



## Investigation report

B4/2009L

# Hard landing for helicopter in Porvoo on 7 May 2009

Translation of the original Finnish report

OH-HVK

Bell 412EP

According to Annex 13 to the Convention on International Civil Aviation, paragraph 3.1, the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability. This basic rule is also contained in the Safety Investigation Act (525/2011) and Regulation (EU) No 996/2010 of the European Parliament and of the Council. Use of the report for reasons other than improvement of safety should be avoided.

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## SUMMARY

### HARD LANDING FOR HELICOPTER IN PORVOO ON 7 MAY 2009

An accident occurred at Ali-Vekkoski near the city of Porvoo on Thursday, 7 May 2009 at 12:21 Finnish Daylight Saving Time. A Textron-manufactured Bell Helicopter, the Bell 412EP Medium Transport Helicopter, registration OH-HVK, owned and operated by the Finnish Border Guard, made such a hard landing during an operational exercise that its landing gear fractured and the sub-floor structure of its fuselage buckled. The helicopter had three crewmembers and a six-man team from the Counter Terrorist Unit (CTU) of the Finnish Police as passengers. Two members of the team sustained minor injury.

The task of the exercise team was to conduct a search in order to detain fugitives in the terrain. Once the pilot-in-command (PIC) of the helicopter spotted their target he decided to land the team in the terrain in front of the target. The crew was unfamiliar with the clearing that was designated as the landing site; it was to the right of where the helicopter was making its approach, behind a spit of trees. It was elemental to the success of the task that the team deplane in front of their target. The PIC began his approach to the landing site by accelerating from the search airspeed to 107 kts while maintaining the approximate altitude of 250 ft. When there was approximately 300 m to go to the landing site he began to reduce airspeed for landing.

The pilot-in-command reduced the airspeed of the helicopter by simultaneously lowering the collective and applying aft cyclic. At this time the main rotor RPM rapidly surged and exceeded 104.5%, at which time the warning system gave a high RPM warning. Once the airspeed had bled off and the collective lever had been raised, rotor drag rapidly increased which resulted in the main rotor RPM dropping below 95%. Consequently, the warning system sounded a low RPM warning. The PIC had to suspend raising the collective lever for a moment, which increased the helicopter's rate of descent. The main rotor was entering into a developing vortex ring state. When the engines spooled up, rotor RPM also resumed and the PIC continued to raise the collective lever.

Raising the collective lever in the state did not stop the helicopter from sinking. According to the DFDR the maximum sink rate was approximately 1100 ft/min. The helicopter collided with the ground approximately four seconds after the low RPM warning.

When the PIC realised that a crash was unavoidable, he warned the rest of the crew of an impending hard landing and straightened out the helicopter. It hit the gently rising ploughed field in the nearly optimal position for minimising damage.

The investigation found no technical fault or malfunction in the helicopter. The helicopter was airworthy. Its weight and centre of gravity were within the permissible range. The meteorological conditions were suitable for the task. Crew ratings were valid and they had the required experience to fly the mission.

The cause of the accident was the helicopter's main rotor entering into a developing vortex ring state during landing in conditions that prevented any further corrective actions.

#### Contributing factors included

- A high approach speed and the late reduction of airspeed combined with sizeable power setting changes with a heavily laden helicopter,
- Inadequate Multi Crew Co-operation, for example, as regards checklists as well as air-speed, altitude, sink rate and wind direction monitoring,
- Insufficient attention to the helicopter's state of flight as well as the unfamiliar landing site during the time when the flight crew was deeply focused on the tactical mission, and
- Deficient standard operating procedures (SOP) and guidelines for this particular type of task.

The Finnish Border Guard's statutory tasks require flight operations in nonstandard situations and demanding conditions, moreover special tasks carry more risks than normal flight operations. The Air Patrol Squadron is responsible for carrying out the Border Guard's flight operations, including special air operations related to cooperation with the authorities.

The investigation commission gave the four following safety recommendations for the Finnish Border Guard:

- The Air Patrol Squadron should review their flight procedures and training syllabi as regards the observed shortcomings. Special attention should be given to Multi Crew Co-operation-related monitoring techniques.
- The Air Patrol Squadron should improve their pilots' awareness of the risks of the vortex ring state as well as associated corrective actions.
- In order to improve flight safety, the Air Patrol Squadron should analyse and consider the applicability of the ICAO's Safety Management System (SMS) in their operations.
- Related to their operational duties the Finnish Border Guard should specify their requirements for the transport of dangerous goods by air. Following this, the Border Guard should revalidate the relevant permits and modernise the regulations.

In addition, the investigation commission gave a recommendation for Trafi Aviation, i.e. the Finnish Transport Safety Agency with regard to improving the requisites of investigation. The investigation commission further proposes that Trafi Aviation amend the national Aviation Regulation AIR M16-1 (initial aircraft inspection) so as to extend the JAR-OPS 3's requirement of readily available recorded flight data to all helicopters fitted with flight recorders.



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## ABBREVIATIONS

ARCC	Aeronautical Rescue Co-ordination Centre
ATPL	Airplane Transport Pilot Licence
BEA	Bureau d'Enquêtes et d'Analyses
CG	Centre of Gravity
CPITCH	Collective Pitch
CTU	Counter Terrorist Unit (Finnish Police)
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
EASA	European Aviation Safety Agency
EFHF	Helsinki-Malmi Airport
ELT	Emergency Locator Transmitter
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCL	Flight Crew Licensing
FDAU	Flight Data Acquisition Unit
FMS	Flight Management System
FP	Flight Plan
ft	Feet
GPS	Global Positioning System
HTA	Hierarchical Task Analysis
IBIT	Initiated Built-In Test
ICAO	International Civil Aviation Organization
JAR	Joint Aviation Requirements
kts	Knots
lbs	Pounds
MRCS	Maritime Rescue Coordination Subcentre
MTOW	Maximum Takeoff Weight
N2	Free Turbine RPM (%),(T2)
NR	Main Rotor RPM (%)
OFP	Operational Flight Plan
PF	Pilot Flying
POKE	Finnish Police Field Command System
RFM	Rotorcraft Flight Manual
RPM	Revolutions Per Minute
SCT	Scattered
SMS	Safety Management System
TOW	Takeoff Weight
Trafi	Finnish Transport Safety Agency
TT	Total Time
UTC	Coordinated Universal Time
VHF	Very High Frequency
VIRVE	Finnish Authority Network
VMC	Visual Meteorological Conditions
VRS	Vortex Ring State





## SYNOPSIS

An accident occurred at Ali-Vekkoski near the city of Porvoo on Thursday, 7 May 2009 at 12:21 Finnish Daylight Saving Time. A Textron-manufactured Bell Helicopter, the Bell 412EP Medium Transport Helicopter, registration OH-HVK, owned and operated by the Finnish Border Guard, made a hard landing during an operational exercise; its landing gear fractured and the sub-floor structure buckled. The helicopter had three crewmembers and carried a six-man team from the Counter Terrorist Unit (CTU) of the Finnish Police as passengers. Two members of the team sustained minor injury.

The Itä-Uudenmaa Police, together with investigators from the Accident Investigation Board of Finland (AIB) conducted an on-scene investigation. The helicopter's crew and the leader of the CTU team were interviewed at the accident site. The interviews were later supplemented.

On 27 May 2009 Accident Investigation Board of Finland appointed investigation commission B4/2009L for this incident. Investigator Ari Anttila was named Investigator-in-Charge, accompanied by Jari Multanen, Chief of Flight Operations at the Finnish Border Guard's Air Patrol Squadron as well as Captain Jari Huhtala, Chief of the Air Patrol Squadron's aircraft repair shop at Malmi aerodrome serving as members of the commission. Dr Päivikki Eskelinen-Rönkä was invited as a sound analysis expert to the commission and Krista Oinonen, a psychologist, was invited as an expert to the commission to assess human performance and environmental factors. Kari Ylönen, M.Soc.Sc., analysed the rescue operation and the flow of information.

The investigation commission requested that the Finnish Meteorological Institute prepare a report of the prevailing weather conditions at the time of the accident. The Flight Test Center (sic) of the Finnish Air Force Materiel Command made a 3D animation of the final phases of the flight as well as parameter graphs using the data from the helicopter's flight recorders and the GPS-based Finnish Police Field Command System (POKE). The investigation commission interviewed the flight safety officer of the Helsinki Air Patrol Flight as well as the CTU team leader who also witnessed the occurrence. In addition, the commission interviewed Mr Esa Rantala, flight instructor and type pilot of AB/Bell 412, who provided his expert opinion.

All times in this investigation report are in Finnish Daylight Saving Time (UTC +3).

The parameters presented in this investigation are based on downloaded flight recorder data. Whereas their absolute values may be somewhat imprecise, the scale of parameter variation is considered reliable.

The Finnish Border Guard's statutory tasks require flight operations in nonstandard situations and demanding conditions, moreover special tasks carry more risks than normal flight operations.

Joint exercises between the Border Guard's Air Patrol Squadron and the Counter Terrorist Unit (CTU) of the Helsinki Police Department are part of the Air Patrol Squadron's special air operations. The Air Patrol Squadron, being the operator, is responsible for relevant regulations and training. The Helsinki Police Department is responsible for the guidelines and training of the CTU. All activity inside the helicopter is done under the command of the helicopter crew.



The activity of the exercise's CTU was reviewed on the basis of guidelines and training programmes. The investigation assessed the extent of the regulations for the operator and the police as well as relevant instructions for joint operations. The investigation also reviewed the Air Patrol Squadron's flight safety management and associated instructions.

The investigation evaluated the task requirements for the mission as well as the pilots' cognitive stress during the mission. The Air Patrol Squadron briefed the investigators on crew cooperation on a typical training flight of this type and flew a re-enactment to the accident site. Both events were videotaped.

On 12 May 2009, pursuant to ICAO Annex 13, section 4.2 AIB sent a notification of the incident to the investigation authority of the helicopter's State of Design: National Transport Safety Board (NTSB) USA and to the investigation authority of the helicopter's State of Manufacture: Transportation Safety Board of Canada (TSB).

The draft final report was sent for comments to the Finnish Border Guard, the Helsinki Police Department, the Finnish Transport Safety Agency (Trafi), Finavia Oyj, the EASA, the NTSB, the TSB, the French BEA (Bureau d'Enquêtes et d'Analyses), who participated in the investigation, as well as to Bell Helicopter Textron and parties concerned. The comments received were taken into account in the final report. The digest of the comments is found as appendix 1.

The investigation was completed on 11 August 2011 and the report was translated into English.

The material used in the investigation is stored at Accident Investigation Board of Finland.



## **1 FACTUAL INFORMATION**

### **1.1 History of the flight**

#### **1.1.1 Events before the flight**

The joint exercise between the Finnish Border Guard's Air Patrol Squadron and the Counter Terrorist Unit (CTU) of the Helsinki Police Department comprised two phases. The first phase involved rappelling and deplaning from the helicopter at the movement area of Helsinki-Malmi aerodrome. The second phase consisted of a tactical exercise in the terrain. The accident occurred during the tactical phase of the exercise.

Prior to the start of the exercise the team leader of the police CTU, one member of the team and the pilot-in-command (PIC) of the helicopter briefed the exercise to each other. Flight planning was normal, including briefing on activated danger areas, ATS information, flying weather and filing the operational flight plan (OFP). The flight plan (FP) of the first phase was later filed by telephone to Helsinki-Malmi tower. The flight engineer conducted the daily inspection for the helicopter and prepared it for the exercise.

The rappelling exercise began at 10:40 and lasted 45 minutes. Following this the helicopter was refuelled to approximately 950 l (1700 lbs). The preparations for the tactical mission of the exercise were immediately started.

The tactical exercise team consisted of the three-person helicopter crew and the CTU unit. The aircrew comprised the PIC, the co-pilot and the flight engineer. The PIC was responsible for the safe conduct of flight as well as procedures. Furthermore, the PIC was the pilot flying (PF) on this flight. The co-pilot was tasked to handle monitoring, radiocommunications and maintaining contact with the tactical command of the exercise. The flight engineer was the senior member in the cabin, running the activities in the cabin. The helicopter crew was Helsinki Air Patrol Flight's duty crew at the time.

The co-pilot filed the FP of the tactical phase by telephoning the Malmi tower. He filed ten persons as the number of persons onboard. A last minute change eliminated one member of the CTU team from the flight. There were nine persons onboard during the flight.

The CTU team consisted of the team leader (rappelling leader) and five members. The team leader was responsible for leading the CTU team and monitoring radio traffic on the VIRVE (Finnish authorities' official) network. The CTU's exercise leader moved by car in the exercise area. He was also the tactical commander of the entire exercise.

The objective of the tactical phase was to practice search and rapid deplaning into the terrain. The exercise team was tasked to search and detain two armed persons as per instructions given during the search.

Prior to the flight the flight engineer reviewed the normal cabin safety instructions with the CTU team. The rappelling leader sat at the back on the right side of the cabin, three

team members sat in the middle seats and two of them sat on the floor, hooked to the rappelling system's anchor (floor) rope. The three rearmost seats were empty. The flight engineer was positioned in the front of the cabin. He was not seated but he was connected to a safety harness.

Through the helicopter's intercom the PIC, the co-pilot and the flight engineer were connected to aviation VHF radios, the VIRVE network, marine VHF radio and the helicopter's own intercom. They maintained contact with Malmi tower through the helicopter's radio. By means of the VIRVE radio the crew maintained contact with the exercise commander and the Maritime Rescue Coordination Subcentre (MRCS). The CTU team leader and one member of the team (the door opener) could monitor the intercom and VIRVE traffic on their earphones. The other members of the exercise team monitored VIRVE traffic through their tactical earpieces.

### 1.1.2 The accident flight

The flightcrew took off towards Sipoo and the planned exercise area from Helsinki-Malmi aerodrome at 11:45. Once airborne the exercise team was given more detailed information regarding their target. They were also told that the target was armed. At approximately 12:05 they spotted a car in which their target was thought to be. The PIC of the helicopter proposed a rapid deplaning so as to stop the target. Nevertheless, the situation developed so rapidly that the PIC almost immediately called the attempt off. Soon after this they lost sight of their target.

