e. without first flying overhead the vessel. If the final westerly course is assumed to be the approach course, this means that during the descent to hovering height they had a crosswind from the left of about 70°/10 knots. It is possible that the crew wanted to avoid turning with a crosswind when making contact with the water, whereby they would have finished up with a tailwind, which was very unsuitable.

The analysis carried out of speeds and heights did not indicate anything abnormal, just a probable direct approach to a point south of the *Märta Collin*.

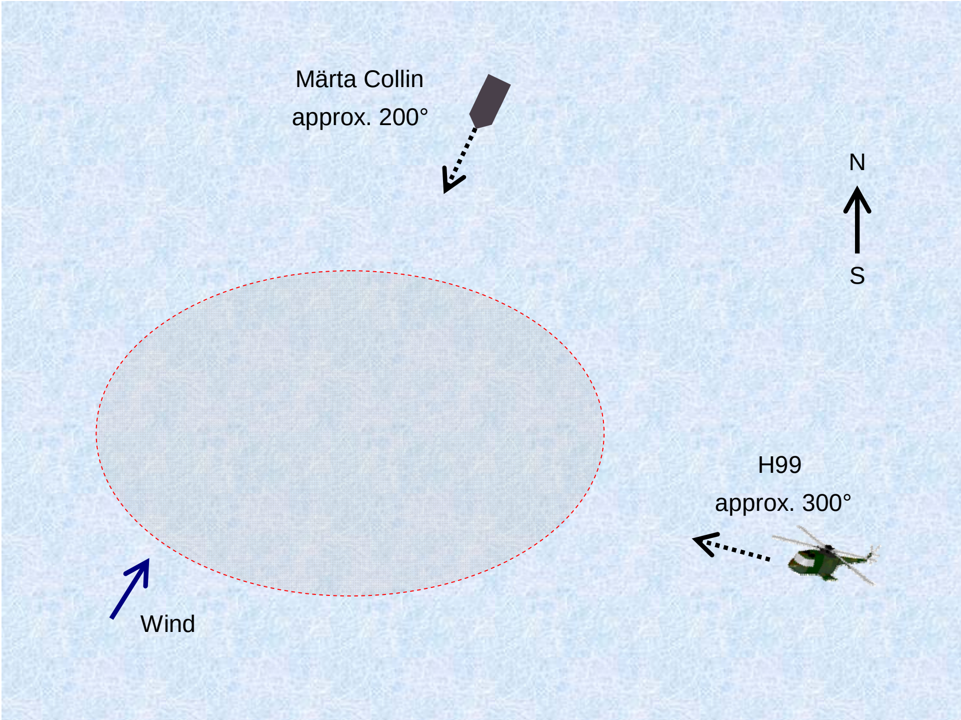

Fig. 29: *Schematic illustration of the exercise area.*

Hovering in the area south of the Märta Collin

From the radar recordings it could be seen that the helicopter hovered for about 90 seconds at a distance of 300-500 m south of the position of *Märta Collin* in the centre of the navigation channel, level with the southern tip of Barlind. The *Märta Collin* waited hove to on a heading of about 200°.

The primary and secondary radar picture shows the position of H99 at 18:40:51 and the SSR response gives the flying altitude as approx. 120 m STD, i.e. approx. 40 m AMSL.

In the final stage of hovering the crew probably consciously turned the helicopter on to a more south-westerly course to position the nose into wind, and in this case the *Märta Collin* would have been more to the rear of and north of the helicopter. After this the helicopter hovered eastwards, backwards or diagonally backwards towards the *Märta Collin*, probably with the aid of the coupler. At this stage all the helicopter's spotlights should have been lit.

During hovering the helicopter, because of its weight, would not have had single-engine performance available. The radar recordings show a clear movement to the east. Hovering was probably stable initially.

Any technical fault during the initial phase of hovering is unlikely, as a fault at this stage should have resulted in a movement and a take-off towards the south-west, against the wind, rather than continued movement towards the east.

The final radar recording

The penultimate and the last radar recording took place at an interval of 6 seconds. The last recorded echo, with a movement towards the west, is however not clear, considering the radar performance. A westerly movement is however supported by the fact that the crew of the *Märta Collin*, immediately after seeing the lights from the helicopter in an easterly movement, observed a brief westerly movement, which ended with the accident.

During the reference flights it could be concluded that the radar stations lost radar contact with the helicopter when flying at a height of 10 m or less.

It was not possible to ascertain the flight path of the helicopter immediately before impact with the water.

Impact with the water

Technical examinations showed that both engines were delivering normal power on impact with the water. The emergency floats had not been activated, which would have been the case if the crew intentionally made an emergency landing on the water.

The probable locations of the crew at the instant of impact indicate that preparations for winching to the *Märta Collin* had probably begun.

The calculated speed, about 80 knots, and attitude on impact with the water indicate that the accident did not take place during hovering or an emergency landing, but does indicate that a take-off had begun. The estimated time from hovering at about 40 m height to about 80 knots forward speed is in the order of 10 seconds.

Conclusions

The crew of H99 seem for some reason to have begun a take-off which failed and resulted in impacting the water.

