



Statens haverikommission
Swedish Accident Investigation Board

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Report RM 2005:01e

**Accident involving helicopter type 11 no 334
(Agusta Bell 412HP)
over Bottensjön, Karlsborg, O county, Sweden,
on 25 March 2003.**

M-04/03

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

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Translated by Tim Crosfield, M.A. from the original Swedish at the request of the Swedish Accident Investigation Board.

Should there be any discrepancy between the English and the Swedish texts, the Swedish text is to be considered the authoritative version.

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M-04/03

Swedish Armed Forces

107 85 STOCKHOLM

Report RM 2005:01

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an accident that occurred on 25 March 2003 at Botensjön, Karlsborg, O county, Sweden, involving a Swedish Air Force type-11 helicopter (Agusta Bell 412HP) with call sign Zulu thirty-four (Z34).

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

The Board will be grateful to receive, by 9 September 2005 at the latest, particulars of how the recommendations included in this report are being followed up.

Carin Hellner

Urban Kjellberg

Carl R. Hellström

Tomas Krave

Letter with identical wording to Swedish National Rescue Service

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APPENDIX

- 1** Technical investigation report (SHK document appendix 1). The appendix is attached only to reports submitted to the Swedish Armed Forces, the Swedish Defence Materiel Administration and the Helicopter Wing.

Abbreviations and explanations of terms

AF1	1. Army Air Battalion —former designation for the 1st. Helicopter squadron, Boden. Approach briefing —short briefing normally given by commander to co-pilot, stating how an approach is to be executed, together with measures for aborted approach.	LÖV	Air-sea rescue, open water —flight profile being executed when Z34 crashed.
ARCC	Aeronautical Rescue Coordination Centre —command centre for search following air accidents	MIF	Military flight information service —simplified military air traffic control service
BOF	Decision to fly —wing commander flying or squadron commander takes decision regarding flying mission. They then assume responsibility for flight safety for that mission. BOF establishes line of command and responsibility and necessary directions for fulfilling the mission, BOF may be given verbally and can cover one sortie or a period with many missions	MilAIP	Military Aeronautical Information Publication.
CVR	Cockpit Voice Recorder —accident-protected tape recorder that records radio communications and cockpit sounds	NVG	Night vision goggles —light amplifier enabling wearer to see in the dark
DA	Occurrence report	OFFG	Mission implementation order —execution of a mission is preceded by orders given to the pilot designated by the commander responsible for flight safety. the authority and limitations specified in the BOF form the basis for an OFFG
DIDAS	Operational maintenance data system —system for monitoring time-limited maintenance of aviation materiel	OSF	Order and safety instruction for military aviation
ELT	Emergency locator transmitter —starts transmitting automatically following an accident	PFT	Periodic flight training
FBS	Swedish Air Force Command School	RAFT	Instructions for reporting, Aviation Materiel Service
FDR	Flight Data Recorder —accident protected tape recorder for recording technical data	RHM	Radio altimeter
FM	Swedish Armed Forces	SFI	Special instruction to pilot
FMV	Swedish Defence Materiel Administration	SHK	Swedish Board of Accident Investigation
Fpm	Feet per minute —1 m/s corresponds to approx. 200 fpm	TRAB	Technical report work order —document with particulars of technical fault or discrepancy in aircraft
Ft	Foot —English measure of length, 1 ft corresponds to approx 0.3 m	UWE	Under water escape —training in emergency evacuation from a submerged helicopter cabin
HKP11	Helicopter 11 —Agusta Bell AB412HP	VFR	Visual Flight Rules
Hot mic	Continuously activated intercom microphone	VRS	Vortex ring state —aerodynamic recirculation phenomenon causing a helicopter to lose lift
hPa	Hektopascal —unit of pressure.	V1	Main rotor average downwash speed
IAS	Indicated air speed	WGS 84	World Geodetic System —map reference system
IFR	Instrument Flight Rules	QFE	Air pressure reduced to aircraft's height above aerodrome or runway
		QNH	Air pressure reduced to aircraft's height above sea level

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Report finalised 09-03-2005

<i>Aircraft; type; registration</i>	HKP11 - Agusta Bell 412 HP, No. 334 (manufacturer's serial number 25804)
<i>Owner/operator</i>	Armed Forces/1. Helicopter squadron, Boden
<i>Time of event</i>	25-03-2003, 14.11.09 hrs in daylight All times are given in Swedish normal time (UTC + 1 hour)
<i>Place</i>	Bottensjön lake, Karlsborg, O county, 58°33'34"N 14°27'08"E (WGS84), 88.7 m above sea level
<i>Type of flight</i>	Military training flight
<i>Weather</i>	Wind north-west/5-15 km/h, visibility >10 km, clear, temp. +12 °C, QNH 1021 hPa
<i>Numbers on board;</i>	
<i>crew members</i>	4
<i>passengers</i>	0
<i>Injuries to persons</i>	1 fatal, 2 slightly injured
<i>Damage to aircraft</i>	Extensive
<i>Other damage</i>	Leakage of approximately 700 litres avia- tion fuel (MC75) into Bottensjön lake
<i>Commander:</i>	
<i>Sex, age</i>	Man, 52 years
<i>Total flying time</i>	4 702, of which 1 155 on type
<i>Military flying hours, lat- est 90 days</i>	17.6, of which 17.6 on type
<i>Total civilian flying hours</i>	1 848
<i>Civilian flying hours, lat- est 90 days</i>	66.9
<i>Co-pilot:</i>	
<i>Sex, age</i>	Man, 50 years
<i>Total flying hours</i>	3 311, of which 404 on type
<i>Military flying hours, lat- est 90 days</i>	26,4, of which 24,4 on type
<i>Cabin personnel:</i>	
<i>Medical orderly 1</i>	Man, 31 years
<i>Cabin personnel:</i>	
<i>Medical orderly 2</i>	Man, 45 years

The Swedish Board of Accident Investigation (SHK) was informed on 25 March 2003 that an accident involving an HKP11 helicopter with registration Z34 had occurred at Bottensjön lake, Karlsborg, O county, Sweden, on that day at 14.11 hrs.

The accident has been investigated by the Board represented by Carin Hellner, chair, Carl R.Hellström, chief operative investigator, Tomas Krave, chief technical investigator and Urban Kjellberg, chief investigator, rescue services.

The Board was assisted by Laci Bonivart, technical expert, Olof Nilsson, operational expert, Jan Linder, aeromedical expert, Kristina Pollack, aviation-psychological expert and Claes Danielsson, flight safety materiel expert.

The investigation was followed by the Armed forces in the persons of Ronnie Larsen and Agne Widholm.

Summary

During the concluding Swedish Army exercise for 2003 "Våreld" (*Spring Fire*) a military ambulance helicopter based on the Karlsborg base took part. In connection with a rescue exercise, air-sea rescue open water (LÖV), the helicopter performed repeated sorties to assist simulated emergency cases in lakes in the vicinity of Karlsborg. In the final phase of the ninth sortie, the pilots lost control of the helicopter which, with a high rate of descent, struck the ice on Bottensjön lake. The ice broke on impact, the helicopter turned over onto its back and sank nose-first towards the bottom of the lake and with the rear of the fuselage against the edge of the ice at water level.

Three crew members were able to leave the helicopter and make their way up to the surface of the water and onto the ice. A fourth crew member drowned in the accident. An eye-witness alerted the SOS rescue services and the survivors were transported by ambulance to the hospital in Skövde.

Coast Guard divers transported by helicopter from Göteborg brought up the deceased crew member who was then flown to Linköping University Hospital.

The helicopter was recovered from Bottensjön lake and transported to Linköping for investigation.

Investigation revealed no technical faults or shortcomings that could have caused the accident.

The Board has found certain formal shortcomings in the documentation of the helicopter's status. However, these did not affect the helicopter's airworthiness or the course of the accident. The helicopter contained some installations that were not authorised or approved as airworthy. These did not affect the course of events.

The safety harness worn by the deceased crew member in the accident was not approved as airworthy.

The accident was caused by the helicopter being manoeuvred into an aerodynamic situation in which, as its speed was being reduced to IAS=0, sank into its own downwash located diagonally in front of and below the helicopter.

This aerodynamic situation developed into a *vortex ring state* (VRS) which became noticeable in the measurement data approximately 8 s before impact on the ice, whereafter the helicopter's rate of descent could not be prevented despite increasing input of collective pitch. A contributory cause of the accident was the two pilots' simultaneous manoeuvring of the helicopter. This allowed small or no chance of discovering in time that they were approaching the helicopter's limit for safe flight.

Recommendations

- The Armed Forces are recommended to increase knowledge of the *vortex ring state* (VRS) and to introduce periodic further training and refresher courses in helicopter aerodynamics for helicopter crews (RM 2005:01 R1).
- The Armed Forces are recommended to investigate the shortcomings brought to their notice in the command and control of helicopter operations (RM 2005:01 R2).
- The Armed Forces are recommended to ensure that insulation suits, dry suits, are available to all helicopter crews and are worn when specified by OSF (RM 2005:01 R3).

- The Armed Forces are recommended to forbid execution of LÖV until further notice. Resumption of this flight profile should be preceded by a thorough safety analysis (*RM 2005:01 R4*).
- The Armed Forces are recommended to ensure that grounded crews do not do flight duty (*RM 2005:01 R5*).
- The Armed Forces are recommended to regularly carry out training in *underwater escape* (UWE) with helicopter crews that operate over water (*RM 2005:01 R6*).
- The Armed Forces are recommended to permit only lifejackets with emergency transmitters for crews, and to introduce waterproof equipment for speech communication among helicopter crews (*RM 2005:01 R7*).
- The Armed Forces are recommended to ensure that only triaxial ELT emergency transmitters are used in existing and future helicopter systems (*RM 2005:01 R8*).
- The Armed Forces are recommended to consider the introduction of emergency breathing apparatus for helicopter crews (*RM 2005:01 R9*).
- The Armed Forces are recommended to review the placing of on-board lifeboats and other emergency equipment to permit safe access after an accident in water (*RM 2005:01 R10*).
- The Armed Forces are recommended to introduce *approach briefing* for all helicopter flights operated by two pilots (*RM 2005:01 R11*).
- The Armed Forces are recommended to introduce *call outs* for all helicopter flights operated by two pilots (*RM 2005:01 R12*).
- The Armed Forces are recommended to conduct mandatory training in crew co-operation for crews of helicopters operated by two pilots (*RM 2005:01 R13*).
- The Armed Forces are recommended to conduct continuous checks of the function and validity of FDR/CVR data in all aircraft systems. They should also create routines to allow simple evaluation of this type of data. (*RM 2005:01 R14*).
- The Armed Forces are recommended to monitor more adequately that prescribed maintenance is carried out and prevent unauthorised modifications (*RM 2005:01 R15*).
- The Armed Forces are recommended to establish routines so that personal and other flight safety equipment is placed in safe keeping and made available to the Board of Accident Investigation for investigation after an accident (*RM2005:01 R16*).
- The National Rescue Services agency is recommended to seek to ensure that municipal planning takes into consideration how access to rescue divers (water) may be assured so as to facilitate effective rescue operations (*RM 2005:01 R17*).

