Statens haverikommission
Swedish Accident Investigation Authority

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Final report RM 2013:02e

Accident involving a Royal Norwegian Air Force aircraft of type C-130 with call sign *HAZE 01*, on 15 March 2012 at Kebnekaise, Norrbotten County, Sweden.

Ref no M-04/12
22/10/2013

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring again, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

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Final report RL 2013:02e

The Swedish Accident Investigation Authority (Statens haverikommission, SHK) has investigated an accident that occurred on 15 March 2012 at Kebnekaise, Norrbotten County, involving an aircraft from the Royal Norwegian Air Force with call sign *HAZE 01*.

In accordance with Section 14 of the Ordinance on the Investigation of Accidents (1990:717), the SHK investigation team herewith submits a final report on the results of the investigation.

The Swedish Accident Investigation Authority respectfully requests to receive, by 10 February 2014 at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas
Chairperson

Agne Widholm
Investigator in Charge

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General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring again, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies. The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once a rescue operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

The investigation

On 15 March 2012, SHK was informed that a Royal Norwegian Air Force aircraft of type C-130 with call sign *HAZE 01* was missing during a military transport flight from Harstad/Narvik Airport (Evenes) in Norway to Kiruna Airport, Norrbotten County, that day at about 15.00 hrs.

The accident has been investigated by SHK represented by Mr Mikael Karanikas, Chairperson, Mr Agne Widholm, Investigator in Charge, Mr Nicolas Seger, Operations Investigator, Mr Kristoffer Danèl, Technical Investigator from 18 March 2012, Mr Jens Olsson, Investigator behavioural science and group leader Air Navigation Services, and Mr Urban Kjellberg, group leader Rescue Services.

The investigation team of SHK was assisted by Mr Leif Åström as flight operations expert and assistant to the Investigator in Charge and Mr Sven Hammarberg as group leader for the technical side of the investigation. Swedish Air Navigation Services experts were Mr Lars-Olof Ek until 10 April 2012, Mr Kjell Magnusson from 2 April 2012 until 25 September 2012, Mr Cay Boqvist from 3 October 2012 and Mr Roland Johansson from 10 June 2013. Norwegian Air Navigation Services expert was Mr Asbjørn Mikalsen from 17 April until 11 May 2012. Meteorology expert was Mr Micael Lundmark and medical expert Ms Liselotte Yregård. The company MAGNIC AB has participated with its sound experts.

Experts in the sub-area of Rescue Services were Mr Göran Hagberg, Mr Leif Isberg, Mr Göran Persson and Mr Per Jarring.

In addition, the following persons have participated in the investigation work for a limited period: Mr Staffan Jönsson (SHK), Mr Sakari Havbrandt (SHK), Mr Lars Alveståll (SHK), Mr Patrik Dahlberg (SHK), Mr Tor Nørstegård (SHT[1]) and personnel from the Armed Forces aircraft salvage group at Blekinge Wing, F 17 and flight technicians from Skaraborg Wing, F 7.

The investigation was followed by Mr Lars-Eric Blad of the Swedish Transport Agency, Mats Ardbreck of the Authority for Civil Contingencies and Ulf Sköld of the police in Norrbotten County.

The following personnel from the Royal Norwegian Air Force have followed the investigation as advisors and experts: Mr Per Egil Rygg, Mr Øivind Jervan, Mr Harald Yttervik, Mr Arild Amundsen, Mr Stein Erik Marhaug, Mr Jens Bolstad, Mr Rune A Johansen, Mr Odd-Ivar Lundseng and Mr Dag Jørgensen.

[1] Statens havarikommisjon for transport. (The Accident Investigation Board Norway).

ABBREVIATIONS AND EXPLANATIONS

Term	Meaning	Explanation
ACC	*Area Control Centre or Area Control Service*	
AFI	*Air Force Instruction*	Instruction for the U.S. Air Force.
AGL	*Above Ground Level*	Height above ground level, usually expressed in feet
AIS	*Aeronautical Information Services*	
AMA	*Area Minimum Altitude*	Area minimum altitude provides at least 1,000 feet of vertical obstacle clearance above the highest terrain or obstacles within the area (but 2,000 feet within a specifically indicated mountain area higher than 6,000 feet MSL). Annex 4 to the Chicago Convention = The lowest altitude to be used under instrument meteorological conditions (IMC) which will provide a minimum vertical clearance of 300 m (1,000 ft) or in designated mountainous terrain 600 m (2,000 ft) above all obstacles located in the area specified, rounded up to the nearest (next higher) 30 m (100 ft).
ANS	*Air Navigation Services*	ANS includes ATS, CNS, MET, AIS and SAR.
ASM	*Airspace Management*	
ATCC	*Air Traffic Control Centre*	
ATFCM	*Air Traffic Flow and Capacity Management*	
ATM	*Air Traffic Management*	
ATS	*Air Traffic Service*	
CAVOK	*Ceiling and visibility OK*	The prevalent and lowest level of visibility is or is expected to be 10 km or more, no clouds of operational significance have been observed or are expected, and no weather of significance to aviation has been observed or is expected.
CNS	*Communication, Navigation and Surveillance Systems*	
DME	*Distance Measuring Equipment*	Radio-based navigation system for measuring distance.
EPN	*Entry Point North*	Nordic training for Air Traffic Services, located in Sturup, Sweden.
Ft	*Feet*	Equivalent to 0.3048 metres.
GCAS	*Ground Collision Avoidance System*	Part of the aircraft systems for Ground Collision Avoidance and Terrain Avoidance
GND	*Ground*	Indicates that a level denotes height above ground level.
GPS	*Global Positioning System*	Satellite-based navigation system.

HKV	*Headquarters*	Swedish Armed Forces Headquarters.
h	*Hour/hours*	
hPa	*Hectopascal*	Unit of pressure equivalent to the millibar.
HDD	*Head Down Display*	Equipment on the instrument panel for the presentation of information to the pilot.
HUD	*Head Up Display*	Equipment for the presentation of information in the pilot's field of vision when looking outside.
IAS	*Indicated Air Speed*	
IFF	*Identification Friend or Foe*	System that enables other units to identify an aircraft by means of telecommunications.
IFR	*Instrument Flight Rules*	
ILS	*Instrument Landing System*	Ground-based system for instrument approach to an aerodrome.
IMC	*Instrument Meteorological Conditions*	
JRCC	*Joint Rescue Coordination Centre*	
Kt	*Knot*	NM/h.
LAF	*Lowest Available Flight Level*	
LAF	Lägsta Användbara Flygnivå	
LFV	Luftfartsverket	A Swedish Air Navigation Service Provider
MET	*Meteorological Services for Air Navigation*	
MSA (according to Norwegian Airforce Instructions AFI)	*Minimum Safe Altitude*	An initial VFR altitude that provides additional terrain and obstacle clearance while the aircrew analyzes situations that require interruption of low-level operations
MSA (according to ICAO)	*Minimum Sector Alttude*	The lowest altitude which may be used which will provide a minimum clearance of 300 m (1,000 ft) above all objects located in an area contained within a sector of a circle of 46 km (25 NM) radius centred on a radio aid to navigation.
MSL	*Mean Sea Level*	
NM	*Nautical mile*	Equivalent to 1,852 m.
PFD	*Primary Flight Display*	
QFE		Atmospheric pressure at airport elevation above sea level or to runway threshold.
QNH		Atmospheric pressure at an airport or other defined area calculated at sea level in accordance with the International Standard Atmosphere (ISA) .
SA	*Situational Awareness*	
SAR	*Search and Rescue*	

STRIL	Stridsledning och Luft-bevakning	Swedish military air combat command
TA	*Transition Altitude*	
TAWS	*Terrain Awareness and Warning System*	Part of the aircraft systems for Ground Collision Avoidance and Terrain Avoid-ance
TMA	*Terminal Control Area*	
TWR	*Aerodrome Control Tower*	
VFR	*Visual Flight Rules*	
VHF	*Very High Frequency*	Frequency range for VHF radio
VMC	*Visual Meteorological Conditions*	
UHF	*Ultra High Frequency*	Frequency range for UHF radio
VOR	*Very High Frequency Omnidirectional Range*	Ground-based transmitting station or receiver for a directional radio beacon.
UTC	*Universal Coordinated Time*	
YKL	Yttäckande Kontrollerat Luftrum	Area-type controlled airspace