2.6.2 Reasons for the decision to take off

Possible reasons for the crew deciding to take off could be one or a combination of the following events:

Engine surging (compressor stall)

There is strong evidence that during the hovering phase, i.e. the easterly movement, something happened to the helicopter which one pilot perceived as an engine surge. The rescue swimmer in conversation immediately after the accident stated that he felt *"it shook and banged in the helicopter like in an air pocket"*. He heard the flight engineer ask what was happening – the other pilot answered that there was *"a usual surge"* and that they had to change course. The rescue swimmer also heard someone say *"we are moving left"*. The rescue swimmer was a crew member in both flights. In an interview with the flight engineer who had been replaced after the first flight, it emerged that he had not heard the pilots discussing any surging. It was therefore ruled out that the rescue swimmer's information about surging could be incorrect, in that it could have been during the first flight.

The helicopter's movement relative to the wind in the hovering phase was such that according to the Flight Manual bleed offset should have been selected to minimise the risk of surging. If selecting bleed offset had been forgotten and the engines also varied their speed at the same time, to maintain the chosen flying height (HOVER HEIGHT), which could have been the reason because of "ground swell", the risk of surging would have been increased.

Engine surging could also be caused by damage to an engine compressor or by foreign objects. No such reason for possible surging was discovered during the technical examination.

The instruments in the helicopter did not show any abnormal engine rotation speed or low rotor rotation speed. This, along with the lack of damage in the engines caused by surging and the rescue swimmer's information should indicate that only a single case of surging occurred.

If surging occurred, regardless of the reason, it is very probable that this led to or contributed to a decision to take off.

High power output

On take-off from Säve the helicopter was carrying 1500 kg of fuel and seven crew members. During hovering the power required was probably in excess of 81% since the helicopter had only made a short flight from Säve and also had two extra crew on board.

If the crew while hovering at the *Märta Collin* realised that they would exceed a power output of 81 % for more than five minutes before winching could begin, this may have contributed to a decision to take off.

Experienced workload

Normally there is a high workload for the crew in hovering and moving in darkness and with poor or no external visual references. This could be a reason for the crew to decide to abort hovering and take off in order to make a new approach to the *Märta Collin*.

Doppler in memory mode

During hovering the doppler is the only sensor that gives the pilot a sense of speed and direction of movement.

If the doppler has a false lock, because the selection of CALM SEA has been forgotten, the helicopter could have picked up speed in a direction of which the pilots were not aware.

During hovering the doppler could have gone into memory mode due to smooth water and/or movement. At speeds of over about 7 kt in still wind and a flying height of over about 60 ft the ruffled water surface below the helicopter caused by the rotor wash begins to disappear, and thereby the capability of the doppler to sense the speed is reduced.

Doppler in memory mode and poor or no external references is a reason to begin a take-off. If during hovering, flying manually or with the coupler activated, the doppler goes into memory mode, one must begin a take-off within 10 seconds at a doppler speed of >5 kt and IAS[15] <40 kt and within 2 seconds at a doppler speed of <5 kt in accordance with the Flight Manual (Part 2, Section IV, page 45).

It was impossible to establish whether the doppler was in memory mode.

Losing Hover height (H.HT)

If the coupler's hover height mode (H.HT) was engaged, inadvertent disconnection could have taken place if the pilot by mistake operated the TRIM COLLECTIVE RELEASE switch on the collective lever, which has the function of trimming out any stick forces when flying manually.

If a difference in the engine output (torque) and/or speed (Ng) occurred, the coupler probably did disconnect H.HT if that mode was selected by the crew. There is no acoustic warning of a disconnection of the coupler's different modes.

Inadvertent disconnection or disconnection due to incorrect indication of the hover height mode could, in those weather conditions, have been a reason for a decision to take off.

It was impossible to establish whether there was a disconnection of the hover height mode.

Technical faults or deficiencies

The occurrence of a technical fault or a fault indication in a system could have resulted in a decision to take off. SHK has not found any technical fault to support this.

Medical reasons

If a member of the crew during the flight became severely incapacitated, there could have been a decision to abort the flight and perform a take off. There were however no medical indications that any illness occurred during the flight.

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[15] IAS: Indicated Air Speed

<u>*Conclusions*</u>
SHK considers it probable that the crew experienced an engine surge and that they therefore decided to turn into wind, to the south-west. SHK, on the basis of witness accounts and technical investigations, also came to the conclusion that this was a single case of surging and not a continuous surging. In connection with the helicopter turning into wind the surging ceased. Due to the probable turn to the south-west the possibility for the crew to maintain visual contact with the *Märta Collin* was markedly reduced. At the same time the possibility from the new position to hover back towards the *Märta Collin* was made more difficult due to the wind direction.

SHK found it probable that the crew decided to abort the hover and perform a take-off, due to the engine surge that was experienced. A contributing factor to the decision to take off could have been one or more of the reasons detailed above.

Whether the intention was to abort and fly back to Säve or to make a new approach to the *Märta Collin* cannot be determined.

2.6.3 *What may have happened during the take-off*

It was dark with a low cloud base and poor visibility, with precipitation, that made visual flying difficult. There was *"almost a flat calm sea"* with an absence of texture, which is assessed to have made visual contact with the water more difficult. In consideration of the pertaining external conditions, the pilots ought to have controlled and/or monitored flying with the aid of the flight instruments and without external references.

Against the background of the earlier mentioned conclusions concerning a possible engine surge, SHK believes that the take-off was performed without the coupler.

The following factors could have contributed, either individually or in combination, to a failed take-off.