Previous recommendations by the Board of Accident Investigation

- The Department of Defence should more clearly define the allowable equipment alternatives and enhance supervision that the correct flight equipment is worn during flight (*RM 2002:01 R3*).
- The Department of Defence should ensure that the stipulated regulations for flight time and maintenance documentation are followed and that required resources are made available to audit, maintain and follow-up the technical documentation of the flying systems so that it attains the accepted standard of quality (*RM 2002:01 R10*).

1 FACTUAL INFORMATION

1.1 History of the flight

In connection with the concluding Swedish Army exercise for 2003 "Våreld" the 1st. helicopter squadron, the 2nd helicopter battalion and the 4th helicopter battalion participated with resources to produce a combined helicopter battalion. The exercise consisted of air operations with fixed-wing aircraft and helicopters in the Västra Götaland area. The 1st. helicopter squadron in Boden participated with, among other equipment, a helicopter 11 (Z34) based on Karlsborg airfield (previously F6) as ambulance helicopter tasked to carry out ambulance transport in case of accidents to personnel participating in the exercise.

During the period of the exercise the media reported on a number of near-drowning incidents and accidents involving civilians. While flying in the exercise area several crews had observed how people were out on the thin ice, and for this reason the commander determined to carry out an air exercise termed air-sea rescue open water, referred to as LÖV in what follows. This is a method of rescuing a person in distress in water using a helicopter that lacks a hoist or floats.

During the afternoon of 25 March Z34 undertook a mission tasked to practise LÖV. The helicopter took off with two pilots and two medical orderlies from Karlsborg at 13.30 hrs, intending to practise offshore over Lake Vättern. After performing four LÖV during approximately 30 minutes' flight time the crew flew to the adjacent Kyrksjön and Bottensjön lakes for further exercises. After eight exercises the commander decided to carry out one more before landing. He selected a hole in the ice on Bottensjön which was to simulate for the rest of the crew a person in distress. The approach to the hole was initiated and speed reduced. After the right-hand cabin door had been opened and locked open, medical orderly 2 was ordered out onto the helicopter's right step to guide the pilots verbally to the simulated person in distress (the hole in the ice).

The orderly, who was wearing a safety harness fixed to the ceiling of the helicopter with an anchor belt, sat astride the step with his body in the direction of travel.

During the letdown the commander ordered the co-pilot "control altitude" meaning that the latter, using the helicopter's collective stick, was to control thrust and reduce altitude to water level. At a height of about 20 metres the crew discovered suddenly and without warning that the helicopter's rate of descent was high, and the co-pilot's attempts to reduce it failed. The helicopter struck the Bottensjön ice, which broke.

On impact the helicopter had a slight right-hand roll and nose-up attitude. It rapidly turned over to the right because of a 'dynamic roll over'. This came about because the helicopter's right skid caught on the edge of the ice as the helicopter moved to the right at high power input. After turning over, the helicopter rapidly filled with water through the open cabin door.

The helicopter sank and came to rest upside-down, nose-down and with the rear of the fuselage against the ice. The two pilots left the helicopter to the left through the co-pilot's door and made their way to the surface. Medical orderly 1 managed after several attempts to open the left-hand door of the cabin and come up to the surface and onto the ice.

Outside the helicopter the commander tried to help medical orderly 2, who was still fixed in his safety harness, by holding his head above the surface. However he was finally obliged to let go as the helicopter sank deeper and deeper.

Up on the ice, the crew attempted to send an alert regarding the accident but failed since their telecommunications equipment did not function: it had been damaged in the water.

A civilian eyewitness on land alerted the SOS emergency services. The three surviving crew members were transported by ambulance to the hospital in Skövde.

The drowned crew member was found later that day by Coast Guard divers, at a depth of approximately 3 m, and taken in a civilian ambulance to Linköping University Hospital.

The accident occurred at 14.11 hrs in daylight in position 58°33'34"N 14°27'08"E (WGS84), 88.7 m above sea level.

1.2 Injuries to persons

1.2.1 The commander

In connection with the evacuation from the helicopter the commander sustained minor cuts.

1.2.2 The co-pilot

The co-pilot suffered no injuries.

1.2.3 Medical orderly 1

The medical orderly was sitting belted with only the waist strap and was leaning forwards to assist medical orderly 2 outside the helicopter.

When the helicopter collided with the ice the orderly sustained a back injury that required medical care.

1.2.4 Medical orderly 2

This medical orderly died through drowning.

1.3 Damage to helicopter

1.3.1 Hull

Hull damage was moderate and no vital parts had separated therefrom.

Below are listed observations on the hull in general:

- Ceiling windowpanes were smashed, adjacent frames had failed and the forward right-hand windscreen was cracked. Ceiling plates and engine cowlings were damaged on the right side.
- The left-hand pilot's door was damaged and the emergency opening handle was pulled out. The upper and the lower catches were both released.
- The right-hand pilot's door was deformed and its rear edge and handle mounting were split open forwards.
- The shock-absorbers in the pilots' seats were depressed 31 mm on the left seat and 20 mm on the right.
- Where the landing gear cross-tube meets the hull (right, forward) there was a fairly minor impact mark, and where the rear cross-tube meets the hull there was a large impact mark both to the left and to the right, and the skin plating had broken.
- In the hull inside the right-hand step there was a minor depression in the plating, about 10 cm in diameter.

- The rear portion of the tail boom was kinked to the left, near the position designated STA 10000.
- The right stabiliser was compressed and the left stabiliser had an upward split.
- The edges of the vertical structural panel under the transmission were damaged and the panel had become displaced.

1.3.2 Rotor system

Below are listed observations concerning the rotor system in general:

- The blue and red flexible yokes of the main rotor hub, together with their associated pitch links, had failed, while the orange and green ones were severely deformed but unbroken. All four main rotor blades showed severe and fairly symmetrical damage.
- All the main rotor gearbox mountings to the hull had failed except the one located in the lifting link underneath.
- The input drive from the reduction gearbox to the main rotor gearbox had failed, as had the output drive from the main rotor gearbox to the tail rotor driving shaft.
- The tail rotor and associated gears had not separated but the gear mounting had failed and was retained only with the bolts to the driving shaft. The tail rotor could be rotated without remark.
- The intermediate gearbox was without remark and rotated normally.
- The tip of the red tail-rotor blade showed no damage but this blade had been penetrated and also bent, while the white tail-rotor blade showed no visible damage.

1.3.3 The engines

The damage observed to the engines can be explained by the course of the accident.

1.4 Other damage

Approximately 700 litres of aviation fuel (MC75) leaked out into Bottensjön lake, which was decontaminated by the Armed Forces.

1.5 Personnel information

1.5.1 The commander

The commander, a 52-year-old man, was serving as a flying instructor on the 1st. helicopter squadron in Boden.

<i>Military flying time (hours)</i>		
	90 days	Total
Latest		
All types	17.6	4 702
This type	17.6	1 155
<i>Civilian flying time (hours)</i>		
	90 days	Total
latest		
All types	66.9	1 848

Type training on the type 31-08-1993.
Latest PFT 23-03-2002.

The commander commenced his flying training at the then Helicopter School in Boden in 1977. He has subsequently served as a flying instructor since 1982, conducting among other things instrument flying and night vision goggles (NVG) training.

The commander left the Armed Forces in 1985, first through leave of absence and then by requesting dismissal, to fly as a civilian. He returned to the Armed Forces and AF1 Boden in 1986.

The commander served for a time as site commander for military ambulance helicopter operations in Lycksele (Swedish Armed Forces contract with Västerbotten County Council).

During his civilian flying the commander had taken part in the development of a method of rescuing a person in distress in the water, LÖV. He described this method to the squadron command and suggested it be applied in military ambulance helicopter operations in Lycksele. The method was tried out and then applied without being formally established and approved.

The commander was himself active in developing the method and carried out training with the medical care personnel, both civilian and military, that made up the crew of the helicopter in Lycksele. He has thus conducted the exercise on numerous occasions.

From 9 March to 15 March 2003 the commander, in his free time from his military duties, worked for a civilian aircraft company, logging about 17 hours as a helicopter pilot.

The commander arrived in Karlsborg to take part in *Våreld* on 23-03-2003, i.e. the day before the accident, and carried out an ambulance flight mission that evening to the university hospital in Linköping in a helicopter 11 (Z34). The flight started at 20.15 hrs and ended in Karlsborg at 21.56 hrs.

The flight that ended in the accident was the first of the day.

1.5.2 *The co-pilot*

The co-pilot, a 50-year-old man and regular officer, served as a flying instructor on 1st. helicopter squadron in Boden.

<i>Military flying time (hours)</i>		
latest	90 days	Total
All types	26.4	3 311
This type	24.4	404

Type training on type 19-09-1996.

Latest PFT 26-02-2002.

The co-pilot underwent his basic military training in the tank corps and was accepted for helicopter training at the then Helicopter School in Boden in 1982. His goal was early to become a flying instructor and he worked chiefly as such after flying instructor training in 1986. He has also conducted instrument flying training.

The co-pilot served between 1992 and 1998 as flight safety officer at AF1 in Boden

The co-pilot had not taken part in the military ambulance flying in Lycksele and had only carried out the LÖV exercise once before, two days before the accident, then also as co-pilot, together with another commander.

The evening before the accident the co-pilot, together with the commander, took part in the ambulance flight reported above.

The flight that ended in the accident was his first for the day.

1.5.3 *Medical orderly 1*

Medical orderly 1, a 31-year-old man and an officer in the reserve, was called up for duty during the exercise. He had civilian training as an ambulance nurse and was included in the crew as a nursing orderly. The day before the accident he took part in a navigation flight, and in the ambulance flight mentioned above.

The flight that ended in the accident was his first for the day.

1.5.4 *Medical orderly 2*

Medical orderly 2, a 44-year-old man and regular officer, had military medical care training and was included in the crew as a medical orderly. The day before the accident this orderly took part only in the ambulance flight mentioned earlier.

The flight that ended in the accident was his first for the day.

1.5.5 *The crew's alert state*

According to the standing orders for the *Våreld* exercise the ambulance helicopter and its crew were to establish and maintain a takeoff alert of 15 minutes between 08.00 hrs and 21.00 hrs and 60 minutes for the rest of the time. In exercises with high risk factors between 21.00 hrs and 08.00 hrs the alert could be raised to 15 minutes on request.

All pilots involved in the air-ambulance operations were on alert for 24 hours at a time, followed by 24 hours' rest, with relief at 18.00 hrs every day.

The medical orderlies were on alert for 48 hours at a time, followed by 24 hours' rest, with relief at 18.00 hrs.