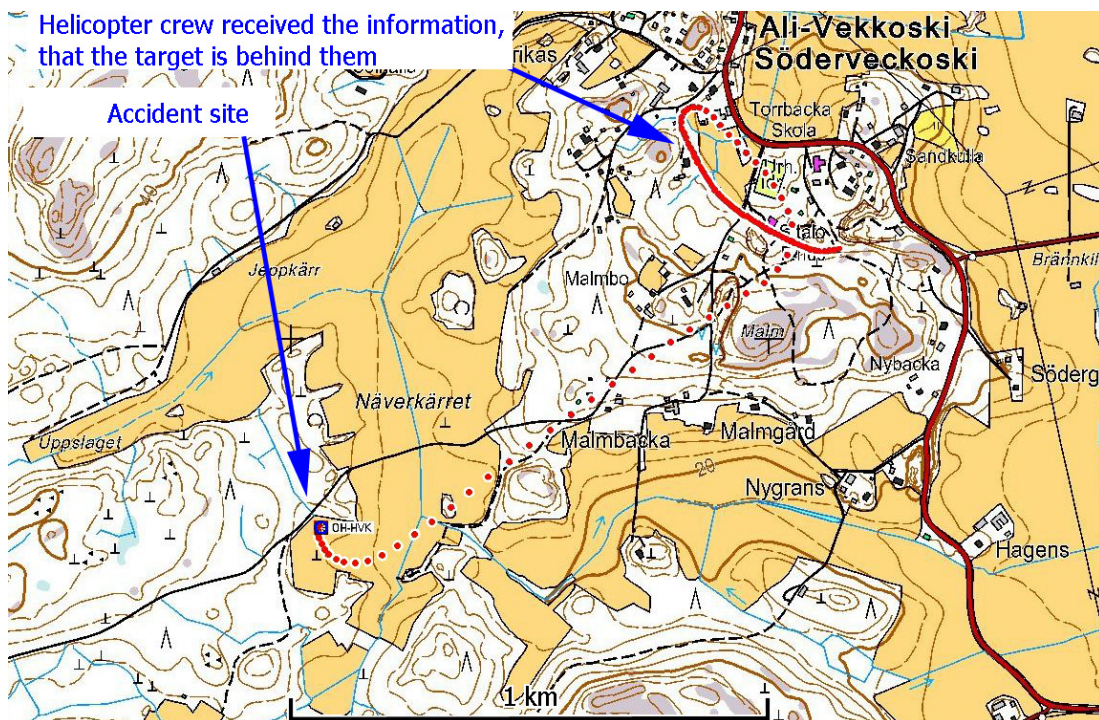


Figure 1. The track of the final phase of the flight and the accident site. Each red dot represents a one second interval. (©The Finnish Border Guard) (Map: KTJ/Ministry of Justice/MMJ)

The flight continued as an active search until approximately 12:20, at which time the tactical command of the exercise informed the helicopter that their possible target had been seen in a field behind them. The helicopter was then flying at 30 kts and the heading was 325 degrees (figure 1). While turning towards 140 degrees the PIC spotted the target which was approaching a narrow spit of woods between two fields. The helicopter was approximately 1.2 km from the target. The PIC continued to turn towards 225 degrees and gave the call “prepare to deplane” while at the same time increasing his airspeed on the way to the landing site. The landing site was to the right of the helicopter’s approach direction, behind a narrow spit of trees (figure 5).

The parameter values in the following depiction are derived from the helicopter’s flight recorders (Figures 2, 3 and 4).

When the distance to the landing site was approximately 300 m, the pilot began to reduce airspeed and altitude by lowering the collective lever. At that time the airspeed was 107 kts and the altitude approximately 250 ft. At the distance of 200 m from the landing site the airspeed remained at 107 kts and the altitude was approximately 230 ft. The nose of the helicopter was 4 degrees above the horizon. The collective was near the full down position. A right turn was commenced.

At approximately 100 m from the landing site the airspeed was 90 kts and the altitude approximately 200 ft. The collective lever was in the full down position. The main rotor RPM increased during the deceleration. Approximately two seconds after the start of the turn they received a high RPM warning (104.5%), indicated in the ‘Master Caution’ legends shown in figures 3 and 4. The co-pilot reported this to the PIC by calling ‘RPM’, which the PIC acknowledged. The main rotor RPM rose to 105.5%. The collective was nearly in the full down position. Simultaneously, the transmission freewheeling clutches disengaged for approximately five seconds.

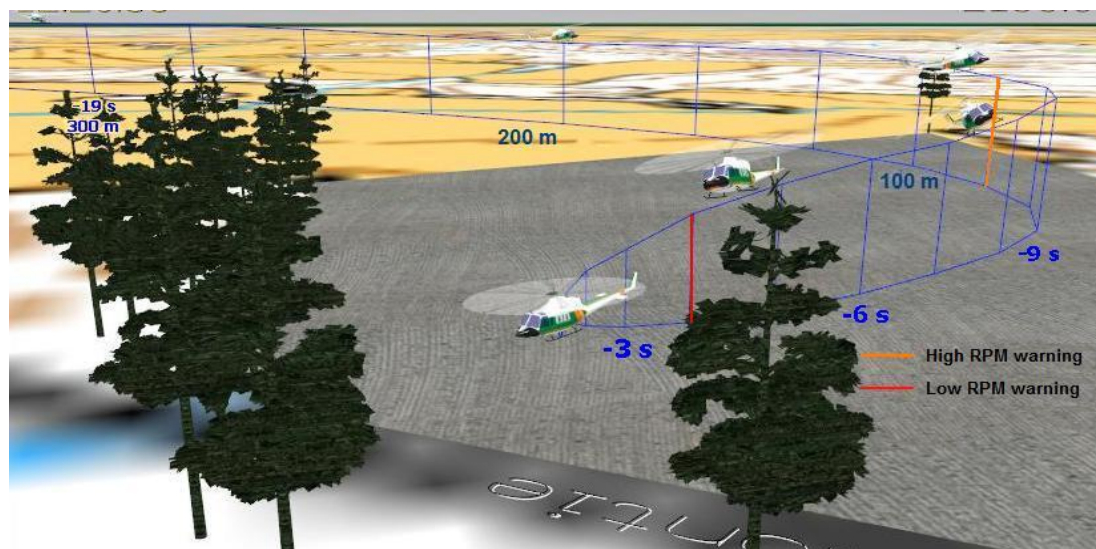


Figure 2. The final phase of the flight. The blue vertical lines represent an interval of one second. The distances are direct distances to the landing site. Because of the data recording rate the helicopter’s position is slightly inaccurate. The graph was generated from an animation. (© Finnish Defence Forces)



Hard landing for helicopter in Porvoo on 7 May 2009

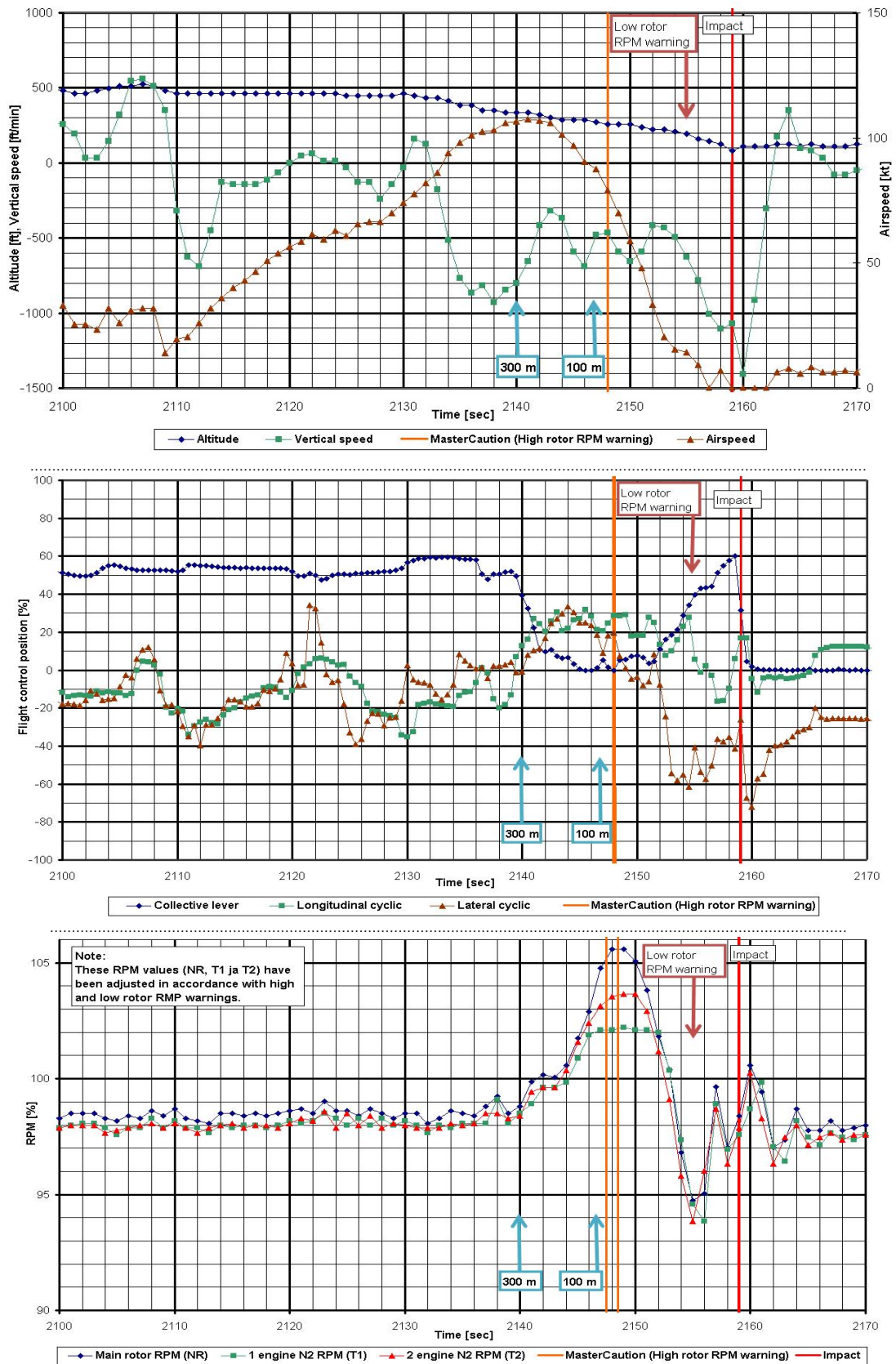


Figure 3. Flight recorder data.

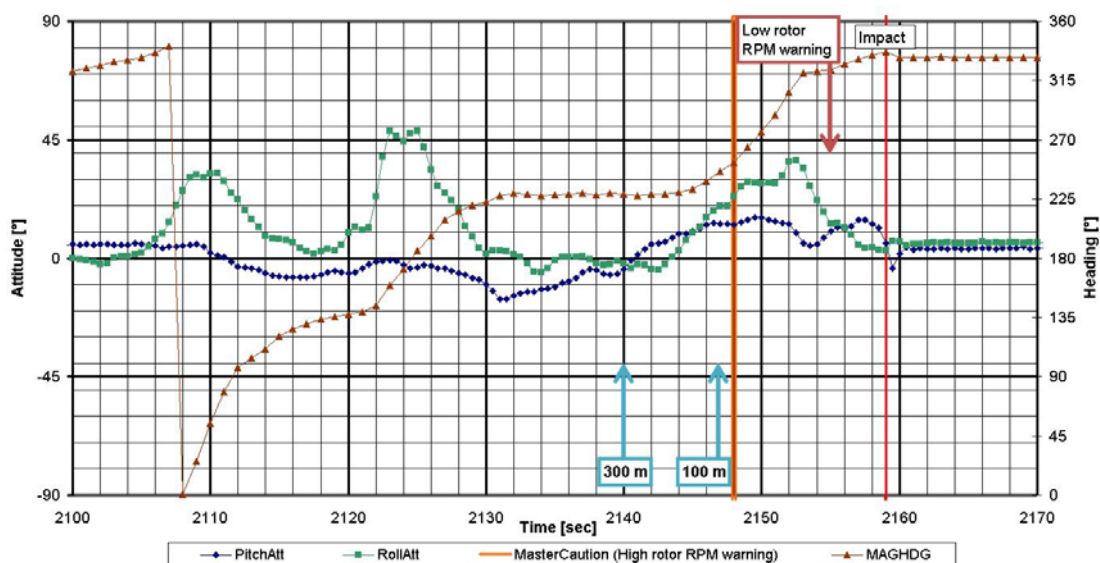


Figure 4. Flight recorder data.

The pilot began to raise the collective four seconds after the high RPM warning. At that time the maximum bank angle of the helicopter was 37 degrees, the distance to the landing site was approximately 50 m, airspeed was 35 kts and altitude 140 ft. The rate of descent was 430 ft/min.

Three seconds after the collective was raised a low RPM warning (95%) was activated. At that point in time the helicopter had been rolled 20 degrees to the right, airspeed was 15 kts and altitude approximately 100 ft. The rate of descent was 530 ft/min.

During the four seconds that followed the low RPM warning the sink rate continued to increase, to a maximum of approximately 1100ft/min. Approximately two seconds before touchdown forward cyclic was applied. Approximately one second before the crash the PIC warned the rest of the crew that they would make a hard landing.

The helicopter collided with the ground at 12:21 (figure 5).

According to flight recorder data the main rotor RPM was set at approximately 98.5% after takeoff. It was not adjusted during the final phase of the flight. Cockpit Voice Recorder data does not indicate the completion of any landing checklists during the final 29 minutes of the flight.



Figure 5. The accident site and the surroundings. (Photo: Border Guard)

### 1.1.3 Events after the accident flight

After touchdown the flightcrew noted that the landing gear was damaged and that the helicopter sat on the ground on its belly (figure 6). Since the crew did not notice anything else out of the ordinary, they shut the helicopter down as per the normal procedure. No serious injuries occurred.

At 12:31 the co-pilot reported the hard landing to Malmi tower and terminated their flight plan 'on a field in Sipoo at 12:25'. The helicopter's PIC reported the occurrence to the commander and to the Chief of Flight Operations of the Air Patrol Squadron. Following this he reported the occurrence to AIB's Chief Air Accident Investigator at 12:36.