<u>*Disorientation*</u>
Disorientation can mislead the pilot to rely too much on his own senses and false external references, along with a conscious or subconscious tendency to suppress information derived from the various helicopter instruments. This could have led to the pilot losing control of the flight path and colliding with the water.

The pilots could have been subjected to disorientation that affected their spatial orientation as follows:

- One light point on the *Märta Collin* provided a single-point reference insufficient for flying visually towards (Autokinesis).
- A lit searchlight (the SX-16) could have provided incorrect visual information concerning the direction of movement when illuminating rain/cloud structures (Relative motion illusion).
- If incorrectly aimed, the SX-16 (too close to the front of the helicopter) could have had both a dazzling effect and also prompted a subconscious lowering of the nose (Crater illusion).

<u>*Instrument monitoring*</u>
Stress has been shown to have effects on a pilot's perception of the flight path (see section 1.23.2). In a stressful situation people tend to act immediately and focus attention on what is perceived to be central, and ignore other vital information. There is a risk of losing altitude supervision.

The first pilot could when deciding to take off have focused on turning into wind and increasing speed, and therefore failed to observe the flying altitude.

The second pilot/aircraft commander could have been busy analysing the engine values after the engine surge and directing the SX-16 searchlight to a suitable position for the take-off and therefore not paying enough attention to the flight path.

EFIS blanking out
The pilot's EFIS display that shows attitude information could have blanked out just at the most critical stage of the take-off. A blanked out or flashing EFIS display is a fault that has happened in the HKP10 system, both around the time of the accident and on occasions thereafter. In the case where the ADI blanks out the pilot must primarily switch to flying with the aid of the standby attitude indicator.

Even if he transfers to this instrument, it could contribute to a distraction to the pilots' attention and a failure by either to notice the flight path.

Over-correction
In a stressful situation the first pilot could have over-corrected on the controls during take-off, so that the nose attitude went too low. Such an over-correction could quickly lead to a critical in-flight situation.

Conclusions
SHK cannot for certain prove what happened during the unsuccessful take-off. The initial situation was however such that a take-off should have been possible. As previously mentioned, no technical fault could be found, but this does not exclude the possibility of a fault or fault indication during the take-off that could not be discovered afterwards. The conditions were such that disorientation could have arisen. There are strong requirements for crew co-operation while taking off in such conditions. In the opinion of SHK the onset of disorientation and/or inadequate instrument monitoring by the crew is a possible reason for the unsuccessful take-off.

The warnings that should have been given from the two independent radio altimeters that the decision height (DH) was being passed were not enough to prevent impact with the water.

With all the above in mind, a possible scenario could have been as follows:

The crew had planned their approach to the *Märta Collin* as a direct approach in crosswind conditions. The chosen approach method and the short distance from Säve could have resulted in unintentionally hovering in front of the *Märta Collin*. A difficult hover back towards the *Märta Collin* began and continued for about 90 seconds with high engine power, and under a lot of stress, when one engine momentarily surging, possibly caused by varying engine power inputs (oscillations) and/or forgetting to switch on bleed offset.

A take-off was performed, during which instrument monitoring was lost. The second pilot/aircraft commander, who could have been busy analysing the engine values after the surge or directing the SX-16 spotlight to a suitable position for the take-off, did not notice the flight path. Warnings by the radio altimeters as the decision height (DH) was passed were either not noticed or came too late for the pilots.

2.7 Other information

The helicopter was equipped for SAR tasks. At the time of the accident the helicopter was carrying 1500 kg of fuel in order to be able to fulfil its SAR obligations for the flying that was being carried out at Malmen that evening. There were also two extra crew members on board.

With the fuel on board, the equipment that was installed and the extra crew, it should not have been difficult for the crew to control the helicopter.

The AURAL WARNING switch was found in the OFF position. AURAL WARNING must always normally be switched on while flying, but the shape and location of this switch mean that it could have changed position in connection with the impact of the helicopter with the water. If AURAL WARNING is switched off while flying, this is indicated by the A. WARN indication light on the warning panel (α32) being illuminated.

No emergency signal was received from the helicopter's ELT. The ELT could have activated at impact and transmitted until its battery was discharged, or the battery could have been short-circuited in the water. If the ELT did activate, its signal could not have been received since the transmitter and its antenna lay on the sea bottom.

The pinger transmitter probably did activate and operate during the time it was in the water. As the wreckage was located with the aid of, among other things, a towed hydrophone, the equipment for tracking the pinger transmitter was not used to locate the wreckage.

2.8 The helicopter's Human-System interface

In interviews with experienced HKP10 pilots it emerged that they consider that there are several human factors deficiencies in the Human-System interface. There are shortcomings in the presentation of information and also in the design and location of knobs and other controls.

Section 2.6 contains a more detailed description of how the following instruments and controls, on their own or in combination with other factors, could have contributed to the sequence of events.

- The hovering indicator, with no doppler memory mode indication.
- Inadvertent disconnection of HOVER HEIGHT with the TRIM COLLECTIVE RELEASE switch.
- The size and scale of the ADI for banking and attitude respectively.
- Blanking out of the EFIS with loss of ADI.
- The differences in banking indications between the ADI and the standby attitude indicator.
- The radio altimeter's height scale and information regarding passing through the selected decision height (DH).