1.6 **The helicopter**

1.6.1 *Technical data*

THE HELICOPTER

<i>Manufacturer</i>	Agusta
<i>Type</i>	HKP11-Agusta Bell 412 HP
<i>Serial number</i>	334 (Manufacturer's serial number 25804)
<i>Year of manufacture</i>	1994
<i>Gross mass</i>	Max permitted takeoff/landing weight 5 400 kg, present 4 691 kg
<i>Centre of mass</i>	3502.6 mm
<i>Total flying time</i>	3 259 hours and 53 minutes to the accident
<i>Flying time since last inspection</i>	156 hours (07-12-2002)
<i>Flying time since latest 25/100 flight hours check</i>	9 hours (21-03-2003)
<i>Latest pre-flight check</i>	25-03-2003, 08.30 hrs
<i>Fuel loaded before event</i>	1800 lbs

ENGINES

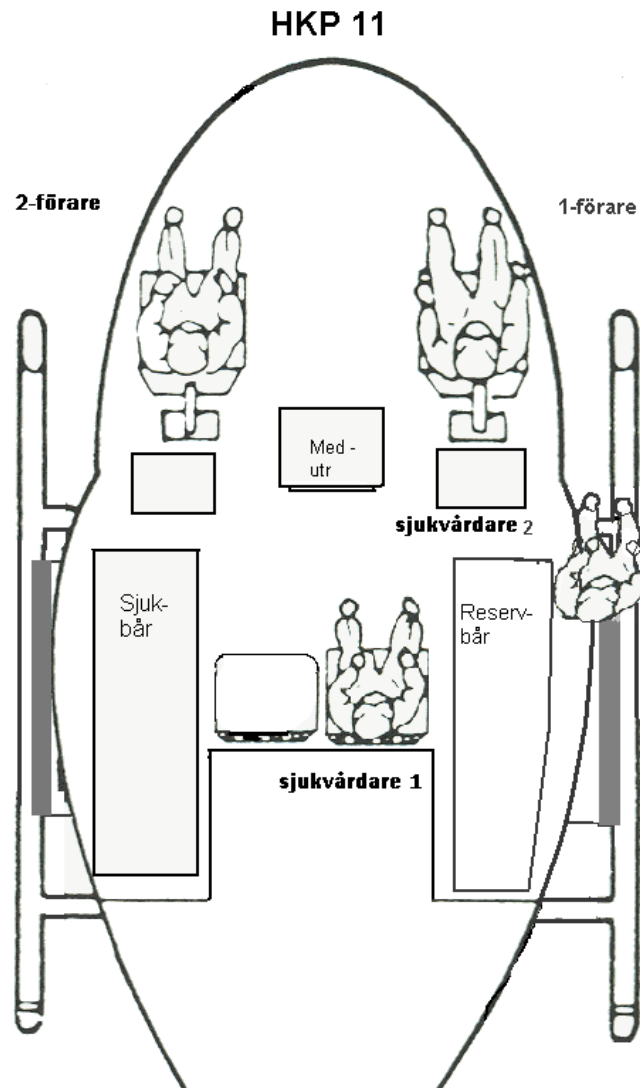
<i>Engine manufacturer</i>	Pratt & Whitney	
<i>Model</i>	PT6T-3BE	
<i>Number of engines</i>	2	
<i>Engine</i>	1: PE-63545	2: PE-63546
<i>Total flying time, hours</i>	3 260	3 260

<i>Operating time since overhaul</i>	739	739
<i>Cycles since overhaul</i>	N/A	N/A

The helicopter was equipped as an ambulance, but the medical care bags had been removed before the flight in question.

The helicopter had no life raft or emergency floats.

The Flight Manual for the AB412 HP (HKP11) contains no operational limits to flying over water irrespective of whether the helicopter is equipped with emergency floats.



- 1. förare = Commander
- 2. förare = Co-pilot
- Sjukvårdare 1 = Medical orderly 1
- Sjukvårdare 2 = Medical orderly 2
- Med.utr. = Medical equipment
- Sjukbår = Stretcher
- Reservbår = Reserve stretcher

1.6.2 Helicopter documentation

At the time of the accident the documentation for Z34 was kept partly in Boden and partly in Linköping. The documentation is kept by both civil and military organisations, for which reason it is hard to gain an overall view of its full extent.

All the documents were checked regarding maintenance, modification status and repairs. The following deviations were found.

- Incorrect weight for the helicopter given in the cockpit.
- 1st. helicopter squadron has made systematic deviations from RAFT regarding the keeping of log-sheets.
- The aircraft's battery had exceeded its flying time by 68 hours.
- A servo was not followed up in DIDAS.
- Service lists for the helicopter had incomplete information.
- Follow-up lists in the log-book were not clearly traceable.

1.6.3 Remaining technical remarks

The helicopter had a remaining remark recorded in DIDAS: TRAB 3302293665 "ID plate main rotor mast missing".

This noted shortcoming did not affect the course of events.

1.6.4 Weight and balance

The helicopter's weight and centre of gravity at the time of the accident were calculated as follows:

Total weight	=4 691 kg
Centre of gravity	=3 503 mm
Max permitted total weight	=5 400 kg
Permitted centre-of-gravity area at 4 691 kg total weight	=3 365–3625 mm

1.6.5 Other observations

SHK has noted the following deviations on the z 34 from the approved configuration for the HKP11 helicopter model:

- A Velcro tape in the cockpit over the *Operational Limits* plate caused the plate to be partly illegible.
- A tie-band was fixed to the commander's left-hand safety harness so that the catches to the shoulder and waist straps were joined together.
- Medical equipment, a perfusor, was mounted in the helicopter with a non-approved version of the mounting.
- A home-made cardboard anti-dazzle shade was mounted over the instrument panel and clock.
- The anchor strap to the medical orderly's safety harness was fixed to the helicopter ceiling with a snap-hook.
- On the safety harness strap near the ceiling of the helicopter a sheath-knife was fixed with silver tape.

Neither the anchor strap, the safety harness, the snap-hook nor the sheath-knife were maintained or approved for use in the HKP11.

1.6.6 Summary

Despite shortcomings in formal airworthiness the, basic helicopter was technically airworthy and in all essentials had been maintained according to regulations in force throughout its whole life.

1.7 Personal flight safety equipment

The Board has considered the following equipment relevant for the investigation:

1.7.1 The commander

- The commander was wearing a civilian ambulance overall, for which the military airworthiness approval expired on 31 December 1996 and has not since been renewed.
- The commander was wearing a life jacket (Ft8F) with manual inflation and with no emergency transmitter.
- The commander was wearing a flying helmet for which the inspection period had been exceeded by 11 months.

1.7.2 The co-pilot

- The co-pilot was wearing a civilian ambulance overall, for which the airworthiness approval expired on 31 December 1996 and has not since been renewed.
- The co-pilot was wearing a life jacket (Ft8F) with manual inflation and without an emergency transmitter.
- The co-pilot was wearing a flying helmet.
- The co-pilot was equipped with the stipulated personal emergency equipment.

1.7.3 Medical orderly 1

- Medical orderly 1 was wearing uniform type 90 H, approved for flying service in helicopters.
- Medical orderly 1 was wearing a life-jacket (Ft8F) with manual inflation and without an emergency transmitter.
- Medical orderly 1 was wearing a flying helmet.

1.7.4 Medical orderly 2

- Medical orderly 2 was wearing a civilian ambulance overall, for which the airworthiness approval expired on 31 December 1996 and has since then not been renewed. On top of the ambulance overall, medical orderly 2 was wearing waterproof trousers type 90.
- Over is ambulance overall, medical orderly 2 was wearing a safety harness (F1230-100359) which via a safety harness strap (F1230-300737) and a snap hook (Make INOX AISA 316) was secured to a safety loop in the helicopter's ceiling. A sheath-knife was taped to the safety harness strap.
- Over his safety harness, medical orderly 2 was wearing a life jacket (Ft8F) with manual inflation and without an emergency transmitter.
- Medical orderly 2 was wearing a flying helmet.

The personal flying equipment worn by the medical orderly during the accident has, apart from his flying helmet, not been retrieved as it was destroyed by the University Hospital in Linköping.

1.7.5 Other remarks

None of the crew was wearing insulation overalls, dry suits, in accordance with order and safety instructions for military aviation (OSF 10.2.5.2: *An insulation overall is to be worn in flight above non-supporting ice and above water with a surface temperature of + 12 ° or below.*

The squadron commander may decide on deviations if special conditions so warrant.

The Swedish Accident Investigation Board is not aware that any departures from OSF 10.2.5.2 have been promulgated.

After maintenance at a local safety equipment workshop, the flying helmet worn by the co-pilot during the accident was used, in contravention of current regulations.

1.8 Meteorological information

On 25 March a high-pressure ridge extended from Denmark to western Svealand in Sweden. During the night, the high-pressure created substantial fog over western Götaland and Western Svealand. This gradually lifted during the morning. Winds were generally light throughout southern Sweden. During the afternoon, the weather was generally clear in the area around Karlsborg. Air pressure (QNH) increased during the day from 1020 hPa in the morning to 1022 hPa in the afternoon. In general, winds were light at the time of the accident. Nothing to cause anything but light winds over the area has been observed. According to the meteorologist the wind over Bottensjön lake below an altitude of 100 metres was north-westerly, 5-15 km/h, with an air temperature of + 12–13 °C.

In connection with the request for take-off clearance at 13.29 hrs the crew from Karlsborg MIF received the following information on wind and airpressure for the airfield:

"Wind 160 ° – 10 km/h - QNH 1021 and QFE 1010 hPa."

The pilots have stated that the wind at the scene of the accident was very light, but their opinions regarding direction vary somewhat.

There was no risk of ice build-up on the helicopter, or of engine ice, during the afternoon, as the air temperature in the exercise area exceeded, by a comfortable margin, the temperature for any risk of ice build-up (<+5 °C and >75 % relative atmospheric humidity).

1.9 Navigational aids

Did not affect the course of events.

1.10 Radio communications

There was limited external radio communication with the helicopter, mainly in connection with take-off from Karlsborg. The last transmission was 3 min and 57 s before the accident, when the crew reported their position.

1.11 Aerodrome data

During the exercise the Karlsborg base had status according to MIL AIP and MIF established for radio communication with aircraft and helicopters taking off and landing.

1.12 Flight and sound recorders

1.12.1 Flight data recorder

The helicopter was equipped with a Flight Data Recorder (FDR) of type LORAL FAIRCHILD F1000, mounted in the nose of the helicopter. All recorded data has been evaluated and analysed, making it possible to establish all of the 41 recorded parameters during the last 39 hours of flying, up to and including the time of the accident.

During evaluation of the FDR data, a constant offset of 1400 ft. was observed in recorded altitude information. After contact with the manufacturer (Agusta) and further analysis, the Board has, however concluded that the value of the recorded data did not give faulty information to the crew.

The recorded values for rate of descent and pitch attitude seemed to be abnormally during the flight in question. The Board therefore carried out a careful validation of recorded FDR data from the last flight and verified that this was correct.

The pressure-altitude and other information in the FDR data shows that the successive approaches were carried at a higher rate of descent and from a lower altitude than in previous approaches during the flight. Recording and storage of altitude information from the radio altimeter (RHM) was not stored in the FDR as this function was not included in the Swedish Defence Materiel Administration (FMV) order when the helicopter was delivered.