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Report completed on 22/10/2013

Aircraft; registration and type/model	Registration 5630, C-130J-30 Super Hercules
Class/Airworthiness	Military, valid American Certificate of Airworthiness
Owner/Possessor/Operator	Royal Norwegian Air Force
Time of the incident	15-03-2012, 14.57.29 hours, in daylight Note: All times are given in Swedish standard time (UTC + 1 hour)
Place	Kebnekaise, Norrbotten county (pos. 67° 54' 9"N, 18° 31' 9″E; 2,014 m above sea level)
Type of flight	Norwegian state aviation/Military flight
Weather	According to SMHI's analysis: - Wind 250^0 60-70 knots - Visibility <1 km in cloud and snow showers - 8/8 with the cloud base at 1,000-4,000 ft - cloud top Flight Level 90-100 - Temp./dp minus 3-5/minus 3-5 °C - QNH 1000 hPa
Persons on board;	
crew members	4
passengers	1
Injuries to persons	5 fatalities
Damage to aircraft	Destroyed
Other damage	Fuel and oil spillage
Commander:	
Age, licence	42 years, Norwegian military and ATPL[2] theory
Total flying hours	6,229 hours, 758 of which on this model
Flying hours last 90 days	78 hours on this model
Number of landings last 90 days	17 on this model
Co-pilot:	
Age, certificate	46 years, Norwegian military and ICAO[3] commercial traffic theory
Total flying hours	3,285 hours, 91 of which on this model
Flying hours last 90 days	18 hours on this model
Number of landings last 90 days	11 on this model
Loadmasters	2 persons
Sweden Control, Stockholm ACC, ESOS, Manning sector in question:	Executive, Planner
Executive:	
Age, licence	32 years, Air traffic controller licence
Licence issued	1 April 2011 by the Swedish Transport Agency
Valid ratings and endorsements	ACP[4], ACS[5], APS[6], RAD[7], TCL[8]

[2] ATPL (Airline Transport Pilot Licence) authorises a pilot to act in commercial traffic as pilot-in-command.
[3] ICAO (International Civil Aviation Organization)
[4] Rating for Area Control Procedure (ACP)

Language proficiency aviation radiotelephony	English 6(6), Swedish 6(6)
Planner:	
Age, licence	26 years, Air traffic controller licence
Licence issued	20 January 2012 by the Swedish Transport Agency
Valid ratings and endorsements	ACP, ACS, APS, RAD, TCL
Language proficiency aviation radiotelephony	English 5(6), Swedish 6(6)
Kiruna TWR (ESNQ) manning:	Single person operation
Air traffic controller (AD1):	
Age, licence	35 years, Air traffic controller licence
Licence issued	25 March 2010 by the Swedish Transport Agency
Valid ratings and endorsements	ADI[9], APP[10], APS, TWR[11], RAD, TCL. (rating in Kiruna since 08-12-2011).
Language proficiency aviation radiotelephony	English 5(6), Swedish 6(6).

[5] Rating for Area Control Surveillance (ACS)
[6] Rating for Approach Control Surveillance (APS)
[7] Endorsement for Radar (RAD)
[8] Endorsement for Terminal Control (TCL)
[9] Rating for Aerodrome Control Instrument (ADI)
[10] Rating for Approach Control Surveillance, procedure.
[11] Endorsement for Tower Control (TWR)

Summary

The accident occurred during a Norwegian military transport flight from Harstad/Narvik Airport (Evenes) in Norway to Kiruna Airport in Sweden. The flight was performed as a part of the Norwegian-led military exercise Cold Response. The aircraft, which was of the model C-130J-30 Super Hercules, had the call sign HAZE 01.

HAZE 01 took off with a crew of four and one passenger on board. The aircraft climbed to Flight Level 130 and assumed a holding pattern south of Evenes. After one hour, the flight continued towards Kiruna Airport. The Norwegian air traffic control had radar contact and handed over the aircraft to the air traffic control on the Swedish side.

Swedish air traffic control cleared HAZE 01 to descend to Flight Level 100 “when ready” and instructed the crew to contact Kiruna Tower. The crew acknowledged the clearance and directly thereafter, the aircraft left Flight Level 130 towards Flight Level 100. The lower limit of controlled airspace at the location in question is Flight Level 125.

HAZE 01 informed Kiruna Tower that the aircraft was 50 nautical miles (NM) west of Kiruna and requested a visual approach when approaching. Kiruna Tower cleared HAZE 01, which was then in uncontrolled airspace, to Flight Level 70, and the aircraft continued to descend towards the cleared flight level.

Neither ACC Stockholm nor Kiruna Tower had any radar contact with the aircraft during the sequence of events because the Swedish air navigation services do not have radar coverage at the altitudes at which HAZE 01 was situated.

HAZE 01 levelled out at Flight Level 70 at 14.57 hrs. Half a minute later, the aircraft collided with the terrain between the north and south peaks on the west side of Kebnekaise. Data from the aircraft's recording equipment (CVR and DFDR) showed that HAZE 01 was flying in level flight at a ground speed of approximately 280 knots prior to the moment of collision and that the crew was not aware of the imminent danger of underlying terrain. The remaining distance to Kiruna Airport was 42 NM (77 km). Everyone on board received fatal injuries.

Accidents in complex systems are rarely caused by a single factor, but there are often several circumstances that must coincide for an accident to occur. The analysis of the investigation deals with the circumstances which are deemed to have influenced the sequence of events and the barriers which are intended to prevent dangerous conditions from arising. In summary, the investigation indicates that latent weaknesses have existed both at the Norwegian Air Force and at LFV. It is these weaknesses and not the mistakes of individual persons that are assessed to be the root cause of the accident.

On the part of flight operations, the investigation has found shortcomings with respect to procedures for planning and following up a flight. Together with a probably high confidence in air traffic control, this has led to the crew not noticing that the clearance entailed an altitude that did not allow for adequate terrain separation.

In terms of the air traffic services, the investigation demonstrates that the aircraft was not issued clearances and flight information in accordance with applicable regulations. This is due to it not having been ensured that the air traffic controllers in question had sufficient experience and knowledge to guide air traffic from the west in towards Kiruna Airport in a safe manner under the present circumstances. The lack of radar coverage reduced the opportunities for air traffic control to monitor and guide air traffic.

The aircraft's Ground Collision Avoidance System is the last barrier and is intended to be activated and provide warning upon the risk of obstacles in the aircraft's flight path. The investigation has shown that with the terrain profile in question and the settings in question, the criteria for a warning were not fulfilled. No technical malfunction on the aircraft has caused or contributed to the occurrence of the accident. The rescue operation was characterised by very good access to resources from both Sweden and abroad. The operations lasted for a relatively long time and were carried out under extreme weather conditions in difficult alpine terrain. The investigation of the rescue operation demonstrates the importance of further developing management, collaboration and training in several areas.

The accident was caused by the crew on HAZE 01 not noticing to the shortcomings in the clearances issued by the air traffic controllers and to the risks of following these clearances, which resulted in the aircraft coming to leave controlled airspace and be flown at an altitude that was lower than the surrounding terrain.

The accident was rendered possible by the following organisational shortcomings in safety:

- The Norwegian Air Force has not ensured that the crews have had sufficiently safe working methods for preventing the aircraft from being flown below the minimum safe flight level on the route.
- LFV has not had sufficiently safe working methods for ensuring, partly, that clearances are only issued within controlled airspace during flight under IFR unless the pilot specifically requests otherwise and, partly, that relevant flight information is provided.

Recommendations

The Royal Norwegian Air Force is recommended to:

- Ensure that procedures are used that prevent aircraft from being flown below the minimum safe altitude or flight level en route in IFR flight. (RM 2013: 02 R1).

- Ensure that flight crew knowledge and routines means that the system for ground collision avoidance is used in a safe manner. (RM 2013: 02 R2).