In the opinion of SHK, the information provided when passing through the decision height is insufficient. It is also considered that the routine of both pilots using a decision height of 30 ft can involve the risk that they do not notice the warning in time, as the crew receive no preliminary warning before the decision height is reached.

The height warning function that exists is to notify the pilots of the passage through the preset decision height. It is thus not primarily a system to prevent collision with underlying terrain. This would require a special ground collision warning system (Terrain Awareness and Warning System, TAWS) designed for helicopters. Such systems exist and can include warnings for example of terrain obstacles, excessive helicopter bank angles or excessive sink rate. The warnings include prior warnings of different levels of danger (NTSB/AAR-06/02). It is however important that the system is designed not to give false warnings.

Barriers that were missing or insufficient
A collective risk assessment after a period of use in this type of helicopter of the Human-System interface had not been made.

The visual and acoustic signals on passing through the decision height (DH), set at 30 ft, were insufficient to act as a barrier.

There was no ground proximity warning system installed in the helicopter.

2.9 Personnel information

2.9.1 Medical status

All the crew members were adjudged to have had a completely satisfactory physical and psychological status before and during the flight that resulted in an accident.

2.9.2 Flying experience

Flying experience is "perishable", which means that the crew need recurrent and regular training in order to be able to safely carry out flying tasks and practice for these.

During the autumn of 2003 the pilots had been allotted a limited number of flying hours and not completed much night flying.

The first pilot was considered to be relatively current, but did not have a great deal of experience with the HKP10. His flying hours in darkness for the previous 90 days as first pilot were rather few.

The second pilot/aircraft commander had long experience of the HKP10. At the time of the accident he was considered to be short of flying hours and had few night flying hours in 2003 due to his service in the spring with the Wing staff.

This limited amount of night flying may have affected their ability to manage the situation that arose in connection with hovering during the accident flight.

Barriers that were missing or insufficient
There were no operational limitations for helicopter crews taking into account actual flying experience after a longer period away from flying.

2.10 Operational flight procedures and crew co-operation

The lack of prescribed and well-practised callouts for different phases of flying is a deficiency, in particular in the case of flying with mixed crews and in situations with high workloads. This lack of procedures can weaken the two-pilot concept and contribute to the crew not acting in time on important information concerning the flight path.

At the time of the accident there was no FOM with prescribed flight operations procedures and standard phraseology. This means that there could be differences in working methods and terminology between personnel from different defence branches, operating locations and helicopter types.

Analyses carried out by FlygSäk showed that in the Swedish Armed Forces helicopter operations there had been problems in communication due to inherited differences in terminology. According to interviews with personnel at Säve/Såtenäs, misunderstandings and a lack of clarity had happened in communications and co-operation between crew members in the HKP10 system during flying. Differences in terminology were seen as a contributory factor. Also, deficiencies in the standardisation of flight operations procedures, callouts and checklists were mentioned. There is also experience from other mergers that negative effects can arise in communications and co-operation if the changes are not managed properly (see 1.23.2).

This was a mixed crew, with the first pilot and operator from Navy HKP4 helicopters at Säve and the second pilot and flight engineer from Air Force HKP10 helicopters at Såtenäs. There were no prescribed flight operations procedures and checklists for descent to water contact or for take-off from hovering. In addition there were no prescribed callouts and standard terminology. This brought a risk of misunderstanding and a lack of clarity, which in turn could contribute to a crew inadvertently misjudging the hovering point, and pilots not apprehending or misjudging the flight path, while taking off from hovering.

In interviews with colleagues of the crew it emerged that it could be difficult to get the time, peace and quiet required to be able to prepare and concentrate in the period before and after flying, the “flying window”.
Between the two flights that evening there was no debriefing of the first flight, nor any planning for the next flight, that involved the entire crew. When two flights are consecutive, it was, according to information received, not uncommon for the planning and debriefing to be lumped together, i.e. before and after both completed flights.

Barriers that were missing or insufficient
There were no prescribed flight operations procedures with checklists and callouts with common terminology.

Risk assessment had not been done to take account of crews consisting of personnel from different defence branches, operating locations and helicopter types, not having prescribed flight operations procedures with checklists and callouts with common terminology.

Routines and tools were missing for a joint risk assessment of several factors that were important for forthcoming flying tasks, such as weather, night flying hours, helicopter experience, worry and stress due to organisational changes, and long periods of duty.

Routines to ensure “a flying window” were not present.

2.11 Flight safety material

The possibility of the crews of the rescue vessels to locate the helicopter crew was considerably lessened by the dark green colour and lack of reflectors on the flying suits and flotation vests.

With brightly coloured immersion suits and flotation vests and reflectors on their helmets the possibility of detection and rescue would have been much better.

2.12 Survival aspects

The extensive disintegration of the helicopter meant that there was no chance of survival of the crew on impact with the water.

The fact that the conscript rescue swimmer survived was due to him not wearing a safety belt at the instant of collision and that during separation from the helicopter he did not strike any of its structure, and that he was quickly rescued thereafter by the crew of the *Märta Collin*.

The conscript rescue swimmer student was not wearing a safety belt either, but struck the helicopter structure on impact with the water. The crews of the participating rescue vessels stated that it was very difficult to find the helicopter crew in the water in their dark immersion suits without reflectors, even though several vessels had very powerful searchlights.