The flight engineer checked the underside of the aircraft for fuel leakage and disengaged the helicopter's battery to preserve the Cockpit Voice Recorder and Digital Flight Data Recorder information. The engineer reported the occurrence to the chief of the Air Patrol Squadron's Malmi aerodrome aircraft repair shop.

The exercise leader reported the occurrence to the Helsinki Police Department's command centre and to the Itä-Uusimaa Police Department.



## 1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Serious			
Minor/None	3	6	



Figure 6. The helicopter on its belly at the accident site.

## 1.3 Damage to aircraft

Substantially damaged.

## 1.4 Other damage

No other damage.

**1.5 Personnel information**

**Pilot-in-command:** Age 37. Serving with the Finnish Border Guard since 1990.

**Licences:** Air Transport Pilot's Licence ATPL (H), valid until 6 Apr 2010.

**Ratings:** JAR class 1, valid until 2 Nov 2009.  
Instrument rating, valid until 31 May 2009.  
Type rated for Agusta-Bell/Bell (AB/B) 206/206L, AB/B 212/412. AB 412 type rating training received in 1995.  
Border Guard duty pilot rating for AB 412 aircraft received in 1998.

**Working hours:** The shift on 7 May 2009 began at 08:00. The PIC claimed to be in good flying condition. The day before he had worked from 06:30 until 16:00 and the day before that his shift lasted from 09:00 to 16:00.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours
All types	1 h 45 min 5 landings	50 h 73 landings	98 h 132 landings	7400 h
Helicopter type in question	1 h 45 min 5 landings	40 h 46 landings	77 h 93 landings	4500 h

**Co-pilot:** Age 32. Serving with the Finnish Border Guard since 2000.

**Licences:** Air Transport Pilot's Licence ATPL (H), valid until 30 Nov 2009.

**Ratings:** JAR class 1, valid until 3 Aug 2009.  
Instrument rating, valid until 30 Sep 2009.  
Type rated for AB/B 206/206L, AB/B 212/412. AB/B 412 type rating training received in 2004.  
Border Guard duty pilot rating for AB 412 aircraft received in 2005.

**Working hours:** The shift on 7 May 2009 began at 08:00. The co-pilot claimed to be in good flying condition. The day before he had worked from 06:30 until 15:30 and the day before that he was off duty.



Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours
All types	4 h 15 min 21 landings	39 h 72 landings	107 h 193 landings	2729 h
Helicopter type in question	4 h 15 min 21 landings	29 h 58 landings	92 h 175 landings	1433 h

**Flight engineer:** Age 47. Serving with the Finnish Border Guard since 1991.

**Licences:** Part 66 Aircraft Maintenance Licence, valid until 9 Mar 2012.

**Ratings:** Type rated for AB/B 206/206L, AB/B 212/412. AB 412 type rating training received in 1991.

Border Guard duty flight engineer rating for AB 412 aircraft received in 1998.

**Working hours:** The shift on 7 May 2009 began at 08:00. The flight engineer claimed to be in good flying condition. The day before he had worked from 08:00 until 18:00 and the day before that his shift lasted from 08:00 to 16:00.

Flying experience	Total hours
All types	2217 h

## 1.6 Aircraft information

The Bell 412EP is a twin turboshaft engine, FAR Part 29 class medium helicopter. This helicopter was specially fitted for Border Guard (the operator) surveillance flights as well as search and rescue missions.

### Helicopter:

Registration	OH-HVK
Owner and operator	Finnish Border Guard
Type	Bell 412EP
Manufacturer	Bell Helicopter Textron
Production number	36242
Year of manufacture	1999
Total hours	3418 h

**Powerplant:**

Manufacturer	Pratt & Whitney
Type	PT6T-3D Twin pack (1800 shp)
Serial numbers	TH0001, total time TT: 3923 h TH0418, total time TT: 3379 h

**Airworthiness:**

Registration number	1789, registered on 19 Oct 2000
Certificate of airworthiness	Valid until 31 Oct 2010

**Weight and Centre of Gravity:**

Helicopter weighed on	7 Oct 2005
Calculated correction done on	22 Jan 2009
Basic empty weight (surveillance version)	3,640 kg
Maximum takeoff weight (MTOW)	5,398 kg
Flight plan's	
<ul style="list-style-type: none"> <li>• Takeoff weight (TOW)</li> <li>• Centre of Gravity (CG)</li> </ul>	5,277 kg 3.504 m
At the time of the accident	
<ul style="list-style-type: none"> <li>• weight</li> <li>• CG</li> </ul>	approximately 5,050 kg 3.477 m

The Bell 412EP helicopter's turboshaft engines are free turbine engines. In a free turbine engine there is no physical connection between the compressor and power turbine. The power turbine (free turbine) is connected to the main gearbox via reduction gear, a freewheeling unit and drive shafts. The main gearbox is connected to the helicopter's rotor assembly through the main rotor mast. A hydro-pneumatic/mechanic power control system attempts to maintain a steady 97–103.5% (both engines running) main rotor RPM (NR) and free turbine RPM (N2), set by the pilot. The power turbine governor reacts to changes in N2 through the fuel control unit of the gas producer. The power turbine governor attempts to maintain a steady N2 and, subsequently, a constant rotor RPM.<sup>1</sup>

When the collective lever is raised the pitch angles of all main rotor blades increase, which increases drag. As a result, the main rotor RPM (NR) and the free turbine RPM (N2) will momentarily decrease. Should the N2 drop below a set value, the fuel control system will supply more fuel to the engine. This raises the RPM of the gas producer restoring the set values of the NR and the N2. Due to the technical features of the control system there is some lag in restoring the RPMs. The lag is dependent on the degree and rate of the change. The pilot can operate a separate trim to adjust the torque of engine No. 2 in relation to engine No. 1.

<sup>1</sup> Raunio, J. (2000). *Helicopter structures and systems*. Helsinki: Edita.

The helicopter's landing gear is of tubular design, constructed of aluminium alloy. The landing gear consists of two longitudinal skid tubes, joined together by two arched cross tubes.

## **1.7 Meteorological information**

The accident occurred in daylight VMC conditions. Visibility was over 30 km. It was a sunny spring day and the winds were light. A weak high pressure ridge was passing over Finland towards the southeast. It had been very cloudy but was clearing up during the course of the morning. There were no showers or thunderclouds.

The investigation commission requested that the Finnish Meteorological Institute prepare a précis of the accident day's weather conditions from 09:00-14:00. The outline was made using the information from the Harabacka observation station, which is the closest station to the accident site in Porvoo and approximately 12 km east-northeast of the site. The summary states that the maximum ten-minute sustained wind strength was 3 m/s. The strongest gusts blew at approximately 4 m/s. In the beginning of this interval the winds were northerly, but they then became easterly and, ultimately, southerly. No rain was observed during this time. The ambient temperature in the beginning of the observation period was +7°C, rising to +15°C at its end. Just before the accident occurred at 12:20 the surface wind was 142 deg and wind strength 2.7 m/s (ten-minute sustained wind), gusting to 4.4 m/s.

The Helsinki-Malmi aerodrome surface wind, as entered into the flight plan, was 300 deg 5 kts.

After the accident the co-pilot listened to Helsinki-Malmi aerodrome weather information Kilo and copied it into their operational flight plan: 09:20 (UTC), wind 240 deg 3 kts, visibility 30 km, SCT clouds at 4000 ft, temp +14°C, dewpoint 2°C, QNH 1006 hPa.

During the post-accident interview the PIC said that, after the occurrence, he had noticed that the surface wind was a tailwind.

## **1.8 Aids to navigation**

The helicopter was fitted with a Racal-manufactured R-NAV-2 FMS-computer (Flight Management System) which receives its positional information from a Trimble TNL8100 GPS device and a Racal Doppler 91 device (81077/DDTW005). The EFIS display shows calculated wind data.

The helicopter was fitted with a GPS device and cockpit map display, linked to the Finnish Police Field Command System (POKE).

## 1.9 Communications

The helicopter crew maintained contact with Malmi (EFHF) tower via the aviation VHF radio. In addition, through the VIRVE network radio they stayed in contact with the Helsinki Maritime Rescue Coordination Subcentre (MRCS) and with the relevant authorities. Furthermore, they monitored the marine VHF radio. All radios operated properly.

## 1.10 Aerodrome and air traffic services information

The flight began at Helsinki-Malmi aerodrome (EFHF).

## 1.11 Flight recorders

The helicopter was fitted with an analogue cockpit voice recorder (CVR) and a digital flight data recorder (DFDR).

### Cockpit Voice Recorder (CVR):

Manufacturer	Fairchild
Type	A100
Serial number	51248
Manufactured on	3/86
Recording capacity	30 minutes

The information contained in the over-writing 4 track CVR was downloaded under the supervision of the AIB at the French civil aviation investigation authority's (BEA: Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile, Le Bourget, France) laboratory. The device was completely intact and in proper working condition. It had operated normally and the data therein were of good quality. The recording lasted 31 min 10 s, beginning 29 min 10 s before the accident and ending 2 minutes after the accident.

The recordings were used to establish the communication within the helicopter as well as radiocommunications for the final 31 minutes of the flight. The limited recording capacity did not facilitate the evaluation of the different phases of the entire flight.

In addition to transcribing the content of the audio channels, sounds recorded through the area microphone were analysed to determine the main rotor RPM.

### Digital Flight Data Recorder (DFDR):

Manufacturer	Fairchild
Model	F1000
Type number	S800-2000-00
Serial number	02454
Manufactured on	10/99



The data were downloaded at the French civil aviation investigation authority's (BEA) laboratory. The device was intact and in proper working condition.

The data were downloaded with Rose L3 Communications Version 3.7a equipment. The information consisted of binary raw data: 256 words/frame and 12 bits/word. The downloading went well and the data were of good quality.

In order to convert the data into readable flight parameter values one needs to use a helicopter tail number-specific Download Grid as stipulated by FAA Advisory Circular 20-141 Annex 1 (Oct 1999)<sup>2</sup>. This table should be included as one of the documents of the aircraft. The manufacturer did not provide the download grid to the operator, nor was its absence noticed (in the initial aircraft inspection). Following some correspondence, the manufacturer delivered the missing file on 15 Jun 2009<sup>3</sup>.

Thirty-eight (38) data points of raw data were downloaded from the DFDR frame structure, out of which 20 parameters were derived. The POKE system provided five additional GPS parameters.

Shortcomings and outright errors were detected in parameter determination. By utilising the resolution and limits of parameters during the flight, the Flight Test Center of the Finnish Air Force Materiel Command prepared parameter correction formulas. For example, indications from RPM warnings were used to help determine the level of main rotor RPM.

Neither the DFDR nor its Flight Data Acquisition Unit (FDAU) had any maintenance requirements. Maintenance actions or parameter calibrations were not included in the operator's maintenance programme. The equipment carries the status 'On Condition'. In other words, a self test/IBIT monitors their condition every time they are turned on. Whereas the lack of system calibration may render the absolute values of recorded data somewhat imprecise, the scale of parameter variation is considered reliable.

## **1.12 Wreckage and impact information**

The accident occurred on a field next to Tuohisuontie road at Ali-Vekkoski, near the city of Porvoo. The coordinates of the location are (WGS84) N 60°21.734, E 025°25.294. The elevation is 25 m.

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<sup>2</sup> Valid when the helicopter was delivered.

<sup>3</sup> Bell 412 DDAFCS. - 6/15/09 6:11:39 PM. Configuration Description - Bell 412 SSFDR With DDAFCS Mod 20 Nov 1992.

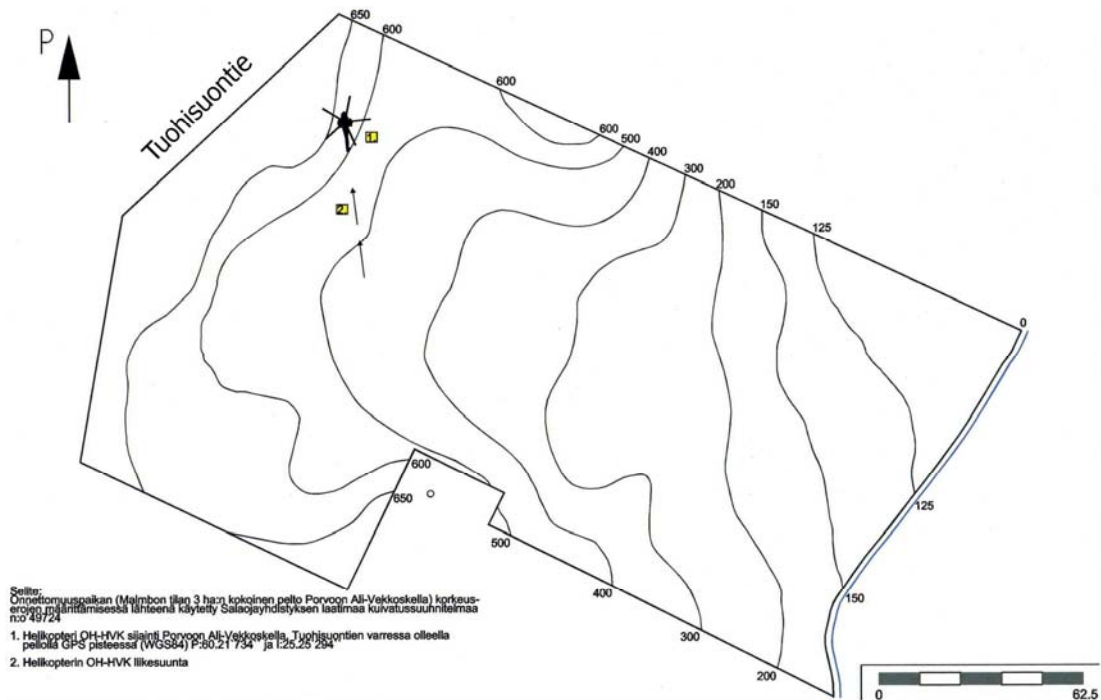


Figure 7. Map of the landing site. (Base map: The Finnish Field Drainage Association, Photo: Finnish Police)

The accident site is approximately 25 m from Tuohisuontie road at the northern corner of a three hectare ploughed field. The lowest point of the field is at the eastern corner, 225 m from the accident site. From there the field gradually rises towards the site, being approximately 6.5 m higher.