- Further examine whether, and where necessary take measures to ensure that, the current crew configuration on the C130J attends to all aspects of the safe implementation of planning and flight. (RM 2013: 02 R3).

- Develop clear rules, manuals and procedures, which make it easier for flight crews to conduct safe air operations. (RM 2013: 02 R4).

The Swedish Transport Agency is recommended to:

- Ensure that an investigation of the safety culture within LFV is carried out with the aim of creating the conditions for maintaining and developing operations from an acceptable aviation safety perspective. (RM 2013: 02 R5).

- Further examine whether, and where necessary take measures to guarantee that, the controlled airspace is so designed that it encompasses an area large enough to contain the published routes for outgoing and incoming aircraft under IFR for which air traffic control is to be exercised, so that aircraft can execute all manoeuvres in controlled air, taking into account the aircraft's performance and the aids to navigation that are normally used in the area. (RM 2013: 02 R6).

- Ensure that air traffic controllers possess sufficient expertise and aids to manage situations that do not frequently occur. (RM 2013: 02 R7).

- Ensure that the discrepancies between the provisions regarding the use of QNH below the lowest usable flight level and the provisions regarding the use of flight levels above 3 000 feet (900 metres) MSL in airspace class G are eliminated. (RM 2013: 02 R8).

- Take measures to remove the ambiguity of having different applications of LAF. (RM 2013: 02 R9).

- Ensure that the English translation of *"lägsta användbara flygnivå"* in AIP Sweden is changed to *"lowest usable flight level"* so as to be in accordance with international regulations. (RM 2013: 02 R10).

- Act so that ICAO reviews its regulations with respect to *"lowest usable flight level"* in order to ensure that they also satisfy the circumstances in an area-type controlled airspace, or clarifies in guidance material how the regulations are to be applied in such airspace. (RM 2013: 02 R11).

- Ensure that regulations and general advice for airborne rescue units are issued that cover helicopter crew training and exercises in a mountainous environment, with requirements for special training and exercise programmes and that completed training and exercises be documented. (2013: 02 R12).

- Ensure that a management model is developed by the Swedish Maritime Administration for the air rescue services at JRCC that encompasses system management and operation management, including local management within the likely area of a crash involving an aircraft, and that the personnel are trained and drilled in accordance with the established management model. (RM 2013: 02 R13).

- Ensure that the Swedish Maritime Administration develops, trains and drills the personnel at JRCC in a staff model adapted for air rescue services and the established management model at the air rescue centre. (RM 2013: 02 R14).

- Ensure that the Swedish Maritime Administration develops documented liaison procedures for air rescue services in a mountainous environment. (RM 2013: 02 R15).

- Ensure that the Swedish Maritime Administration develops planning for appropriate resources regarding search from the ground in a mountainous environment and how these are to be alerted. (RM 2013: 02 R16).

- Ensure that the Swedish Maritime Administration develops and uses an objective for helicopter SAR operations that is possible to evaluate with respect to each individual operation. (RM 2013: 02 R17).

- Ensure that the Swedish Maritime Administration educates and trains the personnel at JRCC in matters of collaboration between air rescue services and mountain rescue services and develops procedures for this. (RM 2013: 02 R18).

The Swedish National Police Board is recommended to:

- Ensure that police authorities with responsibility for mountain rescue services plan and organise activities in such a way that rescue operations are commenced within an acceptable time of receiving an alert and implemented with adequate resources. (RM 2013: 02 R19).

The Swedish Civil Contingencies Agency is recommended to:

- In consultation with the Swedish Maritime Administration, the Swedish Transport Agency, the Swedish National Police Board, the Swedish National Board of Health and Welfare and SOS Alarm, ensure that the alerting of rescue and healthcare resources is carried out within an acceptable time, even in the case of events where there is only an imminent danger of an aircraft accident. (RM 2013: 02 R20).

- Examine measures necessary for guaranteeing that rescue operations are commenced within an acceptable time without delay and are executed in an effective manner, even when parallel (simultaneous) operations are being carried out with the participation of national rescue services, and thereafter inform central and local government authorities responsible for rescue services. (RM 2013: 02 R21).

- Within the Nordic cooperation for rescue services, act so that knowledge of the different countries' rescue service organisations becomes sufficiently familiar to the parties that may be subject to participation in rescue operations. (RM 2013: 02 R22).

1 FACTUAL INFORMATION

1.1 History of the flight

The flight was a Norwegian military transport flight from Harstad/Narvik Airport (Evenes) in Norway to Kiruna Airport in Sweden. The flight was performed as a part of the Norwegian-led military exercise *Cold Response*. The aircraft, which was of the model *C-130J-30 Super Hercules*, had been assigned the call sign *HAZE 01*.

1.1.1 Overview history of the flight

At 13.40 hrs, *HAZE 01* took off with two pilots, two loadmasters and one passenger on board. The aircraft climbed to Flight Level 130 and assumed a holding pattern 45 nautical miles (NM) south of Evenes. After one hour, the flight continued on an easterly heading from the holding pattern towards the directional radio beacon at Kiruna Airport (VOR KRA). The Norwegian air traffic control *(Bodö Control)* had radar contact and handed over the aircraft to the air traffic control on the Swedish side *(Sweden Control)*.

At 14.50 hrs, the crew contacted *Sweden Control* and communicated that they were at Flight Level 130. At 14.53 hrs, a visual approach to Kiruna was requested and the response received was that this should be taken up with Kiruna. At 14.54 hrs, *Sweden Control* cleared *HAZE 01* to Flight Level 100 and instructed the crew to contact Kiruna Tower, which was done one minute later. *HAZE 01* communicated the position 50 NM west of Kiruna and requested a visual approach when approaching, *"and request a visual approach, when approaching"*. The aircraft was cleared to Flight Level 70*, "descend Flight Level 70 initially"* and commenced descent[12]. Neither *Sweden Control* nor Kiruna Tower had any radar contact with the aircraft during the sequence of events because the Swedish air navigation services do not have radar coverage at the altitudes at which *HAZE 01* was flying. At approximately 14.57 hrs, *HAZE 01* reached Flight Level 70.

At 14.57.29 hrs, the aircraft collided with the terrain between the north and south peaks on the west side of Kebnekaise. Data from the aircraft's recording equipment showed that it was in level flight at a ground speed of approximately 280 knots prior to the moment of collision. The remaining distance to Kiruna Airport was 42 NM (77 km). Everyone on board was killed.

Location: 67° 54' 9″N, 18° 31' 9″E; 2,014 m above sea level.

1.1.2 Circumstances of the flight

On 30 June 2011, the Government of Sweden made the decision (*Fö2011/882/MFI)* to permit the Swedish Armed Forces to participate in *Cold Response 2012*. At the same time, the Government permitted admission to Swedish territory during the period 14 – 22 March 2012 for the foreign units participating in the exercise, as further determined by the Swedish Armed Forces.

According to the *Detachment Commander (DETCO)* of the 135 Luftving (Air Wing), the crew came to the briefing room at Evenes Airport at 10 o'clock in the

[12] Expression for an aircraft intentionally reducing its altitude.

morning. The mission was authorised on the basis of an *Air Tasking Order (ATO)* by *DETCO* as a transport flight, which consisted of flying to Kiruna to collect Norwegian military personnel and materiel and then flying back to Evenes. *DETCO* has stated that the flight had been planned as a normal transport mission under Instrument Flight Rules (IFR) at Flight Level 130 to Kiruna and that it had not been discussed whether the last part of the flight would be carried out under Visual Flight Rules (VFR). A transport aircraft of type C-160 Transall belonging to the German Air Force, with the call sign *TORCH 03*, was to participate in the same mission. The plan included the aircraft assuming a holding pattern until the go-ahead was received that the ground troops at the destination airport were ready to be evacuated. The take-off for *HAZE 01* from Evenes had been planned for 13.45 hrs, and the holding pattern was to be departed at 14.15 hrs for landing in Kiruna at 14.25 hrs.

An additional C-130J from the Norwegian Air Force, with the call sign *HAZE 02*, was participating in the same mission and was flying towards Kiruna from a somewhat more northerly position and was planned to land a few minutes later than *HAZE 01* at Kiruna Airport. When contact with *HAZE 01* was lost, *HAZE 02* ended the transport mission and took part in the search for the missing *HAZE 01*.