The rescue swimmer, who was found by the crew of the *Märta Collin,* was wearing a bright green immersion suit and also had reflectors, so that he was quickly spotted at a distance of about 100 m in the searchlight beam from the *Märta Collin*.

The first pilot and second pilot, the operator, student flight engineer and the student rescue swimmer wore civilian or military additional clothing and underwear that had not been approved for flying duty. The difference between wearing undershirt ff M/93 and long underwear under a immersion suit instead of a T-shirt and shorts is 4-5 times as long survival time in water and much better fire (heat) protection.

2.13 Actions by the rescue services

The *Märta Collin* when raising the alarm had reported that the helicopter had gone down in the water in the area of Lilla Barlind. The search area for the crew could in light of this be restricted.

When the Rescue centre put out a general call via VHF channel 16, several vessels that were located near the accident site received a request for their assistance. The Coastguard's *KBV050*, police boat *7050* and the three fishing boats *Astrid, Falken* and *Rebecca* arrived quickly on the scene within 20 minutes of the accident alarm call. No checklist or alarm plan were used in connection with the alarm. A checklist for the event permits follow-up of issued alarms and ensures that no suitable resource is overlooked. When the event happened, the Police helicopter unit, for example, received the alarm relatively late, while other units themselves contacted the Rescue centre to ask whether they were needed. Because the ambulance helicopter could not fly, no medical resources went out to the accident site, instead medical personnel had to wait on the mainland at Lilla Varholmen. In this case a checklist could for example have been able to propose the use of the Rescue services ambulance boat or another suitable vessel as a floating medical unit. With medical staff on board they would have quickly been able to begin resuscitation of the recovered and injured people from the helicopter. With the benefit of hindsight it became clear after the accident that expert emergency medical assistance at the site of the accident could not have kept any of the deceased alive. After the accident an emergency plan for airborne rescue was prepared within the Swedish Civil Aviation Authority Air Rescue Co-ordination Centre, ARCC.

The rescue helicopter that was en route to Säve from Ronneby was recalled by the rescue leader. This helicopter was a resource which could have been used in the efforts if it had been given permission to continue to Säve. There was no helicopter in the area which could if necessary recover a survivor using a hoist winch and rescue swimmer. The police helicopter took part in the search during the night and also the next day. It was this one which saw the oil emanating from the location that later proved to be the crash site of the forward part of the destroyed helicopter, where the operator and flight engineer's bodies were found.

With responsibility in accordance with the rescue services legislation, the rescue leader at the ARCC carried out the management and co-ordination of the rescue efforts in the helicopter accident. An OSC could be established about one hour after the accident occurred, when the rescue vessel *PO Hansson* was on site. The OSC was also then given the task of organising the trawl, which did not leave any room for any more general operations at the accident site.

The fact that one survivor and four deceased from the crew were found within one hour of the accident was due more to the participating crews' own initiative and knowledge than that the search at that stage was well organised out at the accident site.

The fishing boat *Rebecca* took part in the rescue efforts and found three of the helicopter crew, while the boat skipper did not know who was in charge or which organisation was responsible for rescue. Even the personnel on the police boat only found out, after the rescue attempts, which organisation was actually responsible for the rescue. The entire rescue effort was carried out as a maritime rescue mission with radio traffic from the MRCC, without more detailed information as to who was the rescue leader and which organisation was actually responsible for the rescue.

Most of the units participating at the accident site seem to have come to the conclusion that it was MRCC that was responsible for the efforts. At the same time it has not appeared that the implementation of the rescue efforts were harmed by the lack of information concerning the presence of the rescue leader from the ARCC. The most important in this context was that the rescue leader acted energetically and obtained efficient support in various tasks from the personnel in the co-located maritime rescue centre, these belonging to MRCC, the Coastguard regional management west and the Swedish Armed Forces maritime surveillance centre west.

A more organised follow-up of the work of the participating units and the results was issued on the day after the accident. The OSC on the *KBV050* documented which beaches and sea areas had been searched.

One condition for efficiently being able to take part in a search is that the participating vessels have very good lighting that gives their crews the chance to detect people in the water. In this rescue mission two night fishing boats with unusually good lighting took part. The immersion suits for a helicopter crew should have a different colour than the present green, so as to be able to be seen better in water, and in addition the clothing should be equipped with reflectors. It was the reflectors on the student rescue swimmer that were first seen by the Coastguard personnel.

Between 01:00 – 02:00 several units abandoned searching in the area. Despite the strengthening wind, the *PO Hansson* continued the search alone all night after its crew had been changed. There were no measures taken by the rescue management to plan for the endurance of the rescue efforts. The assigned units were at the stated times in need of relief if the efforts were to continue all night. The rescue service stage was declared terminated in accordance with rescue services legislation at 02:49. Recovery operations were resumed on the morning of 19 November, and carried out under conditions similar to a rescue operation, whilst the efforts made earlier during the night were not classified as a rescue operation.

2.14 Organisation and management

2.14.1 *Management of organisational changes*

The organisational changes that took place in the Swedish Armed Forces helicopter operations involved a great deal of turbulence and unclear management conditions. The cultural differences among the merged helicopter units from the Army, Navy and Air Force, meant that there were sometimes different views of how the operational tasks should be carried out, and this contributed to friction and conflicts. The Wing management was seen as finding it difficult to bring the operational units to a joint point of view. The lack of common values and perspectives within the Helicopter Wing was assessed by the Swedish Armed Forces' own investigator as being the largest single contributory cause of the deteriorating flight safety situation in the unit.