The FDR data, and to some extent the CVR data, show that during its ninth approach in connection with the accident the helicopter:

- Had IAS = 0 during the last 11 second of the flight.
- Had 60–110 % engine power during the last 10 seconds of the flight
- Had almost a 90° glide path during the last 10 seconds of the flight.
- Had a rate of descent exceeding $0.25 \times V_1$ during the last 12 seconds of the flight.
- Had a rate of descent exceeding $0.60 \times V_1$ during the last 4 seconds of the flight.
- Had a rate of descent exceeding $0.75 \times V_1$ during the last 3 seconds of the flight.
- When the co-pilot took over the altitude control, the helicopter was in a high nose-up attitude and had a high rate of descent, and this combination lasted for a longer time than what was the case during any of the previous approaches.
- The co-pilot took over the altitude control at a time when the collective stick input was still increasing. During all previous approaches, the handing-over had taken place after the collective stick position had increased to a stabilised position. In connection with the handing over, the collective stick input was delayed by approximately 1 second.
- The collective stick input increase in connection with speed reduction came later and started from a lower level than had been the case during any of the previous eight flights.
- The collective stick was maintained in an unchanged position for 4 seconds, starting approx. 2.5 seconds after the co-pilot had verbally confirmed "*altitude control*". During this sequence, engine power was close to the maximum permitted rate of 100 %.
- At an altitude of approx. 35 m, a lowering of the helicopter's nose position was started towards an attitude parallel to the ice.
- At an attitude of approx. 20 m, the co-pilot observed that the rate of descent was too high. There were then about 2 seconds left before the helicopter struck the ice.

During evaluation of the FDR data, nothing emerged to indicate any technical malfunction on the helicopter before the accident occurred.

The FDR system is not subject to any functional check regarding the validity of the recorded parameters. Neither has any preventive maintenance been prescribed.

Neither the manufacturer of the helicopter, the contracted maintenance company, the Swedish Armed Forces nor the Swedish Defence materiel Administration had an updated calibration file for evaluating FDR data.

1.12.2 Cockpit voice recorder

The helicopter was equipped with a Cockpit Voice Recorder (CVR) of type LORAL FAIRCHILD 93-A100-83 mounted in the nose, with a recording capacity of 30 minutes. For this reason the first 11 minutes of the flight in question were over-recorded. The information recorded on the four channels during the flight was listened to and analysed.

On channel 1, commander's communication is recorded; on channel 2, communication in the helicopter cabin (medical orderlies); on channel 3, the co-pilot's communication and on channel 4 a time code.

From the recording it is clear that the commander, during the final phase of all LÖV approaches, handed over responsibility for the helicopter's altitude control to the co-pilot with the order "*altitude control*". This order was also check-read by the co-pilot.

Comparison between the various approaches shows that the period from IAS = 0 until when the co-pilot verbally confirmed "*altitude control*" varied from 6 to 22 seconds for the first eight approaches, while the period during the final LÖV approach (the accident) was two seconds only.

There is no recording of any communication between the commander and the co-pilot regarding rate of descent, radio height, engine power settings or limit values for these.

1.12.3 Navigational equipment

The helicopter was equipped with a fixed Global Positioning System (GPS) type APOLLO 2020 mounted in the rear of the hull. During the flight there was also a hand-held GPS in the helicopter, of type GARMIN 92.

It has not been possible to evaluate any navigational data from the GPS receivers, as they were both damaged through the influx of water in connection with the accident.

1.13 Technical investigation

When the recovered helicopter was set up for dry-air storage, an initial inspection and documentation were made regarding damage to the hull, engines, rotors and other systems. During this first inspection, nothing was observed that indicated the existence of any technical deficiencies before the accident.

After the initial inspection, the FDR data was evaluated, after which the helicopter was inspected and documented more thoroughly on several occasions during the investigation.

Fuel and oil samples from all of the helicopter's components were analysed by CSM Materialteknik in Linköping and the test results are without remark. All the magnetic plugs were checked without remark.

The pitot system was pressure- and leakage-tested without remark.

The helicopter was equipped with an Emergency Location Transmitter (ELT) type EBC-302 kept in a holder on the pilot's door-frame. The ELT was inspected by Aerotech Telub in Arboga (AT/A). It is specified to trans-

mit an emergency signal at a frequency of 121.5 MHz if subjected to $>5-7\text{ G}$ for longer than 30 ms.

During the AT/A inspection it was observed that the limits for activating the emergency transmitter were somewhat above the required specification. However, the remaining functions of the transmitter were without remark and the battery charge exceeded the minimum level by a clear margin.

In addition it was observed that this model of ELT is only two-dimensional – sensitive in one plane only. In HKP11, this implied that the emergency transmitter is only sensitive to accelerations in the horizontal plane, not the vertical.

The Board did not consider it necessary to inspect the dynamic components in detail.

Representatives of the manufacturers, Augusta, Italy, and Pratt & Whitney, Canada, inspected the helicopter in November 2003 in Linköping.

1.14 Flight-operational circumstances

1.14.1 Exercise *Våreld* (Spring Fire)

The majority of all units in the helicopter wing took part in the exercise. Command and control of the units was carried out by a central exercise command, temporarily located in Karlsborg.

In accordance with helicopter wing Exercise Regulations, VÅRELD FOCUS, 20 February 2003, 19 650: 10 272, the purpose of the wing's participation was, among other things:

- to develop the ability of participating units to utilise helicopter resources regarding transport of materiel, personnel and medical facilities.

According to the same regulations, the exercising helicopter battalion was to:

- maintain ambulance helicopter capability for real-life medical transport.

A co-ordinating wing commander flying took part in the exercise, with operational responsibility for helicopter systems HKP6, HKP9 and HKP11, and a second wing commander flying had operational responsibility for HKP4 and HKP10.

According to the crew's squadron commander, a framework Decision to Fly applied to the commissioned task profiles that were to be exercised during "*Våreld*". Regular squadron commanders had flight safety responsibility for their own personnel.

The VÅRELD-FOCUS Exercise Regulations, section, 27.5.5, Flying Equipment, and the Östgöta Helicopter Battalion Supplementary Exercise regulations, ASÖ-03 VÅRELD, 13-03-2003, section 27.5.5 Flying Equipment, state that: *uniform type m/90H, alternatively a dry suit, is to be worn by all crew members.*

The Norrland Helicopter Squadron regulations FlygkompO VÅRELD V 312-313, 10-03-2003, section 95, Personal Equipment/Clothing, specify: *Ambulance overall new model with reinforcement clothing for ambulance service.* According to the above FlygkompO Våreld V 312-313, no deviation from OSF 10.2.5.2 on the wearing of dry suits was specified.

Flying activity with HKP11 was planned to enable helicopters and crews to maintain stipulated take-off readiness.

Emergency alert systems for the helicopter were to be operated through SOS Alarm (public emergency telephone number 112). Before the start of the exercise, the helicopters reconnoitred landing sites at the relevant hospitals in the exercise area.

Flights to the SOS Emergency Centres in Falköping and Norrköping were also carried out.

1.14.2 *Air-sea rescue, open water (LÖV)*

The exercise profile for LÖV was created in 1998 after the method had been initiated and applied at Ostermans Civilian Ambulance Helicopters in Stockholm. The method permits rescue of a person in distress in water with a helicopter without a hoist.

LÖV was developed further, adapted and applied in the military ambulance flying operations in Lycksele under the AF1/1. Heli Sqn/Heli Wing agreement with the Västerbotten County Council.

No formally attested exercise profile for LÖV has been submitted to the Swedish Accident Investigation Board, but the 1. Heli Sqn had an internally established exercise plan briefly describing procedures and the positioning of the helicopter in relation to the person in distress, mainly dealing with wind direction and rotor wind.

The helicopter crew normally comprises four persons: two pilots and two medical orderlies.

According to the plan and a verbal account, the LÖV was intended to run as follows.

The helicopter flies in towards the person in distress and a steep glide path is initiated, after which speed is reduced. At below 60 knots the medical orderly is ordered to open the right-hand cabin door. At an altitude of 150-200 feet, speed is reduced further and the orderly is ordered to climb out onto the step on the landing gear. The orderly then sits astride the step facing the direction of travel and secured with a safety harness connected to the helicopter with a strap.

The helicopter hovers at approx. 100 feet above the distressed person. The commander then has the distressed person slightly out on the right and somewhat behind him/her, which involves difficulty in seeing the person. The medical orderly is therefore ordered by the commander to assume guidance. The orderly controls the commander through verbal commands – right, left, backwards, forwards, down or up. The commander follows the orderly's "call-out" directions, at the same time checking the helicopter's attitude and altitude above the water.

Finally the helicopter reaches the surface of the water with the rear end of the skids and the orderly can grab hold of the distressed person, who is subsequently towed to firm ground or shallow water where treatment can be initiated.

The exercise plan contains no oral call-outs with regard to speed, altitude or rate of descent in specifically sensitive phases of the LÖV exercise.

The exercise was later modified so that both pilots actively took part in manoeuvring the helicopter. During the flight in question, a procedure was used where both pilots simultaneously manoeuvred the helicopter, the commander manoeuvring the cyclic stick and pedals, and the co-pilot manoeuvring the helicopter vertically with the collective stick. For manoeuvring the helicopter vertically, the co-pilot had to rely on external references and the medical orderly's directions.

As an aid, the co-pilot used a mirror positioned under the helicopter's nose. In this he could see the helicopter's skids and the water surface.

The reason given by the crew for both pilots' manoeuvring the helicopter simultaneously while approaching a person in distress was the com-

mander's difficulty in seeing the person while at the same time manoeuvring the helicopter vertically.

The exercise plan of the 1. Heli Sqn for the LÖV exercise makes no mention of the two pilots' simultaneous manoeuvring of the helicopter.

The helicopter was equipped with a radio altimeter (RHM) for reading altitude and rate of descent. The radio altimeter is positioned in front of the right-hand (commander's) seat and is therefore difficult to read from the left-hand pilot's seat.

When medical orderly 2, on the step outside the helicopter, plugs in his microphone in *hot mic* mode, communication difficulties can arise for the rest of the crew, as engine noise and rotor wind are reinforced via the medical orderly's microphone. When the need arises for the pilots to exchange flight safety information during a critical phase of a flight, this can be made difficult or impossible through the *hot mic* system.

The helicopter's weight was within performance limits for hovering out of ground effect, with both engines operating. Single-engine performance varies with regard to altitude, speed and weight. The main part of a LÖV exercise is carried out within the area where loss of one engine means that the helicopter cannot continue flying on one engine. For this reason, in the event of loss of one engine, the crew is compelled to abort the operation and make a forced landing in the water.

To the Board's knowledge, no safety analysis was done in connection with the drafting of the LÖV exercise plan; nor was any procedure specified for the event of single-engine loss.

In an interview with the squadron commander, the Board learned that he had no detailed particulars of how the LÖV was to be conducted, and there was no safety analysis of the exercise. He proffered the opinion that the exercise was well tried and used while the helicopter squadron was based in Lycksele, where it had worked well for many years.