At the same time as the crew from *HAZE 01* was in the planning room, a crew member belonging to the German aircraft *TORCH 03* arrived. Together, the crew members coordinated how they would fly in relation to one another and agreed to conduct a joint briefing in the Norwegian aircraft prior to take-off.

1.1.3 Planning of the flight

The flight with *HAZE 01* concerned a move from Evenes (ENEV) in Norway to Kiruna in Sweden and thereafter a transport of soldiers and materiel back to Evenes. According to the ATS flight plan to Kiruna, the desired level was Flight Level 130, the flight time 40 minutes and the flight route via the points 6746N/01647E (in Norway) and 6757N/01701E (on the border between Norway and Sweden, south of the reporting point GILEN).

The planning of the flight could be performed by the *planning department (Mission Support)* or by the crew, but under current regulations, it was the commander who was ultimately responsible for the planning.

Mission support had access to a Portable Flight Planning System (PFPS) in the briefing room in question. The system could be used to produce planning documentation, both of the type LFC (Low Flying Chart) using the system Falcon View and of the type Jeppesen Flight Plans using the system JetPlan.com.

The planning documentation that was supplied to the crew was the same documentation that had been produced for earlier missions during the day because the routes and missions were largely identical.

The planning of these earlier missions was mainly performed by the respective crew members because *Mission Support* had little experience of planning that was to be coordinated with *Combined Air Operations.* However, these combined air operations were cancelled before the arrival of the crew in question. Before the flight, *Mission Support* supplied the crew with documentation such as:

- A chart in A3 format of the type *LFC, (Low Flying Chart)* also known as *Falcon View*, scale 1:500,000 with the planned route, see Fig. 1.
- A generic fuel table for the route with waypoints stated in latitude and longitude.
- A memory card for the mission *(Mission Data Card)* with frequencies and other tactical information to be used on board.
- Weather information.

The route on the LFC chart was drawn with an unbroken black line with a distance scale to the destination expressed in nautical miles. Each waypoint was numbered. On each side of the route and round the start and destination points, there was a broken green line that was placed at a distance of five nautical miles from the black line.

By each section of the route were text boxes, *Flight Information Blocks*, also known as *Doghouse*, see Fig. 2, with information on heading, *ESA (Emergency Safe Altitude)*, corresponding to 2,000 feet above the highest obstacle within 22 nautical miles counted from the planned track, the terrain's elevation above sea level at the starting point for each route section and the elevation above sea level for the fuel table's wind information.

According to the *Air Force Instruction 11-2C-130J, Vol 3*, ESA was defined as an altitude that provides "IMC terrain clearance during emergency situations that require leaving the low-level structure".

The Norwegian Air Force's *Basic Employment Manual* contains recommendations on the design of *Flight Information Blocks*. A minimum of heading, distance, flight altitude and *MSA (Minimum Safe Altitude)* is to be noted. On the chart in question, MSA had been replaced with ESA values.

According to the *Air Force Instruction 11-2C-130J, Vol. 3*, MSA was defined as "an initial VFR altitude that provides additional terrain and obstacle clearance while the aircrew analyzes situations that require interruption of low-level operations". MSA is to be planned as the highest value of an indicated altitude that is 500 feet above the highest obstruction, or 400 feet plus the highest terrain elevation, within five nautical miles of the track.

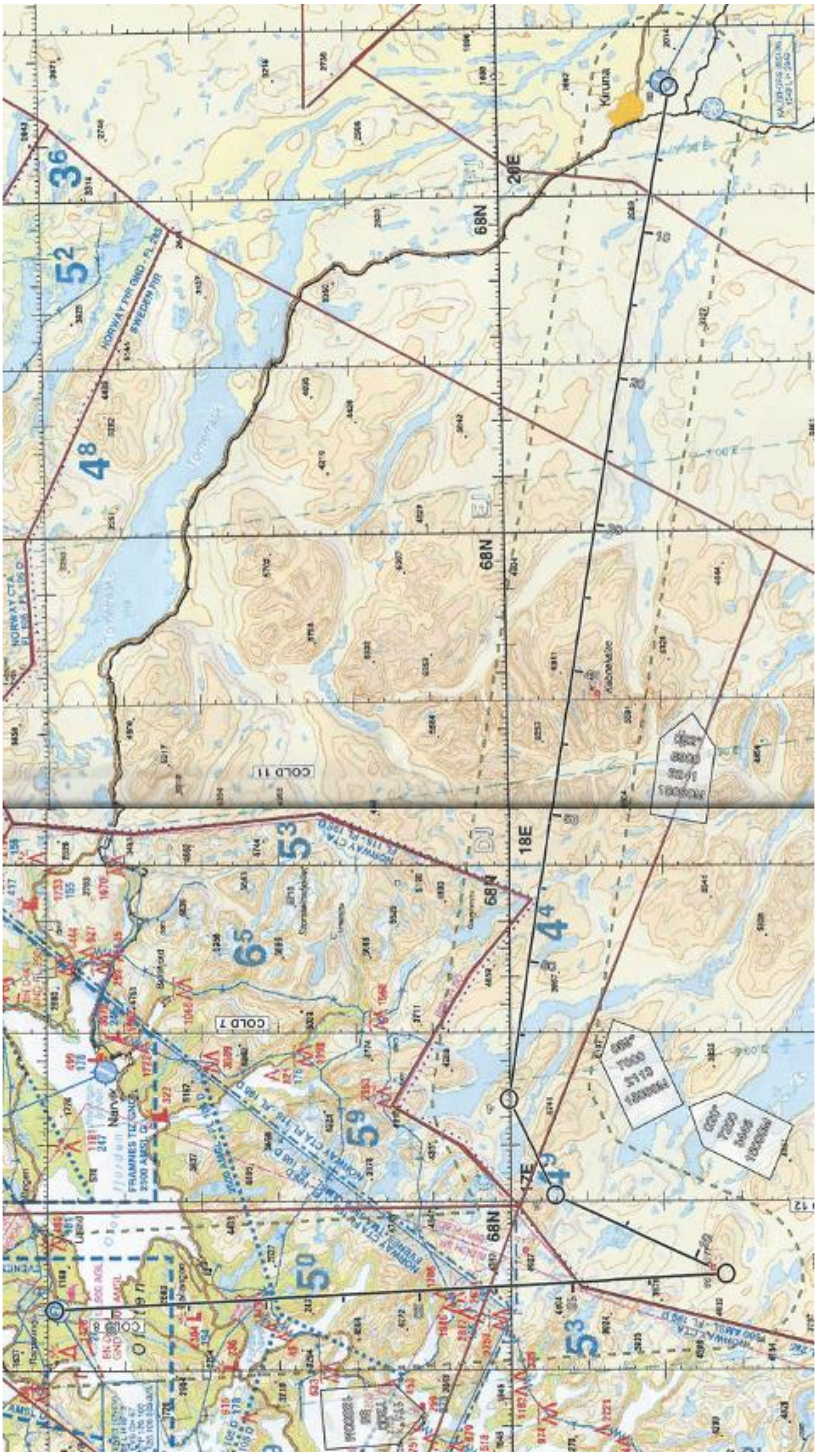

Fig. 1. LFC with entered route and Doghouse for each section of the route. The figures in blue in the various coordinate boxes state Maximum Elevation Figures (MEF) on the Norwegian side of the border.

Latitude/longitude boxes pertaining to the terrain on the Norwegian side of the border stated the minimum obstacle-free altitude, *(MEF, Maximum Elevation*

Figures), with figures in blue. The figures stating this altitude were partly on the Swedish side of the border between Sweden and Norway, but concerned the altitude on the Norwegian side of the border in the respective box. There were no MEF values pertaining to the terrain on the Swedish side of the border. Other elevations were stated in feet in black figures for terrain, with the exception of the elevation of Kebnekaise, which was stated in red figures. Elevations for obstacles were stated in feet in red figures on the Norwegian side of the border. Kebnekaise was also marked with a red dot with a white cross.