Results from a study in 2005 of one helicopter unit and one fighter aircraft unit pointed to a worse organisational climate, psycho-social work environment and safety culture among the helicopter unit's pilots than among those of the fighter unit. One important reason for the differences was probably that helicopter operations had been exposed to comprehensive and repeated organisational changes.

Personnel in the SAR and Flight squadrons experienced frustration, insecurity and stress. Uncertainty prevailed concerning both the organisation's goals and whether their own workplaces would be relocated. Long-term stress affects people's capabilities. Among other things, concentration and attention are impaired. This can involve a particular risk in flying tasks, for example when descending to sea level during difficult external conditions.

For the Flight operations commander the mergers meant an increase in his area of responsibility, with more types of helicopter, different tasking types and operations that did nor appear to be accompanied by increased resources. This is judged to have brought difficulty in following up and supporting flying operations on site.

Organisational changes can, if they are not managed well, reduce flight safety. The RML contain requirements for managing organisational changes in such a way as to minimise risks. These requirements are placed on condition makers as well as operators and providers. According to the judgement of the SHK, the Swedish Armed Forces has not lived up to these requirements. Organisational changes of the helicopter operations within the Swedish Armed Forces appear, in the opinion of SHK, to have been carried out without a preliminary analysis of the possible risks to flight safety.

The Swedish Armed Forces investigation in 2005 of helicopter operational management and control found that the organisational changes were carried out without systematic risk analyses, follow-up and evaluation of the consequences as they would affect flight safety.

According to RML V-1C1.41 each operator or provider within the military aviation system shall establish documented procedures covering preventive measures related to planned changes to the operations, as well as corrective actions when deviations occur. In addition, an operational unit, in accordance with RML V-1C1.42, must have documented procedures for a systematic review of the conditions prior to a change in operations. It is difficult to decide when an organisational change is also an operational change. In general, however, organisational changes in the form of mergers and relocation of operations have an effect on the operations and the work environment of the personnel, by affecting relationships and contact points, priorities and upsets a possible balance between tasks and resources.

Therefore a requirement for procedures should also apply to organisational changes.

There were no procedures for the management of organisational changes in respect of:

- risk analyses before the changes,
- implementation of measures to minimise the risks, and
- follow-up and evaluation of the changes taking into account the consequences as they affect flight safety.

One of the recommendations made by the Swedish Armed Forces investigation in 2005 of management and control was to devise systematic routines for the management of organisational changes.

In accordance with the Swedish Work Environment Authority Provisions on Systematic Work Environment Management, when changes are being planned, the employer must assess whether the changes entail risks of ill health or accidents. SHK could not find that any documented risk assessment had been done in order to identify risks, so that negative consequences of the rearrangement process could be prevented. This is a shortcoming in the preventive work environment process that is also important for flight safety.

The DA (driftstörningsanmälan – operational reporting) system seems at all levels to have been the main tool for following up the consequences of changes from the flight safety viewpoint. The Swedish Armed Forces Flight Safety analysis of 2003 concerning the helicopter operations events of 2002 pointed to certain relationships that could be associated with the organisational changes. The analysis also showed that comparatively few events had been reported in connection with the HKP10 system.

As shown by the analyses, few reports of events might be a result of weaknesses in the system being caught by the two-pilot concept, that events for some other reason were not reported, or there are few weaknesses in the system. The number of reported events is not therefore a good measure of safety in operations. However there were indications of under-reporting, which is a warning signal and should lead to a review of the operations. It does not appear that such a review was carried out.

The DA system is an important aid to safety work, but other tools are also needed to follow up reorganisation processes in order to identify the risks that arise. The Swedish Armed Forces do not seem to have these tools to systematically follow up the risks associated with organisational changes.

In summary, SHK has not found at any level in the Swedish Armed Forces that there were routines or a sufficiently developed code of practice to prevent flight safety risks in connection with organisational changes. This is despite the requirements in the RML on both condition makers as well as operators or providers and for systematic risk management during changes, in the Swedish Work Environment Authority Provisions (2001:1) on Systematic Work Environment Management. In addition, SHK has pointed out before, in the investigation into the Kaskasapakte accident in 2000, that there existed resource, reorganisation and leadership problems, which typically involved risks to flight safety, even though SHK could not associate these directly with the accident.

2.14.2 Implementation of the Rules of Military Aviation (RML)

At about the same time as the changes in the Swedish Armed Forces helicopter operations took place, the new RML rules were to be implemented. There does not seem to have been any clear strategy for how the organisational changes and the implementation of RML would best be managed, in connection with the decision to merge the helicopter operations of the defence organisations. This in the opinion of SHK is a shortcoming, since the RML contains, among other things, requirements that are intended to prevent risks associated with organisational changes and also those related to having personnel with different background experience (defence branches, helicopter systems and operational bases) starting to work with each other in a crew.

It is possible that the rearrangement of helicopter operations was influenced by external decisions, to such an extent that it was difficult to prepare a clear strategy for all the changes that had to be made. However even if operations are affected by external decisions, safety must be maintained, if requirements are also present to maintain FRÄD och SAR operations, which in turn need training to be able to safely perform the tasks.