1.14.3 *The flight in question*

While the exercise was in progress, the media reported a number of drowning incidents and drowning accidents on weak ice. Several crews had also observed people out on the ice and had therefore suggested to the officer commanding that the ambulance helicopter crew should practice LÖV in case any accident should occur during exercise *Våreld*.

According to the VÅRELD-FOCUS Exercise regulations for the helicopter wing, no LÖV activity was ordered.

The crew of the ambulance helicopter were instructed by their regular squadron commander in the Decision to Fly to practice LÖV.

The co-pilot had previously only carried out LÖV once. During that flight, two days before the accident, the helicopter unintentionally dipped into the water to a depth that permitted water to enter the cargo hook compartment. The co-pilot was dissatisfied with that flight and therefore wished for further training in LÖV.

The mission execution order (OFFG) was issued by the commander before the flight. The order was issued and the whole crew briefed on the exercise and the helicopter on the ground pad.

To the Board's knowledge, at the briefing the commander did not mention that the pilots should read aloud, with *call-outs*, any excessive limit values for e.g. rate of descent and altitude; neither were intentions and action in the event of an approach having to be aborted due to, for example, a single-engine loss or a non-stabilised approach, mentioned. There is no requirement for such an *approach briefing* in the current set of regulations.

During the flight, eight approaches were made towards simulated persons in distress before the accident happened during the ninth approach.

The external reference at the accident site was a line of trees 350 m directly ahead of the helicopter, plus a small island to the left at a distance of 100 m.

During the flight, the two medical orderlies took turns to direct the pilots down onto the water and to rescue the simulated persons in distress.

The commander during the flight became instructor for both the orderlies and the co-pilot, at the same time as being responsible for the manoeuvring and safety of the helicopter.

In OSF Chapter 6.7, Flying over Sea it is indicated that:

Flying over sea or major lakes with a single-engined aircraft, which has no device for landing or floating on water, is to be carried out with at least one of the alternatives listed below:

- *under radar surveillance,*
- *in such a way that continuous radio contact can be maintained with a ground station or another aircraft designated for this task,*
- *at least in pair formation,*
- *at such an altitude or with such speed that land or supporting ice can, in the event of engine failure, be reached at an altitude necessary for emergency ejection (or, where appropriate, at a suitable initial altitude for a forced landing).*

For multi-engine aircraft/helicopters, OSF states no limitations, irrespective of whether the aircraft/helicopter has single-engine capacity.

OSF, Chapter 0.5, Definition of Concepts, states that:

The term refers to jet-propelled aircraft, propeller aircraft and helicopters.

The local OSF pertaining to the 1. Heli Sqn, chapter 6.7, states that:

Flying over sea or major lakes with a single-engined helicopter without floats is to be performed in pair formation. Both helicopters are to carry a lifeboat as well as personnel specially designated for lifeboat duty.

For a twin-engined helicopter without single-engine capability, i.e. the Z34 during the flight when the accident occurred, regulations apply as for a single-engined helicopter, according to the local OSF point mentioned above.

Z34 was operating alone and was not equipped with a lifeboat during its flight, which was partly over Lake Vättern.

1.14.4 Vortex ring state (VRS)

A number of concepts in helicopter aerodynamics describe variants of the same aerodynamic phenomenon. The concepts are *vortex ring state* (VRS), *settling with power* (SwP), *power settling* (PS) and the Swedish concept *genomsjunk* (= stall).

The basic principle for all these concepts is that the helicopter flies in its own downwash from the main rotor at such a speed that the airflow through the rotor is disturbed.

When the helicopter sinks into its own down wash, a 'counterflow' is created by the air from below, and this prevents the rotor down wash from being "swept away". Instead, the air starts to re-circulate, disturbing the flow through the rotor. This disturbance starts from the centre of the rotor disc and the higher the rate of descent, the further out on the rotor disc the flow is disturbed. This phenomenon increases gradually and expresses itself in many different ways, depending on a number of factors.

A sign of VRS is the presence of one or more of the following conditions:

- Increased power to maintain flying mode,
- increased rate of descent despite an unchanged power,
- increased general level of vibration,
- pitch-, yaw- and somewhat less roll disturbance,
- delayed or no reduction of rate of descent on increased power
- reduced response to cyclic stick input.

The concept VRS usually refers to re-circulation that has gone relatively far, where increased power hardly gives any reduction in rate of descent. VRS may even have gone relatively far without the pilot experiencing any attitude disturbance or increased level of vibration.

The concepts SwP and PS, (which generally mean the same thing) normally refer to an incipient VRS where one or more of the conditions listed above can be present to varying degrees. What characterises SwP is that increased power can still give some reduction in rate of descent. In early stages, sometimes a sharp increase in power can make the helicopter get out of the incipient VRS.

In certain cases, however, usually when the phenomenon has gone considerably further, an increase in power might give the opposite effect, increasing the rate of descent instead of reducing it.

The Swedish comment *genomsjunk* (stall) often refers to one of the following situations:

- insufficient or delayed increase in power to meet the need for lift
- the helicopter gets caught in a downwind or in a downwash from other helicopters
- VRS, SwP or PS in varying stages

The pre-requisites for risking getting into a VRS are the following:

- IAS = 0 or close to 0
- 20–100 % engine power
- glide paths between 70–90° are most sensitive, but even shallower glide paths can induce a VRS
- rate of descent between 0.25–1.25 times rotor downwash speed (V_1)

(0.25 x V_1	VRS is initiated)
(0.60 x V_1	VRS becomes relevant on AB412)
(0,75 x V_1	VRS culminates)

Normally, the above situations arise in connection with the steep approaches or with downwind landings, but an equivalent aerodynamic situation can also arise during banking in unfavourable wind conditions or during approaches with high nose attitude.

To exit from a VRS, the nose attitude must be lowered with maintained or reduced power. This requires altitude to avoid contact with the ground. During flight testing with HKP2, HKP3 and HKP6 at the Swedish Defence Materiel Administration Test Centre (FMV:Prov), the loss of altitude was 30–125 m during extrication from approximately 70 cases of VRS at different stages.

The Board notes that among Swedish Armed Forces helicopter pilots the presence of the VRS phenomenon in helicopter aerodynamics is well known. Opinions differ greatly, however, regarding the prerequisites for its occurrence and regarding the indications of an upcoming VRS.

In helicopter literature, too, there are different opinions regarding when and how VRS arises.

During type rating training on all helicopter types in the Armed Forces, theoretical training is carried out on the VRS phenomenon with the helicopter in question. During type rating on certain types, there is also a practical demonstration of VRS while flying at a safe altitude.

The Board has not, however, found any recurrent training on VRS, the main reasons given being the difficulty to create a VRS in a simulator and that exercising VRS during real flying means an increased risk in terms of flight safety.

1.14.5 Training in crew co-operation

The fact that crew co-operation is of crucial importance for flight was observed in civil aviation as early as the 1970s. To safeguard against any possible flight safety risk, procedures were created for preventing breakdowns in communication between crew members. Training in crew co-operation seeks to increase awareness of what factors, in the social interaction within a crew, can affect flight safety.

In civil aviation it is a requirement from the authorities that there should be regular training in what is termed crew resource management (CRM).

In military aviation, there are no corresponding requirements. The commander completed a course in crew co-operation when serving in ambulance helicopter operations in Lycksele. The course was procured from a civilian company and was arranged by the then AF1 with a retired civil aviation captain as instructor.

The co-pilot completed a similar course in crew co-operation arranged by AF1 in 1996.

As from 1994, the Air Force Command School (FBS) have organised courses in crew co-operation.

1.15 The accident site

The accident site is situated at Bottensjön lake, approx. 5.5 kms NNW of Karlsborg aerodrome. At the time of the accident, Bottensjön was mainly covered with ice of varying thickness and supporting capacity. Tracks in the ice coincide well with imprints from the belly of the helicopter and the right-hand. The size of holes in the ice also tallies with what can be expected when the helicopter overturned to the right. On the ice, there were solitary minor parts from the helicopter chiefly from the main rotor.

After approx. 24 hours, the helicopter sank completely under the ice, as the supporting capacity of the ice had been further weakened.

1.16 Medical information

1.16.1 The commander

Nothing has emerged to indicate that the commander's mental condition was impaired before or during the flight.

During his most recent annual medical check in May 2002, the commander did not meet the Armed Forces' basic physical requirements. The unit's Medical Officer gave the commander four months' grace to exercise and to build up fitness to the stipulated level.

As the commander did not pass tests for basic physical requirements after the grace period, he was informed by the MO that he was grounded from October 2002.

1.16.2 *The co-pilot*

Nothing has emerged to indicate that the co-pilot's mental or physical condition was impaired before or during the flight. The co-pilot had undergone and passed the basic medical checks and met the physical requirements.

1.16.3 *Medical orderly 1*

As the medical orderly had not been posted to flight duty, there was no requirement for annual medical checks. Nothing has emerged to indicate that the orderly's mental or physical condition was impaired before or during the flight.

1.16.4 *Medical orderly 2*

As the medical orderly had not been posted to flight duty, there was no requirement for annual medical checks and therefore his mental and physical condition cannot be stated. However, nothing has emerged to indicate that his medical or physical condition was impaired before or during the flight.

1.16.5 *Other medical information*

The crew have stated that they had had the necessary periods of rest and sleep before the flight that ended in the accident.

1.17 **Fire**

There was no fire.

1.18 **The rescue operation**

At 14.13 hrs on 24 March 2003, the SOS Alarm emergency service in Falköping received a call via the 112 emergency telephone number from a person who has seen a helicopter accident, from a distance, on the ice at Bottensjön lake. Also, after the accident, three persons were visible on the ice. SOS Alarm ended the telephone conversation with the caller at 14.21 hrs after an interview of approx. 8.5 minutes. They assessed the situation as a presumed accident. SOS Alarm called the alert according to the table below:

SOS Alarm (Falköping):

Time	Event	Steps taken
14.13-14.21	Received 112 call from a witness to the accident.	Assessment: "presumed accident".
14.23		Alerted Aeronautical Rescue Coordination Centre
		Alerted Rescue Ops Unit in Karlsborg (1+4 firemen).
14.24		Alerted ambulance in Karlsborg.
		Alerted head of Skövde Fire Brigade.
14.25		Informed police.
14.33		Alerted ambulance helicopter in Göteborg.

The Aeronautical Rescue Coordination Centre (ARCC) viewed the situation as a suspected accident at Bottensjön lake, where a "dark-coloured military helicopter had crashed on the ice". The ARCC raised the alert according to the table below:

ARCC (Göteborg):

Time	Event	Steps taken
14.23	Alarm call from SOS Alarm.	Assessment: “suspected accident”.
14.25		Alerted SAR helicopter Y67, which was airborne during a rescue hoist exercise in Göteborg.
14.35		Alerted SAR helicopter H92, which was located in Karlsborg.
14.50		ARCC ordered up rescue divers from Coast Guard in Göteborg.

The ARCC initially lacked status of, and direct numbers to, the crew of SAR helicopter 92, which was located in Karlsborg.