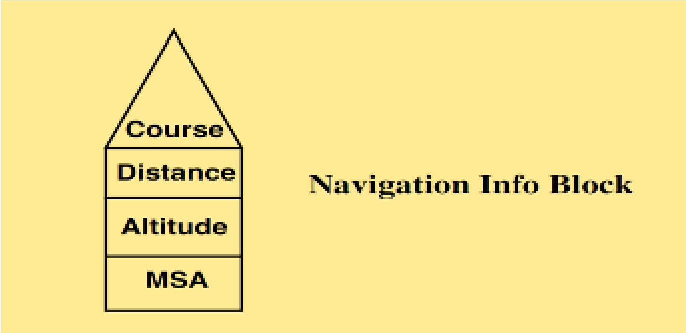

Fig. 2. Flight Information Block, also known as Doghouse.

In their personal equipment, the pilots had access to chart documentation from the *European Aeronautical Group/Navtech*. The documentation included charts for navigation en route, *ENC (En Route Navigation Chart)*. See Fig. 3. On this type of chart, the minimum safe altitude is stated in each latitude/longitude box in pink figures. Along the planned route, this altitude was stated as 9,300 feet.
The mountain area was marked with a broken grey line with the text “Mountain Area”.

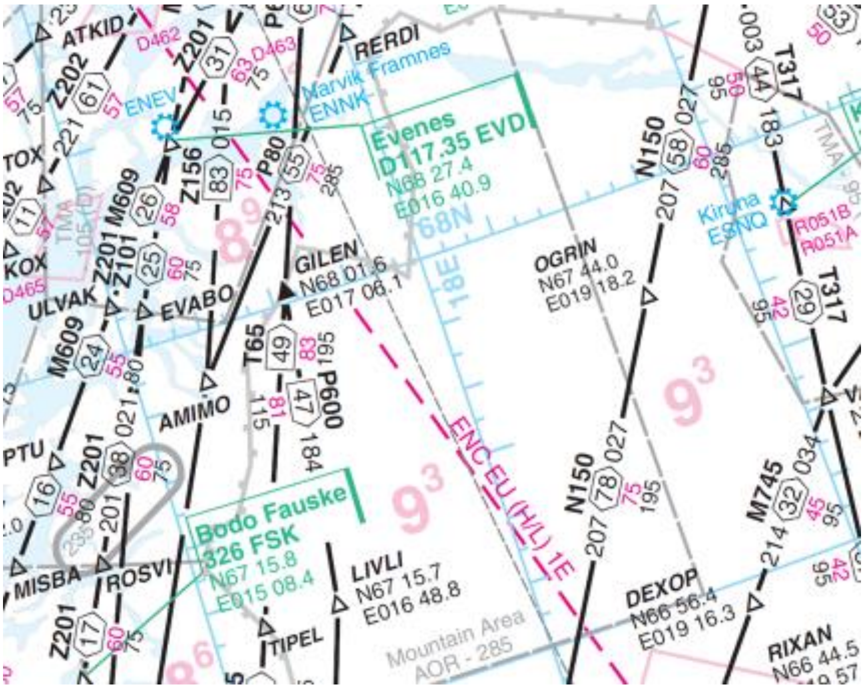

Fig. 3. ENC from EAG/Navtech. The figures in pink in the latitude/longitude boxes relate to MORA (Minimum Off Route Altitude).

The pilots also had access to charts from the United States Department of Defense, of the type *DOD (Department Of Defense) En Route Low* and *High Altitude*

Chart. The chart termed *Low,* see Fig. 4, applied to flight below Flight Level 285 in Sweden and contained information about the minimum safe altitude in each latitude/longitude box in grey figures *(ORTCA, Off Route Terrain Clearance Altitude*). For the final section of the planned route, this altitude was stated as 10,300 feet. The mountain area was marked with an unbroken blue line with the text "Mountain Area". According to Mission Support, the crew did not have access to Swedish VFR aeronautical charts for the area in question.

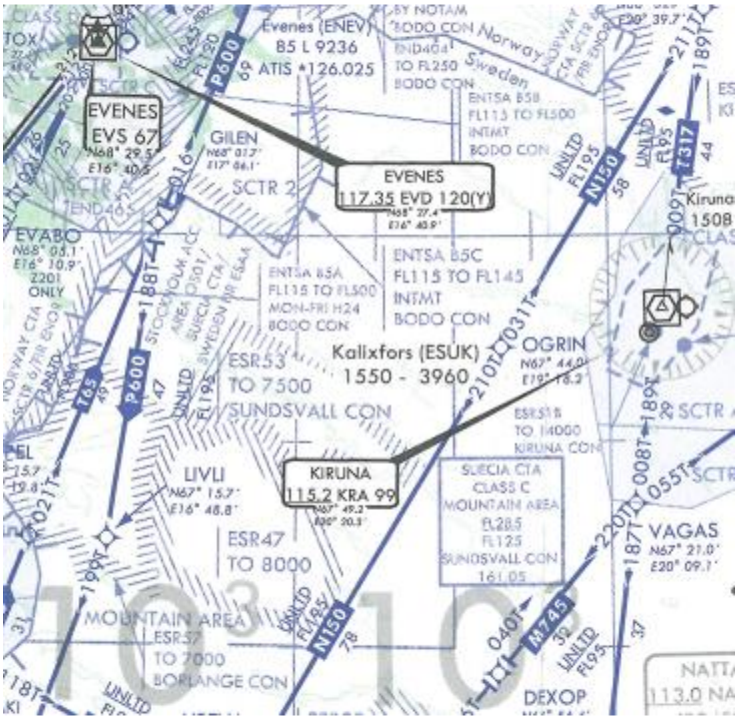

Fig. 4. Chart of the type DOD En Route Low Altitude. ORTCA is stated as 10^3 in grey in the lower portion of the chart.

Pre-flight briefing and take-off preparations

Via information from the recording equipment, it has emerged that the crew's preparations before take-off followed established procedures.

The commander asked the co-pilot if he wanted to fly out or home. The co-pilot replied that he wanted to fly first. This meant that he had the task of manoeuvring the aircraft from Evenes to Kiruna as Pilot Flying (PF), while the commander would have the monitoring role as Pilot Monitoring (PM).

The co-pilot also asked the commander if *Combat Entry* was to be applied and received an affirmative answer (*Combat Entry* refers to a tactical approach with accompanying checklist).

1.1.4 *Detailed history of the flight*

The detailed history of the flight has been reconstructed by means of flight plans, data from the DFDR[13] and CVR[14], recorded data from radar stations and radio traffic as well as interviews.

[13] Digital Flight Data Recorder.

[14] Cockpit Voice Recorder.

The take-off sequence

Time	Event
13.40	*HAZE 01* took off, climbed to about 3,000 feet and headed directly towards the point GILEN. The commander confirmed the minimum sector altitude of 7 300 feet in the direction of climb out as stated on the chart that described the departure procedure. The climb continued to Flight Level 130.

The holding pattern

Time	Event
Approximately 13.44	The aircraft assumed a holding pattern 45 NM south of Evenes. When *HAZE 01* reached the holding pattern, the crew obtained visual contact with *TORCH 03* and had visual contact on several occasions after this.
13.49.44	The crew noted a malfunction of the communication system *TAC SAT* and stated that communication with the ground troops was performed on the UHF frequency.
13.54.24	Communication with *TORCH 03* was established on the VHF frequency.
13.56.52	The checklist termed *"Combat Entry Checklist"* was commenced.
13.58.29	In conversations between the combat command body *VIPER* and *HAZE 01*, *HAZE 01* stated that it planned to carry out the return flight "direct" and at Flight Level 160. *– for the recovery we will pretty much try to fly direct Evenes from Kiruna at Flight Level 160.*
13.59.00	The terrain warning system GCAS[15]/TAWS[16] was put into tactical mode as part of the *Combat Entry Checklist*, upon which the warning system ACAWS provided information with two "ping signals" and the commander stated *"TAWS VOID"*.
13.59.08	The crew selected the same radar altimeter as the source of both pilots' radar altitude presentation. The commander stated "RADALT SAME", and ACAWS confirmed the selection with two "pings".
13.59.17	The radar altimeter was set to 200 feet, after which the co-pilot said *"Ja, det blir ikke noen lavflying ut av dette her, men" ["Yeah, there won't be any low flying from this, though"]*, which was answered with *"Nej" ["No"]* by the commander.
13.59.22	The commander said *"altimeters 1013 for now"*, which was confirmed by the co-pilot.
14.05.27	The passenger asked the crew if it is customary to use the 1:250,000 chart on normal missions or on this type of mission, which was answered in the affirmative by the commander, adding that it is used most at a low level. The commander went on to explain that the

[15] Ground Collision Avoidance System.