The final heading of the helicopter was approximately 340 degrees. In this heading the surface of the field rises approximately two metres within the approximate distance of 60 m. Relative to the heading of the helicopter the crash site terrain slants to the right.

The helicopter ended up on the ground on its belly (figures 8 and 9). The wearpads at the aft ends of the landing gear left clear skid marks on the ploughed field (figure 9). The marks were approximately two metres long. The aft ends of the skid tubes were bent upwards. The left skid tube was almost completely severed from the cross tubes which, themselves, were bent backwards. The right skid tube broke off and lay next to the fuselage. The FLIR camera below the nose was bent backwards and its fittings had damaged the sub-floor sandwich structure. The larger searchlight on the left side had hit the surface of the field and was bent backwards. The smaller searchlight at the aft end of the fuselage did not make any contact with the ground.

A visual inspection did not find any damage to the rotors or the tail boom.





Figure 8. Damage on the left side.



Figure 9. Damage on the right side. The photo shows the skid mark.

### 1.13 Medical and pathological information

At 13:36 the police performed a breathalyzer test to the helicopter crew. All of them had zero blood alcohol.

### 1.14 Fire

There was no fire.

### 1.15 Survival aspects

#### Search and Rescue

There was no need for a rescue operation, nor was one launched.

#### Survival aspects

The helicopter's ground speed at the moment of impact was very small. The flight engineer, hooked to a safety harness, was crouched between and behind the pilot seats, facing rearwards. Once the PIC called the hard landing, the engineer braced himself on the pilot seatbacks, stayed on his feet and was uninjured.

Two members of the CTU team were sitting on the floor, hooked to the rappelling system's anchor rope by rappel harnesses.

The helicopter's manufacturer claims that the elastic landing gear is designed to withstand the energy of a landing at the vertical speed of 2.5 m/s (8.3 ft/s) without sustaining any structural damage. The landing gear's damping capacity will work up to 3.1 m/s (10.2 ft/s), but its structure may be permanently deformed.<sup>4</sup>

The DFDR recording shows that the helicopter's descent velocity at the moment of impact was approximately 5.6 m/s (1100 ft/min, which translates to approximately 18 ft/s).

The crew and cabin doors worked properly after the collision with the ground.

The helicopter's emergency locator transmitter (ELT) EBC-302 ELT P/N EBC-302HM S/N 203824GAHM did not activate.

### 1.16 Tests and research

#### 1.16.1 Flight recorder data analysis

The Flight Test Center of the Finnish Air Force Materiel Command analysed the downloaded raw data and converted them into parameters with the BBN Probe<sup>®</sup> program. The parameter data were entered into MS Excel<sup>®</sup> from which the graphs of the flight's events were generated. A 3D animation of the events was generated by using DFDR and CVR

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<sup>4</sup> Bell Helicopter Textron (2002). *Product data*.

data as well as information from the GPS-based Finnish Police Field Command System (POKE). The animation was made with Insight Animation<sup>®</sup> v.3.0 and Insight Analysis<sup>®</sup> v.3.0 programs. Rotating the view of the animation was made possible by the Insight View<sup>®</sup> program. The Defence Forces geographic data were used as map data for the animation.

Spoken words were transcribed from CVR data. Furthermore, technical and aerodynamic audio information recorded by the CVR was analysed.

The timestamps of different recordings were synchronised by determining the moment of impact from DFDR acceleration data, CVR data and the POKE GPS system's altitude change information.

The data analysis did not suggest to any faults in the helicopter's systems.

### 1.16.2 Component repair information

The repair procedures defined in the manufacturer's maintenance instructions called for an inspection to determine a need for overhauling the transmission, the main drive shaft and the mast. Visual inspections were made on other dynamic components and the fuselage. The following repair report conclusions were made by the inspectors:

**The engines** were inspected for the hard landing. Both engines were overhauled.

Prior to removing the engines their external condition as well as the free rotation of compressors and turbines were checked. The engines' chip detectors were uncontaminated. The external inspection did not find any damage that could point to the functioning of the engines.

When the engines were disassembled, the inspections found the following:

- S/N TH0001
  - The engine was in good internal and external condition
  - Compressor and power turbine stator coatings displayed some wear
  - The seal of the compressor's second bearing bore marks of burnt oil on seal surfaces.
- S/N TH0418
  - The engine was in good internal and external condition
  - Slight corrosion on compressor and power turbine blades as well as wear on stator coatings could be detected.

Nothing outside normal wear on bearings could be detected in engine transmissions.

**The main transmission** showed normal wear on bearings and the gear train.

**The main drive shaft** displayed normal wear. No strike marks or damage was detected on drive shaft junctions.

**The mast bearing** showed wear which was caused by normal use.

**The fuselage's** damage was mostly limited to the landing gear and its fuselage fittings as well as to the fore part of the helicopter where the FLIR and searchlight gimbal fittings are located.

There were deep dents and tears in the fore and aft structures of the landing gear well. Landing gear fitting points were ruptured and bent. The landing gear well bulkhead structure was bent and dented. There were some dents in the sub-floor structure.

**The skid tube** was bent upwards on the aft left side. It was broken to the front of the cross tube. The right aft cross tube was completely severed from the skid tube. The fore cross tube was broken off from the skid tube on both sides. The landing gear was broken beyond repair.

**The Doppler antenna** cowling was flattened from its front end for approximately 6 cm. A more detailed inspection revealed internal damage in its electronics and frame structure.

**The searchlight** (SX-16) gimbal assembly was bent upwards at the point where it connects to the fuselage. The gimbal/searchlight fitting was partly torn loose from the assembly. The searchlight had some external damage.

**The FLIR camera** was bent approximately 50 degrees backwards. This resulted in the delamination of the fore accessory compartment panel's sandwich structure, breakage in nose cowlings and external damage to some of the equipment in the accessory compartment.

**The antennas** under the fore fuselage were bent and partly torn loose. In addition, the searchlights under the fore fuselage sustained external damage.

**Directional gyro and attitude indicator** bearings and gyroscope frames were damaged. It is presumable that the sudden stop and jolt caused by the hard landing contributed to the damage.

### 1.16.3 The Finnish Police Field Command System (POKE)

At the behest of the investigation commission the Air Patrol Squadron's Malmi aircraft repair shop staff downloaded the Finnish Police Field Command System's recordings. The system's GPS-sensor linked memory data were converted into GPSX file format with the GpxExport program. This process generated GPSX-based time, position, speed, direction, vertical speed and altitude information. The values could be studied with the Prune program.

### 1.16.4 Assessing the requirements of the mission

The Air Patrol Squadron briefed the investigators on crew cooperation regarding a mission of this type and conducted a flight re-enactment. During the flight the main points of interest were the terrain and aspects associated with the visual conditions at the landing site. A standard landing was made at the accident site. The briefing and the flight were videotaped for a more detailed task analysis.

### **1.16.5 Interviews**

The helicopter crew was interviewed immediately after the accident. They said that the aircraft functioned normally. Later, in complementary interviews, the PIC pointed out that the engines exhibited a large, transitory torque divergence during the final approach and, hence, he had to stop raising the collective for a moment.

In addition to his normal duties the pilot-in-command of the accident helicopter was the Air Patrol Squadron's Chief of Flight Safety. Because of this, his complementary interview also touched upon flight safety management. The investigation commission interviewed the flight safety officer of the Helsinki Air Patrol Flight regarding the functioning of the Squadron's flight safety organisation.

In conjunction with the briefing the investigation commission interviewed the chief of the Helsinki Air Patrol Flight regarding the special requirements of the mission.

The investigation commission interviewed the leader of the Police exercise team with regard to the CTU unit's techniques and training; the commission also studied the CTU's training manuals.

### **1.17 Organisational and management information**

The Finnish Border Guard is a militarily organised agency operating under the Ministry of the Interior. The Air Patrol Squadron carries out the Border Guard's air operations. The Air Patrol Squadron is an independent administrative unit, led by the Squadron commander. Flight operations have been dispersed to three operational Air Patrol Flights (Helsinki, Rovaniemi and Turku), covering the entire territory of Finland.

Border Guard aviation is state aviation that complies with civil aviation regulations with certain exceptions that are approved by the Finnish Transport Safety Agency (Trafi). Trafi is the supervising authority as regards aviation.

Finnish Border Guard aviation comprises missions flown and practiced pursuant to its statutory tasks, missions carried out as per its Aerial Work Certificate and flight training in accordance with JAR-FCL. Regulations that apply to special air operations and which are not included in civil aviation regulations are included in the Border Guard's Flight Operation Manual.

The Border Guard's Aerial Work Certificate for multi-engine propeller aircraft and helicopters (MM, H) was valid until 31 Dec 2011.

Border Guard aviation is regulated by, among other things, the following internal regulations and instructions:

- The Flight Operation Manual
- JAR-FCL2 flight training manual
- Aircraft type-specific flight procedures (these include Multi Crew Co-operation procedures)
- Training manuals

- The Maintenance and Repair Shop Manual
- The Border Guard's standing documents.

During the course of the investigation the commission familiarised themselves with the organisation of the Air Patrol Squadron as well as the special features and guidelines of its flight operations.

### **Flight Operation Manual**

Among other things, the Finnish Border Guard's Flight Operation Manual provides for the chain of command in flight operations, personnel participating in flight operations (including their tasks and responsibilities) as well as passenger and cargo transports and flight safety.

The Flight Operation Manual only permits a deviation from its regulations when the security of the nation or lives are at risk, or when the pilot-in-command deems it absolutely necessary for reasons of safety.

The Flight Operation Manual demands absolute compliance with flight procedures in training and mission briefing. The Air Patrol Squadron uses a specific log into which exceptional circumstances (occurrences) are entered.

The Flight Operation Manual lists the flightcrew and the cabin crew as aircrew. The flightcrew comprises the pilot-in-command, the co-pilot and the student pilot. The cabin crew consist of the flight engineer, the winch operator, the surveillance systems operator and the rescue swimmer as well as persons being trained for said duties. Only those members of the aircrew who have the requisite licences and ratings are permitted to operate flight controls or other equipment that can affect the safety of a mission.

The Flight Operation Manual stipulates that a passenger list must always be made of passengers who are not Border Guard personnel. Furthermore, every passenger who is four years of age or older must have a seat or stretcher fitted with a safety harness. Passengers must wear their safety belts at all times.

The Flight Operation Manual's cargo and load section provides for the transport of dangerous goods by air and for the exemption granted to the Finnish Border Guard regarding the transport of dangerous goods by air.

The Flight Operation Manual calls for the use of a checklist in every situation for which one exists. These include, among other things, approach checks and checks during the final approach.

### **Flight procedures**

The Flight Operation Manual states that the commander of the Air Patrol Squadron approves aircraft flight procedures on the proposal of the Chief of Flight Operations. Flight procedures are divided into procedures pursuant to JAR-FC (Part I) and special procedures (Part II). The Air Patrol Squadron's flight procedure documents are classi-

fied. When it comes to tactical flight operations, shortcomings were discovered in flight procedure regulations. The operator was informed of this during the course of the investigation.

### **Flight training**

The Border Guard's AB412 pilot training is divided into type rating training as per JAR-FCL2, the Border Guard's special air operations training as well as periodic recurring training. For the most part the special flight training syllabi focus on search and rescue missions. The syllabi do not provide any tactical flight training, *per se*.

### **Finnish Border Guard Standing Documents**

Among other things, the standing documents provide for the use of Border Guard aircraft, carriage of persons and rappelling training.

### **Flight Safety**

The Flight Operation Manual as well as the Maintenance and Repair Shop Manual provide for the internal supervision of the Border Guard's flight operations. The Flight Operation Manual stipulates that internal supervision be conducted in accordance with Trafi's Aviation Regulation GEN M1-2.

The purpose of the Border Guard's flight safety management is to facilitate the safe and efficient conduct of missions, and to reduce the number and risk of air accidents and damage to aircraft.

The squadron commander, the Chief of Flight Operations, the Technical Manager and the Technical Inspector are responsible for flight safety management and monitoring.

The Chief of Flight Operations is responsible for improving and monitoring flight safety. In this capacity he is assisted by the chief of flight safety, to whom the flight safety organisation reports.

According to the Rules of Procedure, flight commanders are responsible for flight safety arrangements in their units.

Any incident which has affected flight safety or the conduct of the mission (e.g. malfunction or crew error) is reported as an occurrence into the TURVA safety reporting system. The Air Patrol Squadron's flight safety organisation regularly processes said reports. In addition, accidents, serious incidents and occurrences are reported in accordance with Aviation Regulation GEN M1-4.

The interviews established that only a few reports in relation to annual flight hours were entered into the TURVA system. Occurrence processing was found to be unsatisfactory.

The Air Patrol Squadron does not use standardised risk assessment methods, nor are flight-specific risk assessments implemented.



## Cooperation between the authorities

The Counter Terrorist Unit (CTU) of the Finnish Police carries out its training together with the operator. Apart from flight operations-related training for safety and joint operations, which are the responsibility of the operator, the Helsinki Police Department CTU unit is responsible for the rappelling equipment and the training of its personnel. The relevant documents are classified. Shortcomings were discovered in guidelines related to cooperation and procedures, of which the operator and the police were informed during the course of the investigation.

### 1.18 Supplementary information

#### 1.18.1 A helicopter's general aerodynamic features

The following information is derived from the FAA's *Rotorcraft Flying Handbook* (FAA-H-8083-21, 2000) and from the book *Helicopter Theory* (Raunio, 1989).

##### The effect of the main rotor RPM

The main rotor thrust greatly depends on the main rotor RPM. For example, a 5% decrease in rotor RPM translates into an approximately 10% decrease of thrust.

A low RPM reduces the velocity of the downward airstream that passes through the rotor (the downwash).

##### Ground effect

When a helicopter hovers close to the ground the power needed to generate the required thrust is smaller compared that of hovering at a higher altitude. This happens because the surface prevents free airflow. This effect ceases in practice at one rotor diameter above the surface. The ground effect also restricts the generation of blade tip vortices compared to out-of-ground-effect hover. The increase in thrust, at maximum, is approximately 15% in ground effect.