The ambulance from Karlsborg arrived at Bottensjön lake at 14.40 hrs – 16 minutes after the alarm alert. The ambulance personnel met the three persons from the helicopter crew. They were informed that one of the crew was missing in the helicopter, which had gone through the ice and sunk. The information was passed on to the Rescue Services.

Surface rescue divers from Heli H92 attempted to rescue the crew member from the water in the crashed helicopter. H92 called up the rescue divers to the site of the accident. The Coast Guard in Göteborg received the request for divers from the ARCC at 14.50 hrs. At that point the Coast Guard had rescue divers available at Nya varvet (the New Shipyard) in Göteborg and transport was arranged via the ARCC with the police helicopter, which was alerted at 15.01 hrs.

The rescue unit from Karlsborg arrived at 14.50 hrs – 27 minutes after the alarm. They walked the last 150 m down to the water’s edge and approx. 250 m out to the hole in the ice where the tail rotor of the helicopter projected above the surface of the water. Firemen in survival suits attempted unsuccessfully to find the missing crew member.

The municipal rescue services commander from Skövde arrived at Bottensjön lake at 15.01 hrs. On his arrival, rescue divers were requested to the site. At this phase of the operation, rescue divers from the Göteborg Coast Guard were already alerted and were estimated to arrive with the police helicopter in about an hour. The Östra Skaraborg rescue services investigated whether there were any available divers at K3 (the Life Regiment of Hussars) in Karlsborg. However, their information was that no divers were available at that moment. Via SOS Alarm, however, the Armed Forces offered divers at 15.36 hrs.

The municipal rescue services commander declined this help since rescue divers were already on their way by helicopter from Göteborg.

SAR helicopter Y67 from Säve aerodrome arrived at the site of the accident at 15.15. hours – 50 minutes after the alert. A surface rescue man in a dry suit made three attempts at finding the missing crew member in the hole in the ice, which also contained large quantities of aviation fuel.

The police helicopter with the rescue divers landed at Bottensjön lake at 16.15 after a flight of approx. 55 minutes from Göteborg. The divers initiated diving operations 10 minutes later. They found the missing crew member outside the helicopter at a depth of 3 m. Two hours and twenty minutes after the alert to SOS Alarm, at approx. 16.36 hrs, the crew member was lifted onto a boat on the ice, which was towed to land. There, medical personnel initiated medical care. The ambulance helicopter transported the crew member to Linköping University Hospital, landing at 17.45 hrs.

The rescue operation in summary:

SOS Alarm alerted 14.13 hrs

ARCC alerted 14.23 hrs

Ambulance and command personnel alerted 14.24 hrs

Time in brackets indicates time after alert to SOS Alarm.

Time in double brackets indicates time after alert to the respective rescue unit.

Time	Event	Steps taken
14.40 (27 min) ((16 min))	First ambulance arrives at site	Information given by crew of crashed helicopter
Info lacking	SAR helicopter H92 arrives at site	Surface rescue men search for missing crew member
14.50 (37 min)		Rescue divers requested to site at 14.50 by H92
14.50 (37 min) ((27 min))	Rescue team from Karlsborg arrives	
15.01 (48 min) ((37 min))	Municipal rescue services commander arrives	Requested rescue divers. Rescue divers already alerted by H92
15.15 (62 min) ((50 min))	SAR helicopter Y67 arrives at site	Surface rescue man makes three attempts at rescuing crew member
16.15 (122 min) ((74 min))	Police helicopter lands at site	Arrives with rescue divers from KBV
ca 16.25 (132 min) ((95 min))	Rescue divers initiate diving ops	
ca 16.35 (142 min) ((105 min))	Missing crew member lifted from Bottensjön lake	
17.45 (212 min)	Ambulance helicopter lands with patient at hospital in Linköping	

Other remarks

The Swedish Civil Aviation Administration (Lvf) is the body responsible for air rescue services. Among other things, air rescue services involve searches for missing air vehicles. Lvf has an agreement with SOS Alarm AB regarding the emergency number 112 service. When anyone in distress needs air rescue, the SOS Alarm operator must without delay connect the call to the Lvf rescue centre, the Aeronautical Rescue Coordination Centre (ARCC) in Göteborg, where the national rescue operations commander directs the actual operation.

Had the accident occurred at sea or in any of the three major lakes (Vänern, Vättern and Mälaren), the national rescue operations commander would have been responsible for the whole rescue operation.

When the location of an accident site becomes known and is confirmed situated in a municipality's area of responsibility, the responsibility for the rescue operation is transferred to the municipal service.

The rescue operation at the scene of the accident in Bottensjön lake became a municipal concern when the exact location was ascertained.

There were no instructions as to how rescue divers should be alerted. It was the municipal rescue services commander who, during the rescue operation and with the help of rescue services staff functions, was to request and organise the assistance needed with water diving.

In 2003, there were rescue divers in fewer than 20 of the country's 223 municipal rescue services organisations.

The rescue services in Östra Skaraborg had no rescue divers of their own.

1.19 Survival aspects

The helicopter struck the ice with a slight right-hand roll and a minor nose-up attitude. The right-hand skid plate got caught in the ice, while the helicopter moved slightly to the right and had increasing lift from the main rotor. The result was that the helicopter, through what is termed "dynamic rollover", rapidly rolled over to the right and was filled with water through the completely open right-hand cabin door. The helicopter turned upside-down and started slowly to sink, after which it came to rest with its nose on the bottom of the lake and the rear part of the fuselage against the edge of the ice.

The co-pilot tried to open the left-hand pilot's door with the emergency handle, but failed as the door was obstructed by the deformed attachment device for the SX16 searchlight. The door could, however, be opened using the regular door handle and the co-pilot left the helicopter and reached the surface and up onto the ice.

The commander tried to open the right-hand pilot's door, but failed. He therefore got out through the co-pilot's door on the left-hand side of the helicopter and reached the surface.

After reaching the surface, the commander made his way to the other side of the helicopter and there tried to help medical orderly 2 by holding his head above the surface. He was however forced to let go when the helicopter sank deeper, pulling the orderly down.

After several attempts, medical orderly 1 succeeded in opening the left-side cabin door using the regular door handle and got out of the helicopter, up to the surface and onto the ice.

It is unknown whether medical orderly 2 had any possibility to, and tried, to extricate himself from the safety harness. He was found by Coast Guard divers with his harness on, connected via the safety harness strap, to the helicopter, and with his life jacket inflated, at a depth of approximately 3 m outside the helicopter. The sheath-knife, which was fixed to the safety harness strap, had not been used.

Both pilot seats were equipped with accident absorbers to minimise injuries in an accident or a hard landing.

The cabin crew's seats lacked corresponding accident absorbers.

None of the crew had had any training in underwater escape (UWE).

Emergency air and a line-knife were not part of the personal aviation equipment. As far as is known to the Board, only the co-pilot was carrying the stipulated aviator's knife.

The Armed Forces surface rescue diver personnel who serve in search-and-rescue helicopters are not trained or equipped for work underwater.

1.20 Special tests and examinations

The Board arranged test flights using the same type of helicopter on three different occasions. The purpose was to verify that the recorded FDR data from the crashed helicopter coincided with real conditions. The test flights

showed that the FDR data was correct, only minor differences being measured.

One of these was that, depending on the basic setting of the horizontal gyro, the pilots could read a 1-2 % variation in pitch attitude between the readings and the recorded values.

In addition, the seat adjustment was checked as well as the length of the pilots' backs, to ascertain their possibilities of acquiring external (visual) reference points, and, hence determine the helicopter's position and movements. This check showed that the commander's seat was adjusted to enable him to see the horizon ahead up to +18–20° pitch, while the co-pilot's seat position allowed clear visibility to the horizon at pitch attitude $\leq +10\%$.

The flight manual contains recommendations as to seat adjustment. The recommendation can be understood in different ways and offers room for interpretation at approx. 3 cm regarding recommended vertical position. The co-pilot regularly, in his own words, used the lower seat position in the helicopter.

An additional reason for carrying out flight tests was to check how well a pilot could assess rate of descent using external reference points only. During the tests, the helicopter's attitude remained constant and the pilot had external reference points straight ahead at a distance of approx. 500 m.

The result of this test shows that pilots assessed the rate of descent with a large margin of error. The rate of descent was assessed at 200 feet per minute (fpm) at a true rate of 500 fpm, while with an assessed rate of 500 fpm, the actual rate was 1,000 fpm.

A number of simulations were carried out by the helicopter manufacturer, Agusta, using a flight-mechanical digital model of the helicopter AB412, which Agusta uses in their development work. In one of the simulations, some of the recorded parameters from the ninth LÖV exercise were used, in order to see what rate of descent was obtained. The parameters were cyclic control movement and power input, pitch angle and adjusted horizontal speed. In another simulation, an "inverted" approach was used, where recorded flight paths and speeds were used, giving cyclic control movement and power input requirements as a result.

Agusta also calculated the accident impact forces working from the damage picture of the helicopter and FDR data. The calculation shows that these forces were over 6Gs at the vertical gyro mounting.

1.21 Organisation and command/control

The Board interviewed the Inspector-General of the Swedish Air Force and representatives of the Safety Inspectorate, the Training and Management Directorate and the Forces Directorate of the Armed Forces. The Board also interviewed the command staff of the helicopter wing (o/c wing, chief of staff, technical director, o/c flying and flight safety officer) in Linköping. The Board further interviewed the former deputy o/c wing and also the head of the flight section.

The purpose was to form an opinion as to how command and control of the helicopter operations has been implemented, how flight safety work has been organised, and how previously implemented reorganisations may possibly have affected personnel and operations.

The helicopter wing was formed in 1998 to assemble all helicopter activity under one common wing, staff located in Linköping. The wing was subordinate to the Joint Forces Command of the Armed Forces HQ (HKV/OPIL) and is ranked equal to the Army, Air Force and Naval Tactical Commands (ATK, FTK and MTK). The wing staff organisation had a co-

ordinating character, since the four areas of helicopter operation; Boden, Berga, Säve/Ronneby and Linköping all had their own individual interim operational authorisations.

These four areas of helicopter operation were autonomous with their own base commander, o/c wing, flying and technical directors to command and control operations.

Through the solution of having several operational authorisations, the wing staff lacked the authority to fully command/control the operations within the wing, but functioned only to co-ordinate the activities between the various units.

Since its formation in 1998, the wing has, in addition, undergone four re-organisations, entailing a high degree of organisational turbulence and an unclear chain of command within the wing.

The helicopter wing is a product of the helicopter operations of the Army, Naval Forces and Air Force. The three branches have had different tasks regarding helicopter operations, and have hence developed different ways of operating.

The differences in culture in the different branches have been transferred to the joint operational form. This has meant that, from time to time, there have been different opinions as to how operational activities are to be performed. In turn, this has contributed to organisational friction and sometimes conflict.

Confidence in the commanding staff of the helicopter wing has at times been weak. The wing command has been perceived as having difficulty in gathering the operators together around a common view of things.