[16] Terrain Awareness and Warning System.

Time	Event
	1:500,000 chart was not available, mentioned 1:1 million, 1:2 million and 1:5 million charts and that it was that and 1:5 million charts that were used when flying normally – high.
14.06.24 - 14.09.17	Series of tones were heard from the radar warning receiver on six occasions, upon which the crew talked about whether or not *COMAO* (Combined Air Operation) was set.
14.10.40	Loadmaster 1 asked about the current position, which was answered by the pilots saying that they were situated halfway between Bodö and Evenes on the border between Norway and Sweden, upon which Fauske was pointed out.
14.16.00	The commander called the ground troops in Kiruna but received no reply.
14.16.28	The pilots talked for just over one minute about the time window for the mission and about the time for departing the holding pattern.
14.19.33	The German aircraft commenced climb to Flight Level 180 in order to obtain better radio coverage. This intention was communicated to the crew on *HAZE 01* about one minute earlier.
14.22.01	The warning system on board *HAZE 01* sounded with two "pings", upon which the co-pilot called out *"IFF 2 FAIL"*, which meant a malfunction of the system for identifying friend or foe.
14.23.08	The co-pilot confirmed the measures for the malfunction *IFF2 FAIL*.
14.24.23	Loadmaster 1 asked *"Hvorfor står det der TAWS Tactical der?"" ["Why does it say TAWS Tactical there"]*, upon which the co-pilot stated *"TACTICAL VOID"*, which was commented on by the commander saying *"så funker han ikke som han skal fordi vi er so høit" ["it's not working as it should because we are so high".]*.
14.28.21	The German aircraft *TORCH 03* was cleared by *Bodö Control* direct to *VAGAS* at Flight Level 180. *TORCH 03* communicated its intention to *HAZE 01* a few minutes earlier.
14.29.15	The co-pilot on *HAZE 01* suggested a tactical approach from a position over Kiruna Airport, which was confirmed by the commander.
14.29.34	*TORCH 03* notified *HAZE 01* that the holding pattern had been departed, and that feedback would be given if contact was obtained with the ground troops in Kiruna.
14.31.01	In connection with several unsuccessful attempts made by *TORCH 03* to come into contact with the ground troops in Kiruna, the commander on *HAZE 01* said *"Vi har 76 mil til Kiruna. Det er klart vi får tak i de på Uniform".* [17] *" ["We have 760 km to Kiruna. We will certainly get hold of them on Uniform"]*. The co-pilot replied to this with *"Ja, synes det er litt merkelig at dem ikke... og det jo nedover, det er jo ikke noe som stikker opp som er i vegen her." ["Yes, seems*

[17] Uniform here refers to the UHF radio.

Time	Event
	a bit strange that they... and further down, there isn't anything sticking up that's in the way here."]
14.31.36 - 14.32.34	The crew on *HAZE 01* had conversations about various codes in the IFF system.
14.34.18 - 14.36.33	The crew on *HAZE 01* had conversations about the loading and securing of cargo.
14.42.14	Loadmaster 1 explained that the radar warning system was functioning again.
14.44.00	The co-pilot asked, *"Stemmer det at fjella her oppe er 7,000 fot?"["Is it right that the elevation of the mountains up here is 7,000 feet?"]*, upon which the commander said *"Ehh 6,600 ett eller annet, ehhh…" ["Ehh 6,600 something like that, ehhh…"]*, upon which loadmaster 1 *commented "Det er vel det høyeste fjellet i Sverige er vel ved Kiruna, er det ikke det?" ["Isn't it so that the highest mountain in Sweden is by Kiruna?"]* The commander replied: *"Jo Kebne... Kebnekaise" ["Yes Kebne...Kebnekaise"]*.
14.20 - 14.47	From *TORCH 03*, 22 calls were registered, which were not answered by the ground troops' radio station *(ORCA)* in Kiruna.
14.47.42	The co-pilot on *HAZE 01* declared that he was ready to descend.
14.47.53	The crew on *TORCH 03* notified *HAZE 01* that they had made contact with the ground troops in Kiruna and stated that *HAZE 01 "should leave your holding and come to Kiruna as well" "*. The message was acknowledged by the commander on *HAZE 01* who responded that they would head towards Kiruna.
14.48.23	The commander on *HAZE 01* contacted *Bodö Control* and announced that they were ready to head towards Kiruna.
14.49.45	*Bodö Control* cleared *HAZE 01* direct to *Kilo Romeo Alfa* (KRA, the directional VOR radio beacon in Kiruna), which was confirmed by the commander.
14.49	Coordination and handover *(release)* was made between *Bodö Control* and *Sweden Control*, regarding *HAZE 01*, which was then south of GILEN at Flight Level 130 and wanted to fly direct to KRA for landing in Kiruna. Bodö: *Ja, han ligger rätt sør [Yes, he is directly south of] GILEN, Flight Level 130.* Bodö: *Ja han vill direkt till Kiruna för landning ja [Yes he wants to head straight to Kiruna for landing, yes].* Sweden: *Okej, men … skicka honom direkt K R A. [OK, but send him direct K R A.]* Bodö: *K R A å over till dej uten radar [K R A and over to you without radar]* Sweden: *Utan radar ja [Without radar, yes]. Och är den released när vi får över den? [And is it released when we get it over?]* Bodö: *Han er released [It is released].*

Time	Event
	Bodö Control notified *HAZE 01* that the radar service was terminated and asked *HAZE 01* to contact *Sweden Control*, which was acknowledged by the commander.

<u>*The flight from the holding pattern towards Kiruna*</u>

Time	Event
14.50.20	After more than an hour after take-off, the flight continued on an easterly heading towards the directional radio beacon at Kiruna Airport *(VOR KRA).*
14.50.25	The commander contacted *Sweden Control* and announced maintaining Flight Level 130 and heading towards Kiruna. *Sweden Control* acknowledged and notified *"Negative radar contact".* HAZE 01: *Sweden HAZE 01.* Sweden: *HAZE* 01, *Sweden* HAZE 01: *HAZE 01 Flight Level 130 inbound Kiruna.* Sweden: *HAZE 01, Roger, negative radar contact*.
14.50.50	The commander on *HAZE 01* initiated the checklist for approach and stated that he was turning off the radar warning receiver. The co-pilot answered yes and explained that he had intermittent contact with the ground, which was acknowledged by the commander.
14.51 hrs	Coordination was made between *Sweden Control* and *Kiruna TWR,* whereby it was agreed that *HAZE 01* would fly towards KRA, then to "intercept" VAGAS 3F (STAR[18]) and descend to Flight Level 100. Kiruna TWR was also informed of the transponder code and that *Sweden Control* did not have radar contact with *HAZE 01. Sweden Control* was to contact Kiruna again with an estimated landing time. Kiruna: *Kiruna.* Sweden: *Stockholm. Nu är den där HAZE 01 på g snart och vill landa. Kan vi köra direkt mot KRA med den för att intercepta en VAGAS 3F, 21?* *[Stockholm. That HAZE 01 is now on the way soon and wants to land. Can we go with it direct towards KRA to intercept a VAGAS 3F, 21?]* Kiruna: *Det kan ni göra [Yes you can].* Sweden: *Och sjunka ner till 100 då [And then descend to 100].* Kiruna: *Ja [Yes].* Sweden: *Kan jag återkomma med tid. Transponder är i alla fall 2470 [Can I get back (to you) with the time. Transponder is in any case 2470].* Kiruna: 2470. Sweden: *Kan jag återkomma med tid, för vi har den inte på vår radar ser du [Can I get back (to you) with the time, because we do not have it on our radar you see].* Kiruna: *Visst gör det … [Sure, do that …]* Sweden: *Bra [Good].*
14.51.26	The commander asked the co-pilot if he wanted a tactical approach, which was answered with yes and then was specified as *"overhead, left turn to final".*

[18] Standard Terminal Arrival Route.