##### Main rotor Vortex Ring State

When the airspeed is low (below 20 kts), the engine power is between 20-100% and the rate of descent exceeds 300 ft/min, there exists the risk of the main rotor entering a Vortex Ring State<sup>5</sup> (VRS, figure 10). In a normal hover the helicopter is able to remain stationary by propelling a large mass of air down through the main rotor. Some of the air is recirculated near the tips of the blades, known as tip vortices. As the sink rate increases the airflow of the inner blade sections becomes upward relative to the disc. The upward airflow from the inner blade sections then re-enters the outer disk, which generates a secondary vortex ring about the point on the blade where the airflow changes from up to down. If allowed to develop, both vortices intensify which results in loss of thrust and a so-called vortex ring state.

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<sup>5</sup> The literature also refers to this phenomenon as *settling with power* (SwP) or *power settling* (PS).



In a vortex ring state the helicopter descends inside self-induced turbulence at the rate of 750-2300 ft/min.

This state can occur, for example, during steep approaches with a limited power reserve (heavy aircraft) or when turning into a tailwind at low airspeed. In addition, a so-called quick-stop type manoeuvre into the tailwind may result in a VRS.

It is not normally possible to recover from a VRS by raising the collective, as this only makes the situation worse. Recovery must be carried out as in airplane stall recovery - by increasing the forward airspeed (reduce collective, apply forward cyclic).

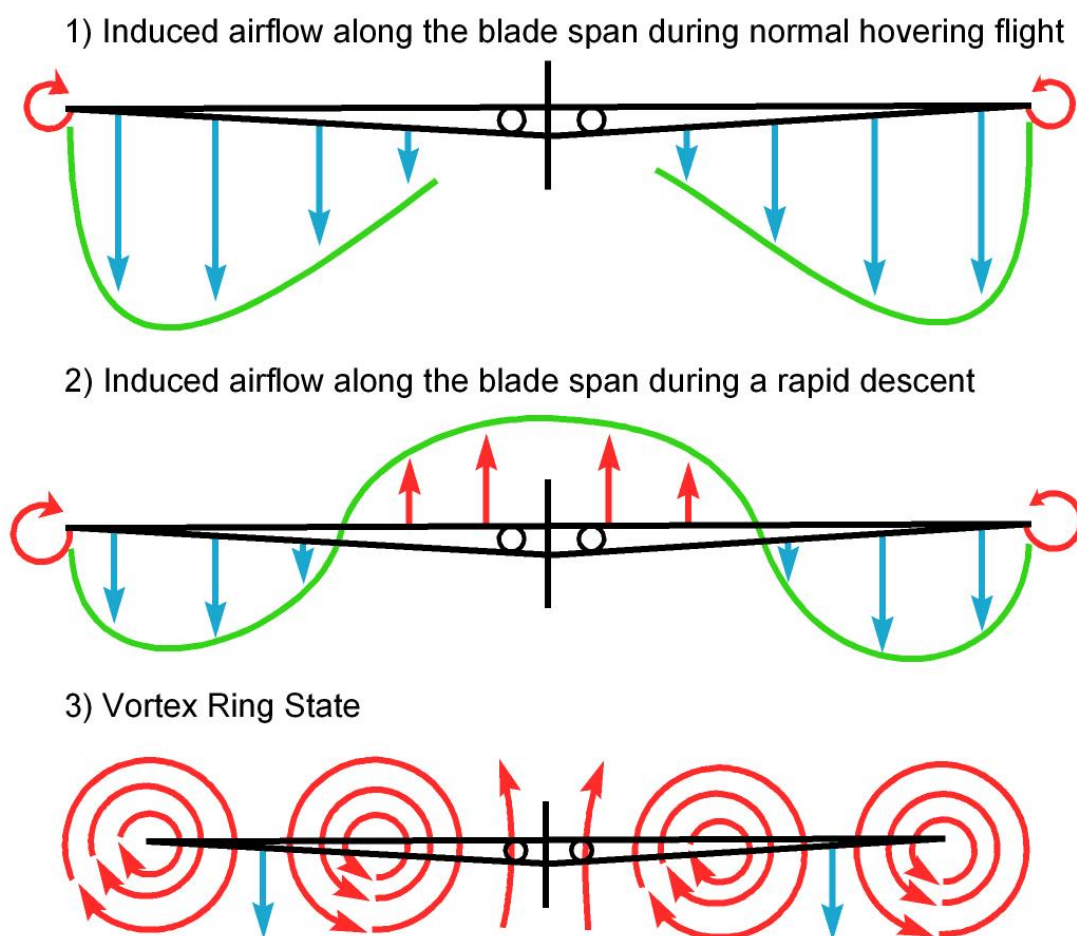


Figure 10. Vortex Ring State.

### 1.18.2 Previous similar occurrences

In 2003 an accident occurred in Karlsborg, Sweden, when an Agusta Bell 412HP, on a SAR training mission, ended up in a vortex ring state. The helicopter collided with the ice and sank to the bottom of Lake Bottensjö. The Swedish accident investigation authority, *Statens haverikommission*, published investigation report RM 2005:01e on this accident.

### 1.18.3 Reporting

After the accident the persons at the site thought that there was no need for an ambulance because nobody was seriously injured. Since there was no fuel leak nor any risk of further damage, they did not report the accident to the Emergency Response Centre.

After the accident a civilian arrived at the site by motor scooter. The police officers at the site questioned his ability to operate a motor vehicle. The leader of the exercise called the Porvoo field commander directly and asked him to send a police patrol to investigate the case. At 13:05 the police unit that acknowledged the task reported a nondispatched mission to the ERC. Their radio call also included information about a ‘crashed helicopter’. Since the police reported that there were no injured persons at the location, nor any need for a rescue operation, the ERC did not take any further action.

The helicopter’s co-pilot reported a ‘hard landing’ to Malmi tower. The air traffic controller did not report the occurrence to Aeronautical Rescue Co-ordination Centre Finland (ARCC), to the aviation authority or to the Accident Investigation Board of Finland. The investigation commission later learned that Finavia Oyj handled the matter as a (quality) nonconformity.

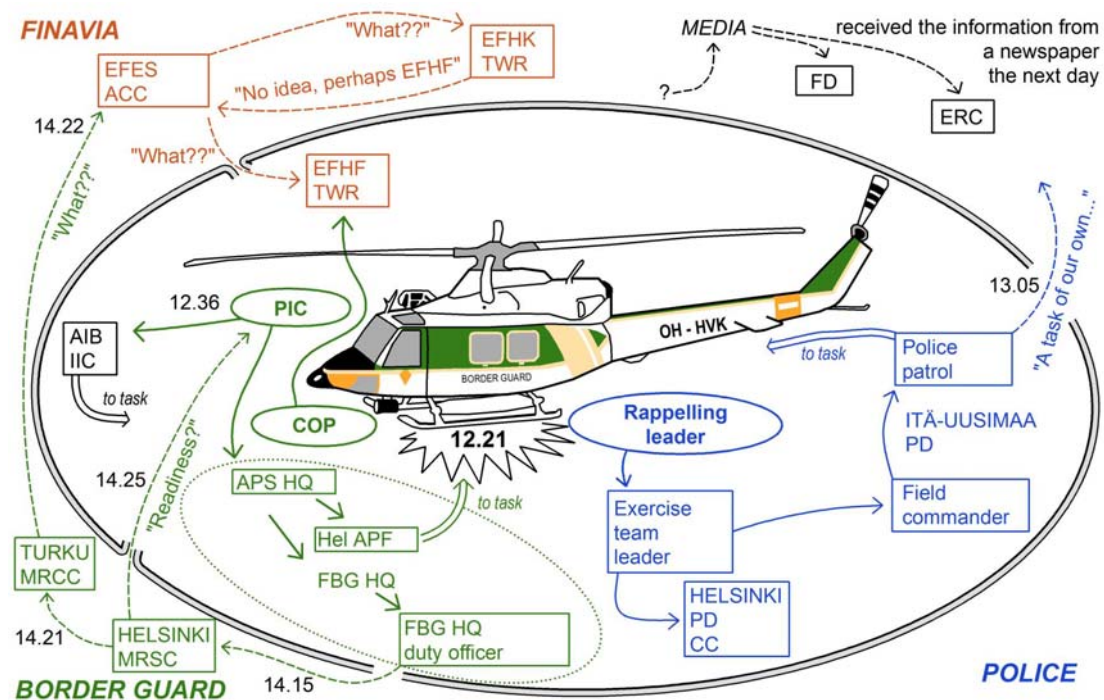


Figure 11. The flow of information following the accident. The flow of information between the police is shown in blue, the Border Guard in green and Finavia in brown, respectively.



Both the helicopter's PIC and the flight engineer reported the occurrence to their respective superiors. Within the Finnish Border Guard Headquarters the information reached the Gulf of Finland Coast Guard command centre at 14:15 when the HQ duty officer relayed the information to them. At 14:15, once confirming phone calls had been made, the command centre realised that the accident helicopter was no longer airworthy or its crew able to act as the maritime SAR duty aircrew.

The police officer who acted as the leader of the exercise reported the occurrence to the Helsinki Police Department command centre.

The PIC's report as per Aviation Regulation GEN M1-4 (accidents, serious incidents and occurrences) was dated 15 Jun 2009. The Regulation states that *the air operator shall submit such a report to the Finnish Civil Aviation Authority (Trafi Aviation at present) without delay.*

The operator's internal TURVA-system occurrence report was dated 10 Nov 2009.

## **1.19 Investigation methods**

### **1.19.1 Merging the recorded data**

The investigation merged data from the Digital Flight Data Recorder (DFDR) and the Police Field Command System (POKE). The Flight Test Center of the Finnish Air Force Materiel Command merged the CVR data with positional information and created a map-based animation of the flight. A 3D animation of the events was generated by using parameters converted from DFDR information and CVR recordings as well as positional data from the GPS-based POKE system.

The animation was created with Insight Animation<sup>®</sup> v.3.0 and Insight Analysis<sup>®</sup> v.3.0 programs. Rotating the view of the animation was made possible by the Insight View<sup>®</sup> program. One of the animations shows the event from the viewpoint of the leader of the exercise who witnessed the accident.

In its analysis the investigation commission used the Flight Test Center's graphs that depict the parameters.

There was variance between POKE GPS data and DFDR altitude data. Since the reliability of POKE GPS altitude information was not exactly known, the animation and the analysis used the aircraft's DFDR altitude information combined with POKE positional data.

### 1.19.2 Task analysis

The piloting task was analysed using hierarchical task analysis (HTA)<sup>6</sup>. The goal was to describe the structure of the task, its sub-tasks or goals as well as the requisite performance, particularly with regard to the pilot flying (PF). The analysis was limited to the final part of the flight, the goal of which was to deplane the CTU unit into the terrain.

Following the HTA, the cognitive demands of the tasks were assessed within the framework of the multiple resources model.<sup>7, 8</sup> The model facilitates, particularly, the theoretical analysis of the cognitive workload related to task interference while performing simultaneous tasks.

The task analysis was implemented in the cockpit on the ground with a Bell 412EP pilot from the Air Patrol Squadron demonstrating the procedures that were to be completed as per the Flight Operation Manual and flight procedures on a similar flight. Following this, a re-enactment was flown to the accident site. The pre-flight briefing, the pilot interview and cockpit operations during the flight re-enactment were videotaped. The pilot later specified the structure of the piloting task and the information processing requirements via the videotape.

A similar task description was later made of the accident flight. The depiction was based on crew interviews as well as information derived from DFDR and CVR recordings. By comparing the task analyses it was possible to demonstrate, among other things, non-standard or omitted procedures and to analyse their role in the accident. The task analysis, including illustrations, is presented in the analysis section of the investigation report.

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<sup>6</sup> Shepherd, A (2002). *Hierarchical task analysis*. London: Taylor & Francis.

<sup>7</sup> Wickens, C. D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, 3, pp. 159–177.

<sup>8</sup> Wickens, C. D. & McCarley, J. S. (2008). *Applied attention theory*. Boca Raton: CRC Press.

## 2 ANALYSIS

No technical fault or malfunction was found in the helicopter or its equipment. The helicopter was airworthy. Its weight and centre of gravity were within the permissible range. The aircrew had valid ratings and sufficient experience. The conditions were suitable for the mission. The functioning of air traffic control had no bearing on the accident.

The analysis concentrates on the aircrew's immediate actions and, especially, contributing task, environmental and organisational factors. The analysis utilises the James Reason model on managing human and organisational factors that affect the onset of accidents.

### 2.1 Flight profile

The swift evolution of the exercise's tactical situation generated the need to rapidly land in front of the target. The approach profile that was used resulted in deceleration too close to the landing site. Counterproductive factors included the relatively heavy (ca. 5,050 kg) helicopter, the longitudinal tailwind in the direction of the landing, which the investigation commission believes prevailed, as well as the rotor RPMs which were set to cruise power.

Wind direction was turning from north to east to southeast during the flight. This being the case, the investigation commission estimates that the final approach occurred in a tailwind. The aircrew did not notice the altered wind direction during the mission.

In order to reduce airspeed for the final approach the pilot flying (PF) lowered the collective and simultaneously applied aft cyclic. The turn into the final approach heading further increased the need for aft cyclic lest the helicopter's sink rate increase. These control inputs resulted in an increase in main rotor RPM and a high RPM warning (104.5%).

After the high RPM warning the PF continued to decelerate and descend while simultaneously continuing the turn. The collective was still almost in the full down position. Standard immediate action following a high RPM warning includes raising the collective and/or easing up on the cyclic, which results in lowering the rotor RPM. When it comes to the accident flight, had the pilot raised the collective more and applied a little less aft cyclic, they would have had insufficient airspeed and altitude for a successful landing. They could have prevented the accident by aborting the approach and going around for a new landing.

When the helicopter was rolled 37 degrees to the right the rotor downwash became diagonal, which did not fully generate the desired aerodynamic deceleration.

When airspeed decreased, rotor RPM also began to decrease. Raising the collective after this increased rotor drag, further reducing rotor RPM before the engines spooled up and began to generate power. Three seconds after the collective was raised a low RPM warning (95 %) was activated, at which time the raising of the collective was momentarily paused. At that time the helicopter had been rolled 20 degrees to the right,

flying at the approximate altitude of 100 ft at 15 kts. The sink rate at the time was 530 ft/min. Since the helicopter nearly stopped above the ground effect the positive features of flying in ground effect (less power required, smaller tip vortices) were not achieved. The rapidly increasing main rotor torque also required more power for the tail rotor, thus increasing the total power requirement.