1.22 Regulations

1.22.1 *Regulations for military aviation (RML)*

The Regulations for Military Aviation (RML) are based on a translation and adaptation of the rules for civil aviation (JAR OPS) for military aviation, and have been produced in stages.

The first part to be produced – RML-G (Grunder) was followed in 1997 by RML-V1 (Verksamheter) (= Operations), which regulates command/control and operations. This was followed by V6 and V2 (Command/Control of Flight Maintenance and Flight Operations, respectively).

A number of RML parts have still not been completed and issued, for which reason the Armed Forces' flight operations are regulated through a mixture of old and new instructions.

The process of authorising operational clearance has been lengthy: each area of operations has submitted an outline plan to the Flight Safety Inspector (FlygI) for scrutiny. Pending approval by the Flight Safety Inspector, the 1. Heli Sqdn received interim operational authorisation, to apply until further notice.

The operational authorisation regulates how activities are to be organised and what organisational positions are to be filled. It also specifies the distribution of responsibility and the authority which any named official is to exercise.

Work on the production of a common operational authorisation for the helicopter wing has been going on for a fairly long time. In the meantime, four interim authorisations have regulated the activities of the four locations of the helicopter wing.

Not until an implemented re-organisation in 2004 did the helicopter wing acquire a common interim operational authorisation, to apply until further notice.

1.22.2 Provisions and regulations

During the Accident Investigation Board's investigation of the accident the squadron command referred to a number of official documents and regulations, which the Board has been able to study. This documentation was intended to describe and govern how training in, and implementation of, the LÖV exercise are to be carried out.

1. Operating Handbook, Ambulance Base (DHB AMB 1. helicopter squadron).
2. LÖV.
3. Flight Ops Unit Operational Orders (VO).
4. Syllabus, Lyksele.
5. Local OSF.

Of this body of regulations, the Board has found that only the DHB AMB and the Local OSF were formally approved and established by a commander with the authority to approve these documents.

The *Flight Manual* describing the helicopter's functions and performance that is used in the Swedish Armed Forces is a civilian version. When the helicopter was procured, it was intended mainly for use as an ambulance helicopter in accordance with civilian regulations, in co-operation with the medical authorities responsible.

The manual contains no information on the maximum rate of descent in a VFR flight at low or zero speed (IAS).

The Italian military version of the manual states that rate of descent higher than 800 fpm are to be avoided at speeds below 320 knots IAS.

The squadron command have shown no documentation or decisions that permit manoeuvring of the helicopter during LÖV by both pilots simultaneously.

As far as the Board is aware there are in the Armed Forces no routine procedures which, except in training, imply that a helicopter can be manoeuvred during LÖV by both pilots simultaneously.

1.23 Miscellaneous

In connection with the co-pilot's LÖV practice exercise on 23 March 2003, the exercise was unintentionally carried so far during the fifth approach that the helicopter was dipped approximately 50 cm too deeply into the water. After that flight no operational disturbance report (DA) or technical report (TRAB) was written even though it was observed that, after landing, water was running from the cargo hook bay and the technical staff inspected the helicopter.

On the last flight, the crew did not report take-off from Karlsborg to SOS Alarm, which is standard practice for ambulance helicopters. At the time of the accident, therefore, the emergency centre had no knowledge of the flight in question.

A helicopter unit designated Gladan (the Kite) comprising four HKP9s, one HKP11, two HKP4 and one HKP10 flew by close to the site where Z34 crashed approximately 11 minutes later, at an altitude of >500 feet over Bottensjön lake and a speed of approximately 100-110 knots.

1.24 Recovery of the helicopter

Preparations for recovery were initiated on Wednesday 26 March 2003. A civilian crane lorry with driver was hired and put on a ferry requisitioned from FMV in Karlsborg. Uncertainties regarding responsibility and insur-

ance between the Armed Forces and FMV entailed delay in the recovery operation. The delay was utilised for preparations before diving and recovery, minimising its effect. After recovery, the helicopter was transported to Linköping for dry-air storage.

Aviation fuel which had drained into Bottensjön lake was cleared up by Armed Forces personnel.

2 ANALYSIS

2.1 Technical malfunction

During the technical investigation of the crashed helicopter, no faults or deficiencies were found that can explain the cause of the accident.

Recorded flight data were analysed but no technical malfunction had been recorded.

The crew observed no signs of technical malfunction during the flight.

2.2 External influence

The weather was clear with light winds. The prevailing wind was so light that its influence was probably without significance for the course of events. Neither did the crew report any problems with wind conditions during the flight.

The meteorological prerequisites for ice formation on the helicopter or engines did not exist, as the air temperature in the exercise area was well above the temperature for ice formation.

The passage over the accident site of the Gladan helicopter unit cannot, in the Board's judgement, have had any influence on the helicopter, as neither turbulence nor rotor-blade-tip vortices from these helicopters could have affected the course of events and the accident 11 minutes later.

Neither is probable that aerodynamic properties at the scene of the accident affected the course of events.

2.3 The conduct of the flight

During the flight the helicopter crew had practised LÖV eight times. The accident occurred when the same exercise was to be practised for the ninth time. Circumstances during the nine exercise occasions were similar, except that the medical orderlies exchanged roles.

After validation and analysis of the recorded FDR data, the Accident Investigation Board noted that the pilots executed the final stage of each approach at increasing speed and along increasingly tight flight paths. A comparison between the average rate of descent, from IAS = 0 to altitude = 0 (linear approximation) shows that the last six approaches involved an increasing rate of descent from 347 fpm to 1,745 fpm for the very last approach.

A corresponding comparison for the durations of the last approaches shows that the last one took 11 seconds, while the previous ones were between 31 and 61 seconds.

The combination of flight-attitude parameters during the last approach was unique and differed from that of all previous approaches in that the pitch angle was unusually high for an unusually long time and that the helicopter had at the same time a relatively high rate of descent. During all the

previous approaches, either the pitch angle or the rate of descent, or both, were considerably lower.

The above-mentioned combination created an aerodynamic situation that caused the helicopter, as speed reduced to IAS = 0, to sink into its own downwash. This at the time was located diagonally in front of and below the helicopter, which entered a VRS that became noticeable in the measurement data approximately one second after the co-pilot had confirmed taking over altitude control, i.e. 8 seconds before impact on the ice. The VRS affected the rotor system continuously from its formation until impact on the ice, making it impossible to decrease rate of descent despite an increase in collective stick input.

The Agusta simulations also confirm the course of events as described above. Until approximately one second after the co-pilot had confirmed "*altitude control*" the simulations show good conformity with the FDR data. Subsequently, the simulation in which rate of descent was calculated shows that the collective stick would have needed lowering to achieve the rate of descent that the Z34 had, while the FDR shows an increase in collective stick input. The "inverted" simulation shows that the collective-stick movement recorded in the FDR should have given a considerably reduced rate of descent, while the FDR shows that the rate of descent increased substantially instead.

The Board notes that all the pre-requisites for the helicopter to enter a VRS were fulfilled at all four points below:

- IAS = 0 or close to 0
- 20–100 % engine power
- a glide path between 90° and 70° is the most sensitive
- a rate of descent between 0.25 and 1.25 times the downwash speed of the rotor (V1).

Evaluation of the CVR verified that the pilots, during the final approaches, had applied a method that involved the co-pilot manoeuvring the collective stick after the commander had given him the "*altitude control*" order and was himself working the cyclic stick and pedals. During the ninth approach, the transfer of responsibility for altitude control to the co-pilot took place in an unstable flight situation with a high rate of descent and a high nose attitude. The latter rendered it difficult or impossible for the co-pilot to check the rate of descent against external reference points. The commander transferred control of the collective stick to the co-pilot during the most critical phase of the flight.

The final phase of LÖV requires a clear division of roles between the commander, the co-pilot, the medical orderly astride the helicopter skid and the orderly inside the cabin. It is based on interactive communication between those involved, with the purpose of giving the commander the best possible overall picture.

During the flight, the commander came to act as instructor for the medical orderlies and for the co-pilot, while at the same time bearing responsibility for the manoeuvring and the safety of the helicopter. This meant that the commander was hampered in his function as pilot, limiting his possibility of supervising the conduct of the flight.

Further, dividing the flight-operational handling during this phase between two pilots increases the risk that their overall situation awareness picture will be lost.

Without well-structured procedures and a well-thought-out, standardised training programme, there will be great risks of misunderstanding. In the Board's view, therefore, there is a weakness in a flight-operational procedure of this nature.

It cannot be excluded that a high rate of descent would have been observed earlier if some form of *call out* had been established for this type of exercise.

However, even if the pilots had discovered the high rate of descent in connection with the transfer or responsibility for altitude control to the co-pilot, the altitude at that moment would probably not have been sufficient to avoid the impact on the ice.

2.4 The helicopter – further remarks

During its investigation of the helicopter's technical documentation, the Board has found certain deficiencies. These consist mainly of insufficient coverage of maintenance status and unsuitable routine procedures. Further, there were several non-sanctioned modifications and installations.

Despite deficiencies in formal airworthiness, the basic helicopter was technically airworthy and in all essentials maintained according to instructions in force.

The 1. Heli Sqn has made systematic deviations from RAFT as regards the keeping of aircraft logbook sheets, which, among other things, has made it impossible to trace refuelling.

The Board has earlier submitted a recommendation (RM2002:01 R10) in its report following the accident involving HKP10 no. 404, on this count.

The ELT emergency transmitter was not activated. The transmitter was of a two-dimensional type. In HKP11, this meant that it was sensitive to forces only in the horizontal plane, not in the vertical plane.

Normally three-dimensional transmitters are used in helicopter installations.

No information could be read from the hand-held GPS receiver on board. A contributory reason for this could have been that water had not been drained from the receiver immediately after recovery.

All the information recorded in the FDR/CVR and pertinent to the investigation has been read and analysed with sufficient quality.

Neither the helicopter manufacturer nor the maintenance subcontractor, the Armed Forces nor FMV had access to the current calibration file needed for evaluating FDR data.

After validation, all recorded parameters proved to be correct, with the exception of pressure altitude, which had an offset deficiency of approximately 1,400 ft. This, however, did not affect the investigation results.

The absence of a calibration file rendered the investigation more difficult. The fact that no preventive maintenance is carried out is unacceptable, since it creates uncertainty about the validity of registered data. This generates extra work when evaluating data.

2.5 The crew

All crew members are judged to have had fully adequate physical and mental status before and during the flight that resulted in the accident.

The commander was grounded, as he had not passed tests showing that he met basic Armed Forces physical requirements. This shortcoming in basic physical requirements, however, is not judged to have affected the commander to such a degree as to contribute to the accident.

The co-pilot's training in LÖV was very limited – only one sortie two days before the accident. This sortie was aborted when the crew, by mistake, dipped the helicopter so deeply that water entered the cargo hook bay.

2.6 Flight safety equipment

The HKP11 was procured in 1994 to act as an ambulance helicopter resource. During the Board's investigation, no indication was found that the system was intended to function as a rescue helicopter.