SHK also, in its investigation into an incident to a military transport aircraft on 11 December 2003 (RM 2007:01) found deficiencies in the implementation of RML and in defining the rules. The reasons for these deficiencies were analysed in greater detail in the investigation. The following were stated as reasons for the incident: Deficiencies in organisation, competence, quality control and resources within the Swedish Armed Forces in respect of implementation, management and the inspection of military aviation.

2.14.3 Inspection during the process of change

Increased inspection efforts are often needed during organisational changes. Such efforts are needed to ensure that both those who affect operations as well as those who carry them out have the necessary formal routines, tools, competence and resources to manage changes, including such changes that are initiated and determined by other than the Swedish Armed Forces. Efforts are also needed to inspect the outcome, i.e. how personnel experience the changes and how the changes are managed, along with how operations are managed in practice by the units.

SHK considers that FLYGI did not have sufficient resources to be able to carry out such inspections in connection with the organisational changes. In order to be able to fulfil the inspection task in a satisfactory manner, FLYGI should be assured sufficient resources.

Barriers that were missing or insufficient
From the documents and information obtained by SHK there is no other conclusion than that risk analysis, with decisions concerning risk-minimising measures in accordance with the RML requirements, was missing before the build-up of a Helicopter Wing or before the subsequent organisational changes.

There were no systematic routines in the management of the organisational changes to minimise safety-influencing consequences.

Insufficient tools were available to systematically follow up the flight safety risks associated with organisational changes.

FLYGI’s inspection of the helicopter operations reorganisation process was insufficient.

2.15 Training procedures

The conversion training that took place of individual pilots from the HKP4 to the HKP10 does not seem to have been carried out with sufficient stringency in all respects. It was a shortcoming that there was not complete and reliable documentation of which exercises the “first pilot” had carried out. It was a shortcoming that the exercise table was not saved by the squadron and was only present in the pilot’s computer.

Nor was SHK able to find any documented analysis of the training requirements, as a basis for GFSU:Ä training, in either its technical or operational aspects.

There was no system for a collective follow-up of which flights each crew member had made and when. Among other things this means that there was no system to transfer information to others, e.g. when changing operational bases.

It is not satisfactory that the training package in UHU HKP10 had not been ratified at the time of the accident. This means that there could be variations between different operational bases, and that there was a risk that cuts could occur.

It was also a shortcoming that, at the time of the accident, there were no clear rules to control refresher training in the case of long periods of absence from flying duty.

3 CONCLUSIONS

3.1 Findings

1. SHK did not find anything to indicate that a technical fault had occurred or contributed to the accident.

2. The helicopter was technically airworthy and had been maintained in accordance with the applicable regulations.

3. The helicopter was not equipped with a Ground Proximity Warning System).

4. The helicopter was not equipped with a flight data recorder (FDR) or cockpit voice recorder (CVR) despite the Swedish Armed Forces decision to introduce these after the accident to a HKP10 on 11 August 2000 at Kaskasapakte.

5. The helicopter had no acoustic warning of a disconnection of coupler modes.

6. The investigation was unable to establish whether the EFIS blanked out.

7. The Flight Manual for the HKP10 does not describe any actions to be taken if an engine surge occurs, and showed deficiencies in the basis for mass and balance calculations.

8. The three spotlights on the helicopter needed 10-20 seconds from being switched on to reach their maximum brightness. If a spotlight was switched off it needed two to five minutes of cooling time before it could be lit again.

9. In certain HKP10 helicopters the radio altimeter switch (ON/OFF) had been fitted with a non-approved modification, a cable tie, to prevent mistaken operation when setting the decision height (DH).

10. On interviewing helicopter pilots it emerged that several important instruments, knobs and switches were designed so that there was a risk of misinterpretation and accidental operation.

11. A collective risk assessment after a period of use in this type of helicopter of the Human-System interface had not been carried out.

12. Problems arose during flying in communication between crew members from different defence services, different helicopter types and operating bases.

13. There were no established flight operations procedures and callouts with common terminology were missing.

14. After the accident to a HKP10 at Kaskasapakte on 11 August 2000 the training in situational awareness and spatial disorientation for flying personnel promised by the Swedish Armed Forces was not forthcoming.

15. The investigation was not able to find any medical effect on the crew that could have contributed to or caused the accident.

16. All the crew members had undergone the prescribed medical examinations in accordance with OSF, with approved results.

17. There were no systematic routines in the management of the organisational changes to minimise safety-influencing consequences.

18. From the documents and information obtained by SHK there is no other conclusion than that risk analysis, with decisions concerning risk-minimising measures in accordance with the RML requirements, was not available before the establishment of a Helicopter Wing or before the subsequent organisational changes.

19. FLYGI's inspection of the helicopter operations reorganisation process was insufficient.

20. There was imbalance between tasks and resources, which affected the ability of the Flight Operations commander to follow up flight safety on site.

21. The flying personnel experienced uncertainty, frustration and stress in association with the repeated organisational changes.

22. Deficiencies in management and control of helicopter operations that SHK had pointed out earlier remained at the time of the accident.

23. The lack of bright-coloured outer clothing and reflectors on immersion suits meant that the vessels taking part in searching after the accident had great difficulty in finding the crew members who were wearing immersion suits.