Time	Event
14.52.03	The co-pilot gave a briefing on the tactical approach procedure at Kiruna Airport. *”Ja. For taktisk overhead kjem inn 220 knop og over rullebanen. Kaller to poteter før en 45 graders bank turn, level. Du setter flaps 50 on speed og kjøre ut hjula on speed. Det blir antakelig en liten wings level down wind for å sjekke posisjon og slowe ned før vi går inn til final.”* *[“Yes. For tactical overhead, come in 220 knots and over the runway. Count two potatoes before a 45-degree bank turn, level. Set flaps 50 on speed and put out the wheels on speed. There will probably be a little wings level downwind to check position and slow down before we go in to final.”]*
14.52.35	*Sweden Control* cleared *HAZE 01* to KRA and intercept VAGAS 3F for runway 21. *HAZE 01* requested a visual approach to Kiruna. *Sweden Control* replied that he had to take this up with *Kiruna TWR* later; until further notice, VAGAS 3F and runway 21 on KRA applied. *HAZE 01* read back the clearance. On request from *Sweden Control, HAZE 01* gave notification that estimated landing time Kiruna was 15.05 hrs. Sweden: *HAZE 01, Sweden.* HAZE 01: *Ja [Yes] HAZE 01, go ahead.* Sweden: *HAZE 01, after KRA intercept a VAGAS 3F arrival, runway 21.* HAZE 01: *And HAZE 01 request a visual approach on Kiruna if possible.* Sweden: *(When) HAZE 01 you can take that later on with Kiruna Tower, but for now it is VAGAS 3F and 21 from KRA.* HAZE 01: *Copy that, KRA VAGAS 3F HAZE 01.* Sweden: *And HAZE 01, what time do you estimate to land at Kiruna.* HAZE 01: *Estimate to be at Kiruna at 14.05.*[19] Sweden: *HAZE 01, thank you.*
14.53.21	The co-pilot conducted a briefing on the recently acknowledged approach to Kiruna Airport. The altitudes mentioned in the briefing were landing minimum for the instrument landing system of 1,640 feet and the corresponding height above ground level of 200 feet.
14.53.50	Sweden Control announced to Kiruna TWR that HAZE 01 expected to land 1405. It was further announced that HAZE 01 would come in via VAGAS 3F 21, directly towards KRA and that a request for visual approach from HAZE 01 had been made to Sweden Control, but that HAZE 01 had been asked to take up the matter with the Kiruna Tower.
14.54.05	*Sweden Control* cleared *HAZE 01* to Flight Level 100, which was acknowledged by the commander with the message that they were leaving for Flight Level 100. Sweden: *HAZE 01, when ready descend Flight Level 100.* HAZE 01: *And we are leaving for Flight Level 100, HAZE 01.*

[19] Time is given in UTC and means 15:05 local time

Time	Event
	The descent was commenced 58 nautical miles from *KRA VOR* with a rate of descent of about 2, 500 feet per minute, with the engines at idle.
14.54.13	*Sweden Control* asked *HAZE 01* to contact *Kiruna TWR.* Sweden: *HAZE 01, contact Kiruna Tower 130.150* HAZE 01: *Tower 130,150 HAZE 01, so long.* Sweden: *So long*
14.54.44	The checklist for approach had been completed except for the altimeter setting, which was pointed out by the commander.

The approach towards Kiruna

14.54.55	Still descending towards FL 100, HAZE 01 called the Kiruna Tower, notified the position 50 nautical miles (NM) west of Kiruna and requested a visual approach when approaching. HAZE 01: *Kiruna HAZE 01.* Kiruna: *HAZE 01, Kiruna.* HAZE 01: *HAZE 01, we are 50 ["Five Zero"] Miles west of the field and request a visual approach, when approaching.*
14.55.12	Kiruna cleared *HAZE 01* towards "overhead Kiruna" and to Flight Level 70 initially, *('overhead Kiruna' referring to a point above the runway centre, ARP)*. The message was acknowledged by the commander, who then asked for and was informed of the current weather. Kiruna*:* *HAZE 01, cleared towards overhead, descend Flight Level 70 initially.* HAZE 01: *Cleared inbound, and descend Flight Level 70, HAZE 01, and do you have the latest weather?* Kiruna*:* *Wind is 210 degrees 22 knots, CAVOK, temp 2, dew point -2 and QNH 1,000, braking action good.* HAZE 01: *Copy weather and QNH 1,000, HAZE 01* The aircraft continued the descent with a rate of descent of about 2,000 feet per minute.
	Neither *Sweden Control* nor Kiruna Tower had any radar contact with the aircraft during the sequence of events because the Swedish air navigation services did not have radar coverage at the altitudes in question in the area where *HAZE 01* was situated.
14.55.49	The co-pilot called out *"Flight level seven thousand…nej [no], seven…"*.
14.55.52	The commander called out *"seven zero ja [yes]"*, which was acknowledged by the co-pilot with *"seven zero"*.
14.56.31	*"Thousand to go"* from ACAWS was registered, which was acknowledged by the co-pilot with *"one thousand co-pilot, one zero one three"*. *SHK's comment:* "Thousand to go" meant that the aircraft during descent passed one thousand feet above the altitude that was set on the control panel.

14.56.47	The warning system for icing was activated, which was confirmed by the commander.
14.57.15	*HAZE 01* levelled out at Flight Level 70. The co-pilot called out *“Autothrottle two forty”*, upon which the recording equipment showed that the aircraft's speed increased from approximately *210 knots to 240 knots.* 20 seconds later, the co-pilot called out *“Slower ned till to tjue her jeg” [“Slowing down to two twenty here”]*, and three seconds later *“To ti kanskje” [“Two ten maybe”]*, upon which the recorded speed decreased again. Data from both the CVR and DFDR shows that the aircraft was subjected to turbulence in connection with flying at Flight Level 70.
14.57.27	The autopilot disconnected, which was announced with a synthetic voice *“Autopilot”*.
14.57.29	*HAZE 01* collided with the west side of Kebnekaise at a height of 2,014 metres, corresponding to Flight Level 70, in level flight at a ground speed of approximately 280 knots.
14.58	*HAZE 01* was called by *Kiruna TWR*, which cleared *HAZE 01* for continued descent to 5,000 feet, QNH 1,000 and transition level 65. *Kiruna: And HAZE 01, descend altitude 5,000 feet, QNH 1,000, T-level 65.* *[No answer from HAZE 01]* *Kiruna: HAZE 01, Kiruna.* Thereafter followed several attempts to contact *HAZE 01*, directly or via *HAZE 02*.
	The continued measures performed by the air traffic controller at Kiruna ATS are reported in Appendix 1, Rescue services (available only in Swedish).

1.2 Interviews conducted

During the course of the investigation, some fifty interviews have been conducted. The following were interviewed: Relatives of the pilots on *HAZE 01* as well as the crew on *TORCH 03*. From the Norwegian Armed Forces the following have been interviewed: aviation medical examiner, psychologist, pilots (including from *HAZE 02*), loadmasters, mission support and several persons in managerial positions. From LFV, interviews have been conducted with air traffic controllers from Stockholm ACC[20] and air traffic controllers from the control tower in Kiruna. Interviews have also been conducted with personnel from the Swedish Armed Forces, the Swedish Maritime Administration’s air rescue centre at JRCC[21], the Norrbotten County Police, the rescue services in Kiruna and the County Administrative Board of Norrbotten.

The information presented only constitutes the information provided by the interviewees and thus does not contain any assessments or conclusions by SHK.

[20] Area Control Centre.

[21] JRCC: Joint Rescue Coordination Centre, that is the sea and air rescue centre.