The HKP11 was not fitted with emergency floats or equipped with a life-raft; the crew had not been given UWE training; the crews are normally not issued with insulation suits: they use life jackets without emergency transmitters; the helicopter was operating over water/ non-supporting ice in such a way that land could not be reached in an emergency. These facts show that the flight in question, which in these regards was in no way unique, was carried out in a way for which HKP11 was not intended when it was procured.

The Board regards it as serious that it was impossible for the crew to issue any alert since no functioning voice-communication/emergency equipment was available. The equipment on board was not water-resistant.

The deficiencies in airworthiness with regard to the flight safety equipment were:

- the safety harness, the safety harness strap, the snap-hook, the sheath-knife and the ambulance overall were not formally approved for use in HKP11, nor had they been maintained
- the stipulated maintenance period for the commander's flying helmet had been exceeded by 11 months
- the commander's left-hand safety harness was held together with ribbon in an unauthorised manner.

The above deficiencies are in all cases except one, however, assessed as being without importance for the accident. The exception is the safety harness which, in combination with the life jacket worn on top of the harness, did not permit rapid evacuation from the helicopter.

In its investigation of an accident involving a helicopter HKP10, no. 404 (RM2000-08-11 at Tarfala) the Board issued the following recommendation:

The Department of Defence should more clearly define the allowable equipment alternatives and enhance supervision that the correct flight equipment is worn during flight (RM 2002:01 R3).

Had the recommendation been implemented, the Armed Forces ought to have observed that the ambulance overall had not been airworthy since 31 December 1996.

2.7 Survival aspects

The reason for the commander's inability to open the right-hand pilot's door after the accident was probably obstructing ice on the outside.

The reason for the co-pilot's not being able to jettison the left-side pilot's door with the emergency handle was that the holder for searchlight SX16 had been deformed on impact and was blocking the door's outward movement at its forward edge.

The difficulties in rescuing medical orderly 2 were caused chiefly by:

- the helicopter overturning to the right with its right-hand side door open. Hence the helicopter very rapidly filled with water. This prevented medical orderly 1 from extricating medical orderly 2 from the helicopter during the initial phase of the accident.

- medical orderly 2 was wearing his life jacket on top of his safety harness, which prevented the commander from undoing the snap-hooks on the harness
- the commander had no suitable knife for cutting off the safety harness strap to which medical orderly 2's safety harness was attached.
- the crew had no emergency breathing equipment
- the surface rescue men could not dive below the surface of the water to extricate medical orderly 2 due to the buoyancy of the dry-suits they were wearing and the absence of weight-belts
- the temperature in the water was low and visibility was limited.

2.8 The rescue operation

The incoming emergency call to SOS Alarm was put through to the Aeronautical Rescue Coordination Centre (ARCC) after a fairly long interview. After the 112 call had been answered, ten minutes elapsed before the ARCC, as the emergency alarm centre responsible, received the alert. This period could have been shortened if the call had been put through directly to the ARCC when it was clear that a possible helicopter accident was involved. At the same time, the SOS Alarm operator could have continued to listen in parallel to the conversation between the caller and the ARCC.

After the interview with the alerting caller, the alert procedure was initiated by the municipal rescue services and the ambulance unit. In a different emergency alert procedure, using and "pre-alert", a rescue team can be alerted during a lengthy conversation. Such a routine can in similar cases hasten call-out of the rescue unit closest to the accident site, in this case the part-time-manned station in Karlsborg.

To avoid unnecessary delay and to safeguard the necessary resources for rescue diving, it is reasonable that preparations are planned before the acute need arises during an accident. The goal of this planning should be the possibility to alert adequate resources for rescue diving directly, according to a prearranged emergency alert plan, so that they may be committed as rapidly as possible where there is need for a rescue operation.

The rescue services' operational command on this occasion did not foresee any need for rescue divers and did not request reinforcement with such during transport to the accident site.

A plan where rescue divers are specified in prearranged emergency plans can also act as a reminder and an aid to the avoidance of delay where the need for some resource does not seem to be self-evident in the initial phase of an operation.

2.9 Organisation and management

The investigation indicates a number of deficiencies with regard to safety in the operations in question, such as:

- the commander flew despite the fact that he was grounded
- the commander was wearing a flying helmet with a maintenance period which had been exceeded by almost a year
- none of those on board were wearing insulation suits in accordance with OSF
- deviations from regulations were made with regard to the keeping of an aircraft log-book
- there were shortcomings in the documentation of the helicopter's status

- no TRAB or DA was written when, the day before, the helicopter had been unintentionally dipped in the water during the same type of exercise
- unauthorised equipment was installed in the helicopter.

The squadron's direction and control of its operations has, in the opinion of the Board, shown deficiencies in the areas dealt with above regarding flight operations and technical duty.

The LÖV procedure has not been formally authorised by the squadron command, but the command group was informed of the exercise. This implies that the personnel had been given a kind of authorisation to use the method.

In sum, this event, and hence also the circumstances that have come to light, demonstrate deficiencies in the management of the organisation.

3 CONCLUSIONS

3.1 The result of the investigation

- Nothing in the investigation indicates that any technical malfunction in the helicopter contributed to the accident.
- The weather probably did not influence the course of events.
- The helicopter was manoeuvred into an aerodynamic condition that resulted in a *vortex ring state* (VRS).
- The commander lacked formal qualification for the flight, as he had not passed the basic Armed Forces physical tests. As regards the rest of the crew there were no remarks.
- The technical status of the helicopter was not fully documented, but the helicopter was technically airworthy.
1. Heli Sqn had introduced a number of unauthorised modifications in the helicopter.
- The safety harness worn by medical orderly 2 during work outside the helicopter was not approved as airworthy.
- Medical orderly 2's wearing of his life jacket on top of his safety harness, and the lack of a line-knife, meant that he was unable to extricate himself from the safety harness without previously removing his life jacket.
- The crew had not been trained in *underwater escape* (UWE).
- The simultaneous manoeuvring of the helicopter by both pilots in connection with the LÖV had not been formally decided upon or documented in any set of regulations.
- The crew carried out flight duty with personal flight equipment that was not approved as airworthy.
- The crew performed the flight without insulation suits in contravention of OSF.

- m) The commander performed the flight wearing a flying helmet that had exceeded its maintenance interval by 11 month.
- n) After an eyewitness had alerted SOS ALARM (telephone 112) notification of the accident did not reach the ARCC until after approximately 10 minutes.
- o) The first ambulance arrived at the accident site 27 minutes after the alert to SOS Alarm.
- p) Rescue divers did not arrive at the accident site until approximately two hours after the accident.
- q) The helicopter was equipped with a two-dimensional ELT that was not activated on impact with the ice.
- r) Neither the manufacturer, the maintenance contractor, the Armed Forces nor FMV had, at the time of the accident, an updated calibration file that would permit any direct evaluation of FDR data.
- s) The FDR system does not undergo any preventive maintenance or function checks with regard to the validity of parameters recorded.
- t) The crew lacked water-resistant telecommunications equipment for alerting the authorities regarding the accident.
- u) The 1st. Heli Sqn had deficient ability to follow up HKP11 operations adequately.
- v) The LÖV concept was incompletely handled from the safety point of view.
- x) The 1st. Heli Sqn had poor knowledge of, and routines for, care of personal flight equipment after an accident.
- y) Knowledge of VRS in the Armed Forces is uneven, and misconceptions exist as to all the guises and “grey zones” in which the phenomenon may manifest itself.
- z) The Armed Forces lack established ‘call-outs’ for critical parameters such as maximum rate of descent or minimum speed for two-pilot helicopters.

3.2 Causes of the accident

The accident was caused by the helicopter being manoeuvred into an aerodynamic situation where, during a speed reduction to $IAS = 0$, it sank into its own vortex located diagonally in front and below. This aerodynamic situation developed into a *vortex ring state* (VRS) which became evident in the measurement data approximately 8 seconds before impact on the ice. After this, the helicopter’s rate of descent could not be arrested despite increased collective-stick movement. A contributory cause of the accident was the two pilots’ simultaneous manoeuvring of the helicopter. This allowed small or no chance of discovering in time that they were approaching the helicopter’s limit for safe flight.

4 Recommendations

- The Armed Forces are recommended to increase knowledge of the *vortex ring state* (VRS) and to introduce periodic further training and refresher courses in helicopter aerodynamics for helicopter crews (RM 2005:01 R1).
- The Armed Forces are recommended to investigate the shortcomings brought to their notice in the command and control of helicopter operations (RM 2005:01 R2).
- The Armed Forces are recommended to ensure that insulation suits, dry suits, are available to all helicopter crews and are worn when specified by OSF (RM 2005:01 R3).
- The Armed Forces are recommended to forbid execution of LÖV until further notice. Resumption of this flight profile should be preceded by a thorough safety analysis (RM 2005:01 R4).
- The Armed Forces are recommended to ensure that grounded crews do not do flight duty (RM 2005:01 R5).
- The Armed Forces are recommended to regularly carry out training in *underwater escape* (UWE) with helicopter crews that operate over water (RM 2005:01 R6).
- The Armed Forces are recommended to permit only lifejackets with emergency transmitters for crews, and to introduce waterproof equipment for speech communication among helicopter crews (RM 2005:01 R7).
- The Armed Forces are recommended to ensure that only triaxial ELT emergency transmitters are used in existing and future helicopter systems (RM 2005:01 R8).
- The Armed Forces are recommended to consider the introduction of emergency breathing apparatus for helicopter crews (RM 2005:01 R9).
- The Armed Forces are recommended to review the placing of on-board lifeboats and other emergency equipment to permit safe access after an accident in water (RM 2005:01 R10).
- The Armed Forces are recommended to introduce *approach briefing* for all helicopter flights operated by two pilots (RM 2005:01 R11).
- The Armed Forces are recommended to introduce *call outs* for all helicopter flights operated by two pilots (RM 2005:01 R12)
- The Armed Forces are recommended to conduct mandatory training in crew co-operation for crews of helicopters operated by two pilots (RM 2005:01 R13).
- The Armed Forces are recommended to conduct continuous checks of the function and validity of FDR/CVR data in all aircraft systems. They should also create routines to allow simple evaluation of this type of data. (RM 2005:01 R14).

- The Armed Forces are recommended to monitor more adequately that prescribed maintenance is carried out and prevent unauthorised modifications (*RM 2005:01 R15*).
- The Armed Forces are recommended to establish routines so that personal and other flight safety equipment is placed in safe keeping and made available to the Board of Accident Investigation for investigation after an accident (*RM2005:01 R16*).
- The National Rescue Services agency is recommended to seek to ensure that municipal planning takes into consideration how access to rescue divers (water) may be assured so as to facilitate effective rescue operations (*RM 2005:01 R17*).

Previous recommendations by the Board of Accident Investigation

- The Department of Defence should more clearly define the allowable equipment alternatives and enhance supervision that the correct flight equipment is worn during flight (*RM 2002:01 R3*).
- The Department of Defence should ensure that the stipulated regulations for flight time and maintenance documentation are followed and that required resources are made available to audit, maintain and follow-up the technical documentation of the flying systems so that it attains the accepted standard of quality (*RM 2002:01 R10*).