As the bank angle and airspeed were decreasing the helicopter was in a situation in which

- Airspeed was below 15 kts
- Approximately 80% of the power (torque) was in use
- The sink rate exceeded 500 ft/min
- The wind was a tailwind
- The main rotor RPM was low (below 95%)

The main rotor was entering into a developing vortex ring state (VRS). Raising the collective did not stop the helicopter from sinking - on the contrary. The maximum sink rate was approximately 1100 ft/min. The helicopter collided with the ground approximately four seconds after the low RPM warning.

The immediate corrective action in a VRS is to lower the collective and to apply forward cyclic. This increases forward airspeed and directs the downwash behind the helicopter. Because of the low altitude and the trees in the direction of the landing this was not possible.

By applying forward cyclic approximately two seconds before the crash the pilot straightened out the helicopter to the extent that it collided with the ground in a nearly optimal position for minimising damage.

## **2.2 Main rotor RPM analysis**

On the accident flight the main rotor (NR) RPM was not set at 103%, the CAT A approach setting that the Rotorcraft Flight Manual (RFM) allows. According to DFDR data (figure 12) the RPM was set at 98.5%, which means that not all of the rotor's thrust was being used. The low rotor RPM (below 95%) during the landing, and hence weaker rotor downwash, exposed the main rotor to a vortex ring state.

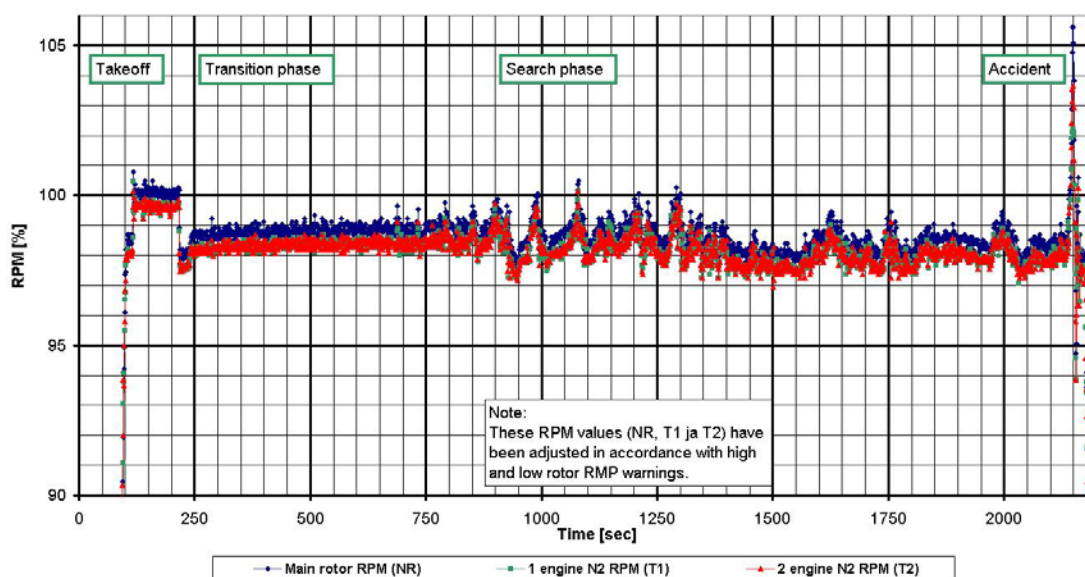


Figure 12. Main rotor RPM during the accident flight.

### 2.3 Engine torque analysis

During the complementary interview the helicopter's pilot-in-command brought up his observation pertaining to the large mutual variance in engine torque during the landing. He said that this was the reason why he momentarily stopped raising the collective. The interviews at the accident site did not produce any information as regards a malfunction or a technical fault. Everything was said to have functioned properly.

Since the investigation commission was unaware of any possible malfunction before the powerplants and the power governors were disassembled, no test runs were conducted. Nor did the DFDR data point towards the need to carry out any further tests. Overhaul reports did not find anything out of the ordinary.

In its analysis the investigation commission came to the following conclusions:

- The collective was raised from nearly the bottom position and was paused when the main rotor low RPM warning (aural warning) was activated. Once the RPM increased the collective was again raised (Cf. figure 3, flight control positions).
- The possible variance between engine torques was fleeting, which is typical when engines are rapidly spooling up from minimum power. The variance was caused by the normal difference in engine RPM increase. The possible higher power setting on engine No. 2 during the flight may have increased the reactions of engine No. 1 to different power settings. The engines generated torque just like they did during the earlier phases of the flight.
- The torque difference between the engines after the collective's raising was paused, as shown in figure 13, is the result of the pause itself as well as considerable changes in main rotor drag caused by the vortex ring state.



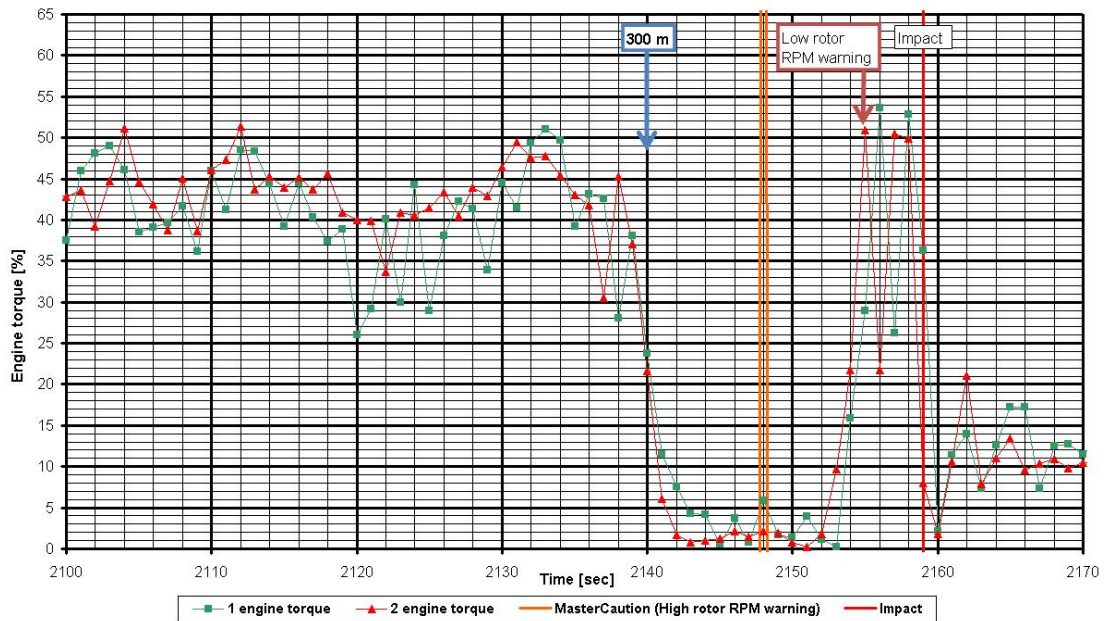


Figure 13. Engine torque during the final minute of the flight.

The investigation commission believes that the torque difference was not abnormally high before the low RPM warning sounded and when the raising of the collective was paused, nor did it have any bearing on the accident.

## 2.4 Task and environmental factors

### 2.4.1 The perceptual environment at the landing site

The perceptual environment at the landing site, such as the visual details of the terrain and lighting conditions, affect the pilot's perception of the aircraft's state of flight. When flying in good VMC conditions an experienced pilot gauges altitude (distance) and air-speed from visual environmental cues rather than from his instruments in the cockpit. The interpretation that is based on perceptual cues from the outside environment is relatively automatic and unconscious. Prior experience in a familiar setting supports the perception process, which reduces the probability of error in perception. Then again, a person is more prone to erroneous interpretations in unfamiliar surroundings.

**The perception of distance** is based on visual cues from the environment. These include, among other things, the familiar or relative size of objects, the textural gradients of the surface as well as their scale of detail. For example, objects are perceived to be farther when the objects are smaller than normal or when their details are difficult to see. Moreover, dark objects are perceived to be smaller or farther than their immediate surroundings.

**Speed perception** is based on the perceptual cues related to surrounding objects, texture and, especially, their relative motion. It is more difficult to visually estimate speed when surface textures (such as the details of the terrain below) are barely discernible or in small supply. For example, it is more difficult to visually estimate airspeed when flying



at a high altitude compared to flight at a low altitude. In the latter case the texture of the terrain as well as its relative motion (e.g. trees below or around) is easier to discern.

Whereas the perception of egocentric motion normally occurs in the peripheral visual field, a perception of detailed distance cues demands foveal vision, in other words fixating on the target (such as a landing site or obstacle). Since a helicopter pilot in a corresponding terrain landing must process several sources of information and perform visual scanning from one target to another (landing site, obstacles, the person to be apprehended, cockpit instruments), the approach speed becomes an important factor as regards time sharing and attention shifting between tasks. The greater the approach speed, the more the environmental perception changes while the pilot is focusing elsewhere. When changes in distance and detail are larger between the so-called visual samples, the inaccuracy of perception increases, which may result in overlooking critical distance cues.

**The landing site**, including its perceptual environment (figure 14) that was selected for deplaning the team was unfamiliar to the aircrew. Trees of varying height surrounded the landing area. There was a clearing to the north of the area, straight ahead in the helicopter's approach heading. Dark coniferous woods grew behind the clearing. The trees in the clearing were substantially lower than the other trees. They were for the most part deciduous trees and, due to the season, their small leaves made them more difficult to discern against the terrain. From a distance the pilot may have interpreted the low and difficult-to-discern deciduous trees as being farther away than they actually were. Evergreen trees that are much darker than their surroundings can also create the same impression.

The approach occurred over a field which gradually rose towards the landing site. The ploughed field's surface had dried and become lighter in the spring sunshine. The dry, light surface reflected the rays of the sun more intensely than its surroundings. This made it more difficult to detect the contour of the surface and the details, especially from a higher altitude (Cf. figure 5). The road at the northern edge of the field was clearly visible against the backdrop of the clearing. This kind of clearly noticeable visual shape or outline may prompt the observer to believe that its surroundings, too, follow the same shape or outline. During the flight re-enactment the pilots noticed that they could not distinguish the gently undulating surface of the field from a higher altitude. The contours of the surface were only discernible when the helicopter was flying down on the deck.

Nevertheless, the landing site and its perceptual environment were suitable for a helicopter terrain landing. The aforementioned visual environment would have permitted a safe landing. The approach speed may have contributed to the insufficient perception of visual cues from the terrain and the surroundings.



Figure 14. View of the landing area. The helicopter's flight path traversed the field from the bottom right of the photo turning along the left side of the field towards the landing site. (Photo: Border Guard)

#### 2.4.2 Cognitive task demands

The cognitive demands of the piloting task were assessed in more detail by analysing the structure of the task using hierarchical task analysis. Following this, the cognitive demands were assessed using the multiple resources model as a theoretical frame.

The task analysis was done by adopting a baseline which was a depiction of the actions of the pilot flying on a corresponding mission flown in accordance with the Flight Operation Manual and flight procedures (figure 15). The analysis was limited to the final stage of the mission where the overall goal was to deplane the passengers, i.e. the CTU unit, into the terrain after the pilot made a preliminary selection of the landing site and the approach began. The overall goal was divided into smaller subgoals. The key subgoals as regards the accident were further divided into more detailed sub-goals. The hierarchical description also expressed which goals required constant attention and which of the goals were to be simultaneously implemented.

Hard landing for helicopter in Porvoo on 7 May 2009

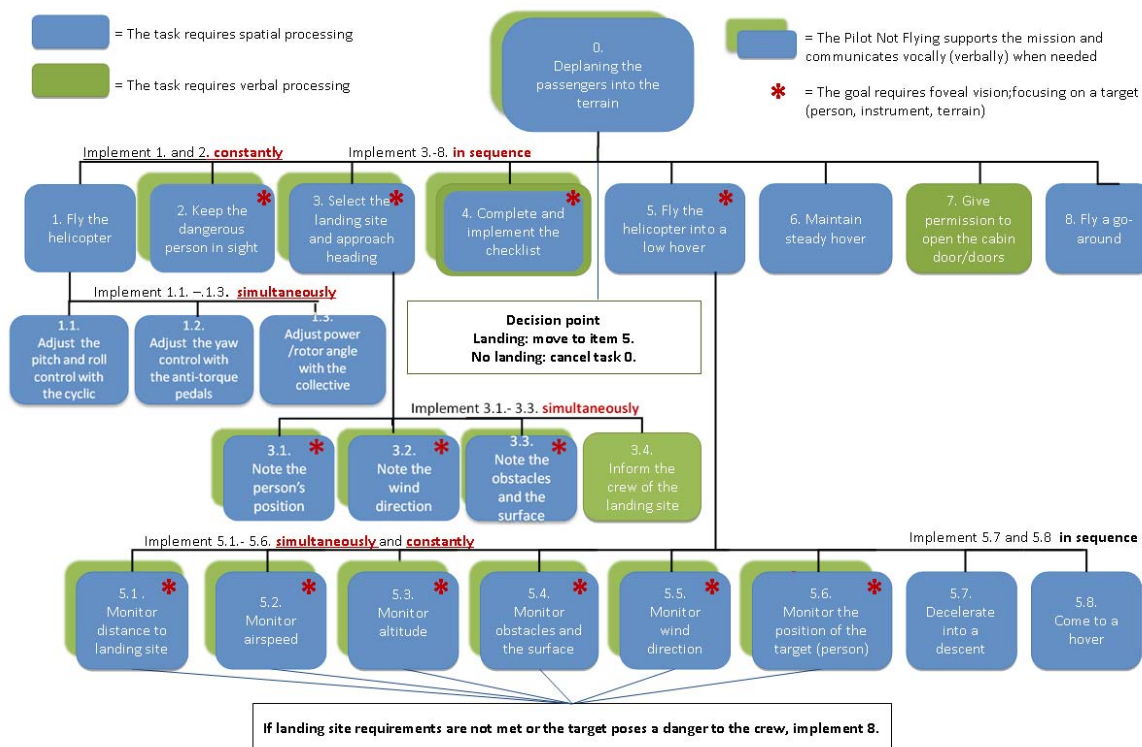


Figure 15. A hierarchical task analysis depicting the actions taken on a flight similar to the accident flight as per the Flight Operation Manual and flight procedures.