24. Some crew members were wearing non-approved or private inner garments and underclothes.

25. The personal emergency equipment prescribed by OSF cannot be carried by rescue swimmers when they are wearing immersion suits as these have no pockets for this equipment.

26. Flying helmet type 124C, that the student rescue swimmer was wearing, had no maintenance plan at the time of the accident.

27. The first aid bags, included in the medical SAR equipment, had separated without damaging the frames, securing straps or bag contents.

28. The cardioscope included in the medical equipment was not formally approved for airworthiness for the HKP10.

29. There were major deficiencies in DIDAS in respect of the medical material that was included in the SAR equipment in the helicopter.

30. No checklist was used in connection with the alarm to the rescue units.

31. The rescue helicopter that had been alarmed was recalled before it reached the accident area.

32. An OSC was assigned about one hour after the flight accident alarm.

33. One survivor and four bodies were found within one hour of the flight accident alarm.

34. Several of the rescue units did not receive information from the ARCC as to who was the rescue leader.

35. The rescue service stage was completed by the time the search was resumed the day after the accident.

36. The day after the accident the OSC documented which sea and beach areas had been searched.

37. During the search on the day after the accident the Rescue centre sent out a directive that all units should log all items found and state the time and location of the finds.

3.2 Causes

It has not been possible to establish the cause of the accident.

A combined assessment indicates that the crew did not have full situational awareness while taking off after hovering at a low height. The investigation revealed that several safety barriers to prevent an accident were missing. Such barriers that are important are a ground collision warning system, a combined risk assessment of this type of helicopter's Human-System interface, laid down flight operation procedures and callouts, and risk assessment of organisational changes with decisions on measures to be taken and the evaluation of their effects. In addition the FLYGI inspection was inadequate.

4 RECOMMENDATIONS

It is recommended that the Swedish Armed Forces:

- Takes action to secure the function of EFIS and minimise the risk of the display being blanked out during flight (*RM 2007:02 R1*).

- Equips helicopters with ground proximity warning systems (*RM 2007:02 R2*).

- Introduces an audio warning to draw attention to the disconnection of all modes of the AP/Coupler (*RM 2007:02 R3*).

- Modifies searchlights so that the time from switching on to maximum illumination power is minimised (*RM 2007:02 R4*).

- Modifies the radio altimeter ON/OFF function so that it cannot be switched off by mistake thus affecting the decision height (DH) function (*RM 2007:02 R5*).

- Determines and describes in the Flight Manual for HKP10 helicopters the emergency measures to be taken in the case of engine surge , and updates the basic values for mass and balance calculations (*RM 2007:02 R6*).

- Ensures that the forthcoming modification package for the HKP10 takes into account the crews' experience and human factors requirements (*RM 2007:02 R7*).

- On procurement, sets requirements that helicopter interfaces meet ergonomic requirements, and performs documented verification and validation of the Human-System interface (*RM 2007:02 R8*).

- Ensures that current education and training are expanded, implemented and documented in respect of situation awareness (SA) and spatial disorientation (SD) (*RM 2007:02 R9*).

- Sets detailed goals for SAR/FRÄD operations by helicopter units (*RM 2007:02 R10*).

- Introduces prescribed flight operations procedures with callouts and checklists (*RM 2007:02 R11*).

- Reviews the allocation of flying hours and training content, in order to achieve established goals for crew members included in SAR/FRÄD operations (*RM 2007:02 R12*).

- Introduces documented procedures for a systematic review of the conditions prior to organisational changes, with decisions on risk-minimising measures and the evaluation of the effects of these measures (*RM 2007:02 R13*).

- Ensures that the organisation and resources enable Air station commander and Flight operations commander to check flight operations and support Flying Squadron Commanders and flight crews on a regular basis and to a high standard (*RM 2007:02 R14*).

- Introduces an outher garment for flying personnel that will facilitate detection in water and on land in conditions of darkness (*RM 2007:02 R15*).

- Takes measures so that personal emergency equipment, in accordance with OSF, can be carried by rescue swimmers dressed in immersion suits (*RM 2007:02 16*).

- Establishes an expiry age for personal flight safety material (*RM 2007:02 R17*).

- Ensures that securing of medical equipment inside the cabin meets the prescribed requirements (*RM 2007:02 R18*).

The SHK report RM 2007:01 concerning an incident to a transport aircraft on 11 December 2003 contains among other things the following recommendation, which this investigation also finds applicable:

- To arrange so that supervision of military aviation is provided with such an organisational setting and with such resources that independent and efficient inspections can be put into effect *(RM 2007:01 R1)*.

- That RML will as soon as possible be developed in accordance with the ambitions in U-RML *(RM 2007:01 R3)*.

- The developed RML will as soon as possible be implemented in all areas of military aviation *(RM 2007:01 R4)*.

Earlier submitted recommendations to the Swedish Armed Forces:

- The introduction of regulations concerning how training schedules for flying personnel shall be documented (*RM 2005:03 R5*).

It is recommended that the Swedish Civil Aviation Authority:

- Introduces procedures so that rescue helicopters capable of hoisting are provided at an accident site where the need for such a resource cannot be excluded (*RM 2007:02 R19*).

- Introduces procedures for following up the work carried out by participating units during a rescue operation, as a basis for future planning and the management of rescue efforts that are in progress (*RM 2007:02 R20*).

- Develops procedures for bringing emergency airborne rescue operations to a close (*RM 2007:02 R21*).