The task’s cognitive workload can be assessed through the requirement of simultaneous tasks and active control of information in the working memory. The multiple resource model maintains that simultaneous tasks and actions will increasingly interfere with one another if they require shared information processing resources. Correspondingly, if the sub-tasks utilise separate resources, they are less interruptive to one another. When tasks must ‘compete’ for the very same processing and perceptual resources, the cognitive workload increases. This may emerge as imprecise action, an increase in errors or the omission of procedures.

The resources of human information processing can roughly be divided into verbal and spatial processes or codes. In figure 15 the sub-tasks that mainly utilise the spatial resources are shown in blue. Verbal tasks are shown in green. Communication related to Multi Crew Co-operation, in which the pilot not flying (PNF) supports the PF by monitoring the same sources of information and communicates vocally (verbally) is shown as a green shadow in the relevant sub-tasks.

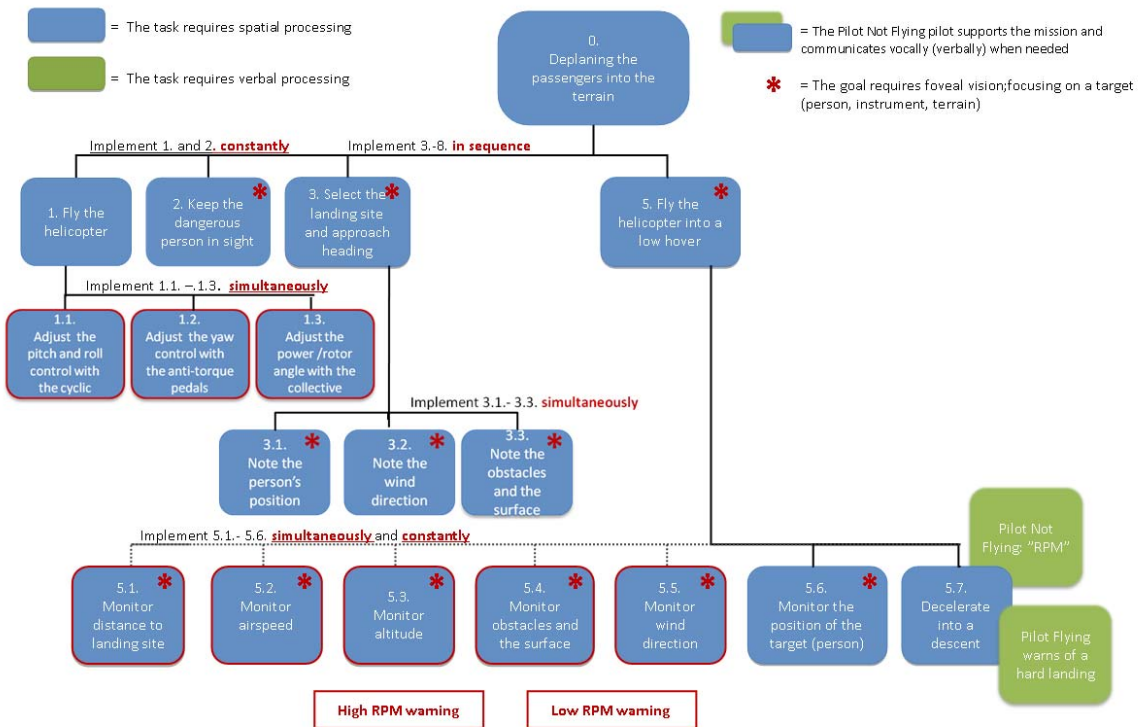


Figure16. A hierarchical task analysis of the actions taken during the actual flight.

According to the multiple resources model task concurrency alone cannot predict workload. The state of processing also creates its own resource. The more the task requires cognitive control and active processing in the working memory, the higher the cognitive workload. A demanding task that occupies a human being’s limited attentional and working memory resources is more difficult to combine with other concurrent tasks. In contrast, a task that only demands little cognitive and attentional control is easier to combine with other tasks. These tasks include, for example, simple response selection or well-learned (nearly or completely automatic) skills.

Experienced pilots can fly helicopters in good conditions without paying much attention to the task. Activity can be carried out quite automatically (implicitly), combining visual information with proprioceptive sensory information. An experienced pilot does not have to actively control flying *per se*, nor its detailed subgoals. This is why it is possible to combine basic flying manoeuvres with, for example, a visual search over the terrain without inducing any marked change in the workload level. This, however, may inadvertently result in the pilot transferring his focus away from flying the helicopter.

Perceptual modality (visual vs auditory) also creates its own information processing-limiting resource. If simultaneous tasks require perception through shared sensory modality, the tasks interfere with one another. Among other things, visual perception is limited by foveal vision, the centre of the retina specialised for detailed vision. The size of foveal vision is only two degrees of the visual field. This means that the area of high visual acuity is only about two degrees around the location where eyes are fixating at a

given time. Outside the field of foveal vision, peripheral vision can only distinguish blurred shapes and motion.

The human experience of visual perception that covers the entire field of vision is an illusion, derived from rapid eye movement and transition within the field of vision. When fixating on a target the detailed perception of targets in the peripheral field of vision is largely memory-based. Monitoring several visual targets concurrently requires active visual scanning and switching between the targets. The more targets and the wider apart they are from one another, the more time-sharing and attentional resources they require.

The task analysis (figure 15) shows that the piloting task requires mostly visuospatial processing. The task load is created from multiple concurrent spatial tasks which in addition require using a shared sensory modality (vision) for perception. Especially in item (sub-task) 5, in which the goal is to come to a low hover, several visual sources of information need to be simultaneously monitored. Furthermore, the targets' visuospatial features (e.g. location, direction, distance, size, shape and visual details) change during the course of the approach. The demands only increase when the landing site and visual conditions are unfamiliar. Since perception requires sequential monitoring of the environment, the time allotted to the task is a significant factor as regards time-sharing and workload.

The relationship between the aforementioned cognitive factors to the events on the accident flight were assessed by preparing a corresponding depiction of the accident flight (figure 16). The description was based on crew interviews as well as DFDR and CVR data. The flight profile analysis notes that deceleration was initiated too late. This infers human error when it comes to estimating the helicopter's state of flight and visual cues regarding the distance of the landing site (figure 16, items 5.1-5.6).

When the PF called 'prepare to deplane' the helicopter was flying at approximately 300 ft and more than 800 m from the landing site (table 1). Still, the pilot had not made visual contact with the final landing site because it was beyond a spit of trees. Judging by the helicopter's track, they saw the landing site approximately ten seconds later. The procedures described in the task analysis (figure 16) can be considered to have begun at this point in time. Distance to the landing site was 300 m, altitude was approximately 260 m and airspeed in excess of 100 kts. During the final five seconds of flight the helicopter's flight path and position obscured the pilot's view to the landing site, at least partly. The site remained outside the pilot's field of view, under the bottom of the helicopter, while he was turning to the right and decelerating by raising the nose. This being the case the pilot only saw the landing site for approximately 15 seconds. During this time the helicopter flew from a 300 m distance towards the landing site at the average airspeed of 75 kts. The time available for the task was extremely short considering the requirements of vision and visual perception (figure 15) as well as the rapidly changing perceptual conditions caused by the approach speed.

Judging by the cockpit voice recording (CVR) both the pilot flying (PF) and the pilot not flying (PNF) actively engaged in the search of the target person as well as related dis-

cussions during the entire flight. Since search for dangerous persons was the entire exercise’s primary goal, this may have resulted in the search also becoming a primary goal for the pilot’s attentiveness.

During the search mission when the experienced pilots did not need to pay much attention to basic flying, the pilots mostly focused their attention on the terrain and the target. The interviews also established that the time pressure to land in front of the fugitives before they would disappear in the woods also influenced the selection of the landing profile and the landing site. Had they lost their target into the woods the mission would not have been accomplished. The subjectively felt pressure to successfully land the CTU team at the right moment may have inadvertently resulted in failing to adequately transfer the pilots’ attention back to the piloting task as the demands of the flight kept increasing.

Table 1. The helicopter’s state of flight, key events and the pilot’s estimated view to the landing site during the final 30 seconds.

Time to accident [s]	Helicopter			Event	The pilot’s estimated visual contact with the landing site
	Height [ft]	Straight distance to landing site [m]	Airspeed [kts]		
-30	300	850	70	"...prepare to deplane!"	No visual contact with the landing site
-28			...		
-26			<i>accelerating (70 → 107 kts),</i>		
-24	280	550	<i>average air-speed 90 kts</i>		
-22			...		
-20			107		
-18	260	260	107	<b>High RPM warning</b>	Visual contact with the landing site
-16			...		
-14			<i>decelerating (107 → 20 kts),</i>		
-12	190	100	<i>average air-speed 75 kts</i>		
-10			...		
-8			20		
-6			...	<b>Low RPM warning</b>	Visual contact with the landing site partly obscured by the bottom of the helicopter
-4			14		
-2			0		
0			0		

The accident flight’s task description revealed differences between the procedures of the Flight Operation Manual and flight procedures. **Multi Crew Co-operation** did not include





the pre-landing procedures as per regulation, such as the completion of landing checklists and informing the crew of the decision point.

Flight procedures oblige the PNF to support the PF by monitoring the instruments and the state of flight as well as be aware of the aircraft's position and the flight procedures to be used. CVR recordings show that the only communication between the pilots during the approach was the PNF's call regarding the high RPM warning. This indicates that the PNF was monitoring the instruments during the approach. Conversely, communication related to the flight procedure, flight profile, the location of the landing site or the decision point never ensued. This being the case, the PNF's conception of the planned approach profile and the landing site was based on assumption. This makes it more difficult for the PNF to anticipate changes in the helicopter's state of flight, to estimate the conditions at the landing site (including obstacles and wind direction) in relation to the helicopter's state of flight, or to provide relevant information at the correct time.

Apart from checklists, there are no detailed instructions for crew cooperation and relevant communication with regard to tactical terrain landings. During the mission briefing for task analysis it became apparent that on a search mission into the terrain the checklist and relevant procedures may be completed earlier, when the active search phase begins. This is so because the need to deplane the CTU team can arise so suddenly that the checklist being completed before the decision to land is made speeds up the operation. Still, this procedure is not standardised, nor do any guidelines for it exist.

No detailed instructions exist for the **cooperation** or related communication within the **exercise team**, i.e. the helicopter crew and the CTU team pertaining to tactical air operations. Procedures have evolved out of lessons learned from exercises.

The PF is responsible for the safe conduct of flight, including decisions related to tactical flying. The PF maintains radio contact with the CTU team's leader and/or the police ground units and, piloting duties permitting, actively participates in the search of the persons to be apprehended. In addition, the PF must remain aware of the dangerous person's position during a landing into the terrain. This is achieved by the PF attempting to monitor the position of the target during the demanding landing process. The PF also assigns tasks to the PNF, such as completion of checklists, and informs the cabin with regard to tactical measures. He also gives permission to open the cabin doors during the landing or while in hover.

During the search flight the CTU unit and the crew mainly communicate by shouting, as the intercom is not available to all team members. As an example, everyone did not hear the call for the hard landing. The interviews also established that the exercise team had differing notions regarding the permission to unbuckle themselves or when the cabin door was to be opened. Neither did all exercise team members agree on whether the helicopter was supposed to come to a hover or land on the ground.

The unpredictability of tactical flight operations is a factor which makes it more difficult to standardise crew cooperation. Nonetheless, standard operating procedures in a given situation or phase of a mission make it easier to remember to complete tasks, thereby reducing the mental workload during the mission. The situation at hand and the phase of the mission act as reminders. If the task or the moment it is to be implemented are not



standardised their execution relies more on memory. Tasks that need to be held in memory are more easily forgotten, especially in a high workload situation.

Rapidly developing situations and the subjective pressure to complete the mission in time are also typical features in tactical flight operations. Time constraints may result in reduced communication in order to control the mental workload. This, in turn, diminishes the chances of the other crew members, especially those of the PNF, to support the PF and share his cognitive workload. Hence, the task load is mainly carried by the PF, leaving the resources of the other crew members or the team untapped.

**The key factors of task and environmental demands related to the accident:**

- The crew was unfamiliar with the landing site and its perceptual environment.
- The piloting task comprises several simultaneous spatial tasks that require using a shared sensory modality (vision) (figure 15). The time allotted for the task becomes a key factor with regard to the mental workload.
- A subjective pressure to complete the mission in time is a typical feature in tactical flight operations. Subjective time pressure has a tendency to increase the mental workload. This probably resulted in deficient monitoring of the helicopter's state of flight and the environment and may also have resulted in the omission of completing the required flight procedures.
- The pilots' considerable flying experience made it possible for them to intensely pay attention to the terrain and the pursued target during the search phase of the mission. The aim of successfully completing the search mission may have inadvertently resulted in failing to adequately transfer the pilots' attention back to the piloting task as the demands of the flight increased.
- The method of crew cooperation which was used in this occurrence places the highest demands on the pilot flying who, in addition to landing in the terrain, actively participated in the monitoring of dangerous persons during the attention demanding landing phase.
- There are no detailed instructions for crew cooperation and relevant communication with regard to tactical air operations and landings in the terrain. The fact that cooperation between the members of the crew or the entire exercise team has not been standardised increased the taskload of the mission and decreased the possibilities of more evenly sharing the task demands between the crew and the CTU team.

## 2.5 Organisation and management

The Air Patrol Flight in Helsinki has mainly been responsible for developing the cooperation between the Air Patrol Squadron and the Helsinki Police Department's Counter Terrorist Unit. Tactical procedures and techniques have evolved from lessons learned throughout the years. Associated guidelines and training have not been updated to meet the present requirements.

Due to shortcomings in guidelines and training the procedures of the helicopter crew and the CTU unit are not standardised, which makes crew cooperation more difficult.

The existing guidelines are inadequate or inconsistent, among other things, regarding Multi Crew Co-operation, passenger seating and safety belt use as well as egress from the helicopter.

This has created an organisational culture in which activity may partly be implemented counter to regulations or by manipulating them. For example, members of the CTU team are given crew-like tasks without proper training or certification. Neither does the exemption granted to the Finnish Border Guard regarding the transport of dangerous goods by air (CAA Finland's decision 362/74/88) meet modern requirements.

The Border Guard's Flight Operation Manual provides for the Air Patrol Squadron's flight safety activity. Personnel can report any flight safety-related occurrences or nonconformities in the TURVA reporting system. Nevertheless, the interviews established that only a few reports in relation to annual flight hours were entered into the TURVA system. It is likely that occurrences are not actively reported. The processing of TURVA reports was considered to be inadequate and protracted. The flight safety organisation's post-holders pointed out that due to work pressure, flight safety issues that are carried out in addition to their normal duties have received less attention.

The investigation commission also considers the missing risk analyses of tactical air operations a shortcoming.

The investigation commission believes that by focusing on operational tasks, combined with limited occurrence reporting, safety monitoring and improvements do not materialise in the best possible manner.

## 2.6 Survival aspects

The helicopter's position and the forward motion at the moment of impact contributed to the landing gear attenuating the impact force as planned. The helicopter did not fall over, nor did the rotor blades make contact with the ground. The short skid marks (2 m) on the ploughed field and the fact that the flight engineer who was crouching and hooked to the safety rope stayed on his feet, indicate that the forward motion was almost zero at the time of the crash.

In addition to the flight engineer there were two persons in the cabin who were not seated. They were hooked to the floor anchor rope with safety harnesses that would not have offered any protection had the direction and the force of the impact been any different. Moreover, the interviews revealed that passengers in the cabin may unbuckle their seat belts even before the helicopter comes to a hover, which increases risks.

Since members of the CTU team were not connected to the intercom, they did not hear the PIC's call for the hard landing. Some of the CTU's members were unaware of the incident and, rather, were preparing for rapid egress from a hovering helicopter.

The aircrew did not have a checklist or anything similar for post-accident procedures. Still, they were sufficiently implemented.

The direction and force of the acceleration of the impact were such that the emergency locator transmitter did not activate.

On the accident flight no passenger list was made as per the Flight Operation Manual. Had the accident been more serious, the lack of a passenger list as well as the incorrect number of persons on board in the flight plan would have complicated the rescue operation.

## **2.7 Reporting**

The helicopter crew made the immediate reports in accordance with regulations. The verbiage of the report to Malmi tower was such that the air traffic controller did not pursue the situation any further. Finavia Oyj handled the information flow problem as a nonconformity (ePHI 000688).

The helicopter's pilot-in-command filed his written reports to CAA Finland (nowadays Trafi Aviation) and the operator's information systems with a delay.

### **3 CONCLUSIONS**

#### **3.1 Findings**

##### **The helicopter**

1. The helicopter's certification of airworthiness and certification of registration were valid.
2. The helicopter's weight and centre of gravity were in the permissible range.
3. The investigation found no such technical fault or malfunction in the helicopter that could have contributed to the onset of the accident.

##### **The crew**

4. The helicopter's crew had valid licences and relevant ratings for the mission. Their flying experience was sufficient.
5. The aircrew's work and rest periods complied with regulations.

##### **The accident flight**

6. Apart from the absence of a passenger list and the erroneous number of persons in the flight plan, the pre-flight briefing was completed in accordance with regulations.
7. The flight was flown in daylight VMC. The conditions were suitable for the mission.
8. The objective of the mission was to practice a search to detain armed persons in the terrain as an inter-agency exercise. It was a tactical exercise.
9. The pilot-in-command of the helicopter decided to deplane the team into the terrain in the front of the target. Since it was a rapidly developing situation, they were in a hurry.
10. They did not complete the landing checklist. The pilot flying did not inform the rest of the crew of the landing method he planned to use.
11. The main rotor RPM was not set to 103%, the CAT A approach setting that the Rotorcraft Flight Manual allows.
12. The approach speed was approximately 107 kts. The investigation commission estimates that the final approach occurred in a tailwind.
13. The flightcrew did not notice that the wind direction was turning from north to southeast during the flight.
14. The deceleration was initiated too late.



15. When the deceleration and descent began, the high RPM warning activated. The engines' freewheeling clutches disengaged for approximately five seconds.
16. The co-pilot informed the PIC of the high RPM warning by calling 'revolutions' (RPM). This was the only verbal communication between the pilots during the final approach.
17. The immediate corrective action after a high RPM warning would have resulted in an aborted landing. They could have prevented the accident by going around for a new landing.
18. The PIC continued the landing with the collective nearly in the down position, waiting for the airspeed to bleed off and the rotor RPM to diminish. This resulted in a delayed raising of the collective.
19. When the helicopter was rolled 37 degrees to the right the rotor downwash became diagonal, which did not fully generate the desired aerodynamic deceleration.
20. The raising of the collective increased the main rotor drag and also required more power for the tail rotor. The engines, set at minimum power, could not spool up in time to maintain the RPM.
21. The momentary pause in the raising of the collective returned the diminished rotor RPM.
22. The helicopter nearly stopped at out-of-ground-effect: its airspeed was below 15 kts, 80% of power (torque) was in use and the sink rate exceeded 500 ft/min.
23. Approximately four seconds before the crash the main rotor was entering into a developing vortex ring state. The rate of descent increased.
24. Approximately two seconds before the crash the pilot applied forward cyclic to straighten out the helicopter before colliding with the ground.
25. Approximately one second before the crash the pilot-in-command warned the passengers that they would make a hard landing. According to flight recorder data the helicopter collided with the ground at the approximate sink rate of 1100 ft/min.

#### **Task and environmental factors**

26. The crew was unfamiliar with the landing site and its perceptual environment
27. The piloting task comprises several simultaneous visuospatial tasks that require using a shared sensory modality (vision). The time allotted for the mission becomes a key factor with regard to the mental workload
28. The tactical situation involved the pressure to reach the target in time and complete the mission. A subjective time pressure has a tendency to increase the mental workload. This may have contributed to deficient monitoring of the helicopter's

state of flight and the environment as well as in the omission of completing the required flight procedures.

29. While paying intense attention to the tactical mission, the pilots may have inadvertently failed to adequately transfer their attention back to the piloting task when the demands of the flight increased due to landing.
30. There are no detailed instructions for crew cooperation and relevant communication with regard to tactical air operations and landings in the terrain.
31. The lack of standardised procedures increases the taskload of the mission and decreases the possibilities of more evenly sharing the task demands between the crew and the team.

### **Organisation and management**

32. The investigation commission noted that Flight Operation Manual regulations were binding when the activity of the aircrew was being assessed.
33. The accident flight was part of the operator's special air operations, regulated through the operator's guidelines. The guidelines do not provide instructions for tactical flight operations.
34. The procedures and techniques used on the accident flight were not recorded or standardised. Rather, they have evolved from lessons learned throughout the years.
35. There are no guidelines for helicopter crew and CTU team cooperation. The investigation commission regards the exercise team as passengers, albeit assigned with tasks during the flight.
36. The CTU team was not positioned in the cabin as per the Flight Operation Manual's regulations regarding passenger seats and safety belts.
37. The exemption granted to the Finnish Border Guard regarding the transport of dangerous goods by air (CAA Finland's decision 362/74/88) does not meet modern requirements.
38. The Air Patrol Squadron does not use standardised risk assessment methods, nor are flight-specific risk assessments implemented.
39. Personnel can report any flight safety-related occurrences or nonconformities to the TURVA reporting system. Shortcomings were noted in occurrence recording and processing.
40. The investigation commission believes that limited occurrence reporting has resulted in a situation in which safety monitoring and improvements do not materialise in the best possible manner.



### **Survival aspects**

41. The helicopter collided with the ground in the nearly optimal position as regards minimising the damage.
42. Two of the passengers and the flight engineer were not seated. Instead, they were only hooked to safety harnesses.
43. Not everyone heard the PIC's call for the hard landing because the intercom was not available to all team members.

### **3.2 Probable causes and contributing factors**

The cause of the accident was the helicopter's main rotor entering into a developing vortex ring state during landing in conditions that prevented any further corrective actions.

Contributing factors included

- A high approach speed and the late reduction of airspeed combined with sizeable power setting changes with a heavily laden helicopter,
- Inadequate Multi Crew Co-operation, for example, as regards checklists as well as airspeed, altitude, sink rate and wind direction monitoring,
- Deficient monitoring of the helicopter's state of flight and the unfamiliar landing site while focusing on the tactical mission, and
- Deficient standard operating procedures and guidelines for this particular type of task.

## **4 SAFETY RECOMMENDATIONS**

### **4.1 Safety actions already implemented**

The Air Patrol Squadron has begun to update their flight procedures. Some of the AB/B412 flight procedures have been updated and the preliminary AW119 Ke flight procedures will take note of the shortcomings established in the investigation.

The special air operations syllabus for the new helicopter type (AW119 Ke) will include tactical flight training as a new entity.

The Air Patrol Squadron has honed its flight safety organisation compared to the time before the accident. Among other things, reporting-related training and instructions have been improved.

Flight-related risk management training has been provided to all units of the Air Patrol Squadron.

### **4.2 Safety recommendations**

#### **To the Finnish Border Guard**

The Finnish Border Guard's statutory tasks require flight operations in nonstandard situations and demanding conditions, and special tasks carry more risks than normal flight operations. The Air Patrol Squadron is responsible for carrying out the Border Guard's flight operations, including special air operations related to cooperation with the authorities

1. Tactical procedures and techniques in the Air Patrol Squadron have evolved from lessons learned throughout the years. Associated guidelines and training have not been updated to meet the present requirements. The existing guidelines are inadequate or inconsistent, among other things, regarding Multi Crew Co-operation, passenger seating and safety belt use as well as egress from the helicopter. Members of the CTU team have been used in crew-like tasks. Due to shortcomings in guidelines and training crew procedures have not been standardised. This complicates crew cooperation.

*The investigation commission recommends that the Air Patrol Squadron review their flight procedures and training syllabi as regards the observed shortcomings. Special attention should be given to Multi Crew Co-operation-related monitoring techniques.*





2. Tactical flight operations are often conducted in nonstandard situations and demanding conditions. For example, landings are often made in unfamiliar sites. The risk for factors resulting in a vortex ring state increases.

*The investigation commission recommends that the Air Patrol Squadron improve their pilots' awareness of the risks of the vortex ring state as well as associated corrective actions.*

3. The Flight Operation Manual provides for the Air Patrol Squadron's flight safety activity. Personnel can report any flight safety-related occurrences or nonconformities in the TURVA reporting system. The interviews established that only a few reports in relation to annual flight hours were entered into the TURVA system. In addition, shortcomings were noted in occurrence recording and processing.

*The investigation commission recommends that the Air Patrol Squadron, so as to improve flight safety, analyse and consider the applicability of the ICAO's Safety Management System (SMS) in their operations.*

4. The Finnish Border Guard has an exemption for transporting dangerous goods by air (CAA Finland's decision 362/74/88). When it comes to operational flights the investigation noted that neither the content of the decision nor the regulations in the Flight Operation Manual meet modern requirements.

*The investigation commission recommends that the Finnish Border Guard specify their requirements for the transport of dangerous goods by air as regards their operational duties. Following this, the Border Guard should re-validate the relevant permits and modernise the regulations.*

#### **4.3 Other remarks and proposals**

##### **To Trafi Aviation**

Pursuant to JAR-OPS 3.715 Flight data recorders-1, Commercial Air Transportation (Helicopters), the operator shall have the means of readily retrieving the recorded data from the storage medium. This requires that the aircraft's documents include a tail number-specific Download Grid.

*In order to safeguard the requisites of investigation, the investigation commission recommends that Trafi Aviation amend the national Aviation Regulation AIR M16-1 (initial aircraft inspection) so as to extend the JAR-OPS 3's requirement of readily available recorded flight data to all helicopters fitted with flight recorders*



Helsinki on 11 August 2011

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## The digest of the comments

### The Finnish Border Guard / Air Patrol Squadron

Air Patrol Squadron had no comments on the safety recommendations and content of the draft final report.

### The Finnish Transport Safety Agency, Trafi

Trafi Aviation had no comments on the safety recommendations of the draft final report.

### Finavia Corporation

Finavia had no comments on the content of the draft final report.

### European Aviation Safety Agency, EASA

In the draft final report there was a proposal for EASA with regard to improving the requisites of investigation by adding positional (latitude, longitude) and radio altitude data to the list of helicopter parameters to be recorded (JAR-OPS 3.715/3.720, Appendix 1, Table A). EASA informed that the subject has been already included in the incoming regulation, which will become valid in 2016. The proposal was deleted from the final report.

### The Transportation Safety Board of Canada, TSB

The Transportation Safety Board of Canada had no comments on the draft final report.

### The State of Manufacture, Transport Canada

In its comments Transport Canada emphasized that vortex ring state and settling with power are two different phenomena. In the Finnish literature they are however comprehended as synonyms of the term *pyörrevirtaustila*, i.e. vortex ring state.

*Older texts on helicopter aerodynamics refer to vortex ring state and settling with power as the same phenomenon however they are not. Transport Canada differentiates between vortex ring state and settling with power as follows:*

*... Vortex ring state is as aerodynamic stalling phenomenon wherein the helicopter is descending in its own vortices, thereby losing lift. ... Conversely, settling with power is akin to stopping a heavily laden vehicle in a short distance from speed, where the inertia of the mass exceeds the available braking power for the distance remaining.*

Transport Canada disagreed with the draft final report's conclusion, which states that the cause of the accident was the helicopter's main rotor entering into developing vortex ring state. Transport Canada suggested that the primary cause of the accident was a human error resulting in settling with power situation.

### The manufacturer, Bell Helicopter Textron Inc.

Bell proposed that in the draft final report's wording *landing gear failed* should be changed to *landing gear fractured* which describes the occurrence more accurate.

Bell Helicopter Textron did not believe that the aircraft was placed in a settling with power (i.e. vortex ring state). According to Bell the cause of this hard landing was a result of improper control inputs, which led to an excessive rate of descent to develop that was not been able to arrest prior to impact.