1.2.1 Interviews with personnel in the Norwegian Air Force

The interviews with pilots of the Royal Norwegian Air Force have revealed varying information as to how the planning and preparations for a flight are performed. In summary, it can be said that more detailed planning and preparations are made when the flight covers areas and locations not previously visited. Furthermore, it has been stated that more planning is required in the case of flights with tactical elements. In addition, differences among the pilots also emerged in terms of knowledge regarding the derivation of the minimum safe flight level.

One pilot explained that the mission that *HAZE 01* was flying was considered to be routine and did not require particularly great preparations. Furthermore, the pilot who performed the planning for an earlier mission on the route in question explained that he proceeded from the highest obstacle on the route section of 6,864 feet (Kebnekaise) and then added 2,000 feet, to then round up to the nearest hundred feet. This resulted in an ESA of 8,900 feet. The pilot further explained that the altitude was computer-calculated and covered a distance of 22 NM on either side of the last planned route section.

Furthermore, it emerged that *doghouses* in LFC charts could be tailored according to various pilots' preferences, but that the mobile computer system that was used for flight planning during the exercise offered few variations for such doghouses, in which case the option considered most suitable for the flight was selected. It also emerged that the charts of the type DOD are always found on the aircraft, and that the ENC charts were included in the personal "crew bag."

One pilot stated that he would use a chart of the type DOD or ENC for an IFR flight in the Nordic countries. When flying in another and a little more unknown place, he would use a product from Jeppesen.

According to the pilots, there have been a large number of error warnings with GCAS, and the week prior to the event, one pilot experienced four error warnings in the system.

In an interview with the *Mission Support* department, it was stated that the crew in question was carrying what was needed for the flight. A tactical movement during the mission was not relevant because the weather did not permit this. It was also mentioned that at *Mission Support*, no assessments of the terrain had been made on the LFC chart. No discussion of Sweden's highest mountain was held by the crew during the time they were at *Mission Support.* It was further explained that charts of Sweden had been received from the Swedish representative in the tactical cell, but that the charts were never used during the exercise.

Similarly, it was stated that the crew requested the weather for the different airports in the area, and that a standard set of chart information was entered on a card in the aircraft.

Mission Support explained that they did not perform any Jeppesen planning, but that an ATS flight plan was issued as this was not a tactical flight.

Another pilot has stated that it was important for the mental process to plan the flight independently rather than receiving a completed one. Similarly, it was stated that trials had been performed where a finished product was received or a route taken over from someone else, which resulted in having an inferior tool compared with independent planning.

Regarding the question of how clearances from air traffic control are generally perceived and how great confidence was placed in these in various situations, it was stated that they have great confidence in the controller and the quality of what is supplied.

Regarding the transition from the H to the J model of the aircraft C-130, it has been stated that this worked very well and that the course in the United States was intensive, professional and demanding. It also emerged that the new model, that is the J model, is highly automated and that it had been a major transition from the old to the new system, which also meant that the new version no longer has a navigator and that in the new version, the crew members have a greater need to monitor each other. It was also stated that the new model entailed that there was a better situational awareness (SA) and that a *moving map* system is used to maintain SA. However, it was also discovered that it was beneficial to have a navigator in stressful situations when flying with the J model, and thus improve situational awareness. The interviews have revealed that previous navigators have not, as far as is known, been involved in quality assurance in terms of ensuring previous duties are retained in the crew configuration in the new model.

It was further reported that not much information about GCAS/TAWS was received on the conversion course in Little Rock. At the Block 6.0 Upgrade that, among others, the commander on *HAZE 01* had completed, the limitation on the tactical database was explained. Similarly, information was given about the fact that they thus did not have coverage north of 60 degrees North, something which evoked a response as they normally flew in this area.

The interviews and other fact gathering revealed that the following duties could be performed by the navigator on the former aircraft model:

- Flight planning, keeping the flight log.
- Diplomatic clearance, ATS flight plan.
- Navigation.
- Communication with ATC en route.
- Use of radar with a focus on weather and terrain.
- Airborne Radar Approach.
- Management of the countermeasures panel (Chaffs/Flares).

Furthermore, it has been described that the manuals for tactical flight were actually copies of manuals from the U.S. Air Force (USAF).

Several of the interviewees have stated that the commander on *HAZE 01* was considered to be the most experienced commander by far on the C-130 from the Royal Norwegian Air Force. The co-pilot was considered to have “little” experience, but competent, and to have respect for the commander. It was also expressed that it was difficult to surpass the co-pilot with regard to knowledge of systems on the aircraft.

1.2.2 Interviews with the crew on TORCH 03

The interviews with the crew on *TORCH 03* revealed the following:

Shortly before take-off, the pilots on *TORCH 03* visited the crew on *HAZE 01*, and they gathered at the front, in the cockpit, to carry out a *plane side brief*. The commander on *TORCH 03* explained that their intentions were to fly to the holding pattern, wait there for a signal and subsequently fly to Kiruna. The commander on *HAZE 01* explained that they intended to fly directly towards Kiruna from the holding pattern and then cancel IFR and go VFR to Kiruna. The commander on *HAZE 01* also pointed out that they had Satcom[22] and that they would call *TORCH 03* later during the flight.

The commander on *TORCH 03* informed *HAZE 01*'s commander that *TORCH 03* would try to fly VFR, but considering that their system was older, they were not sure that this was possible. Furthermore, they did not have access to Swedish VFR charts and they therefore decided that they would fly IFR and, if possible later, VFR if weather permitted.

The commander on *TORCH 03* explained during the interview that the weather during the flight was not good enough for flying VFR. According to the commander on *TORCH 03*, everything felt normal on board *HAZE 01* before the flight, and the commander on *HAZE 01* is also said to have shown a chart sheet with the planned flight. The crew of *HAZE 01* offered this "*Falcon View*" chart to the crew of *TORCH 3* but they declined.

Once up and established in holding, *HAZE 01* announced that their Satcom was not functioning and that they had tried UHF but that they were unable to make contact. In holding, *TORCH 03* had visual contact with *HAZE 01* because they were above the cloud cover, but beneath them was a solid layer of cloud.

1.2.3 Interviews with ANS personnel (Sweden control)

<u>*Air traffic controller; ACC-E has stated the following during interviews*</u>

The shift in question was the first shift of the day for the controller, and there were many flights from the Cold Response exercise in the airspace. After a while, the controller received coordination from Bodö regarding *HAZE 01* and a little later *HAZE 01* also called up. There was then no radar contact with the aircraft, which was communicated by the controller. Shortly thereafter, *HAZE 01* requested to perform a "visual on Kiruna." The controller then directed *HAZE 01* to take this up later with Kiruna Tower. A coordination took place with the controller in Kiruna so that ACC-E could descend *HAZE 01* to Flight Level 100.

The controller had the current sector altitudes [for Kiruna] (see 1.10.2) in mind in connection with the clearance being given to *HAZE 01* and therefore did not give thought to the fact that the YKL[23] lower limit was Flight Level 125 in the area in question. The controller stated that since Kiruna had a lower TMA than usual, it was agreed with the controller in Kiruna to descend *HAZE 01* to Flight Level 100.

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[22] Satellite communications.
[23] Yttäckande Kontrollerat Luftrum (Area-type Controlled Airspace).

Because the controller could not see *HAZE 01* on the radar, it was not possible to know on which side of the border (Sweden/Norway) the aircraft was when it called on the frequency. The controller also thought that the weather was probably good on the route in question because *HAZE 01* informed him of their interest in performing a visual approach to Kiruna. The controller did not reflect on whether or not *HAZE 01* had the field in sight because the controller did not know exactly where the aircraft was situated.

It was not common to have traffic to Kiruna from the west, and it was probably the second time the controller had ever experienced this.

The controller also stated that the radar coverage, especially in the northern sectors, can vary somewhat with the weather. At Kiruna, it sometimes happens that the aircraft are no longer visible on radar at Flight Level 100 or slightly above; sometimes the aircraft disappear at Flight Level 70.

Military exercises always mean a higher workload. During the shift in question, the workload was medium or high.

Collaboration with Kiruna Tower worked well. The ACC controllers phone in with estimated arrival and handover messages to Kiruna Tower. Kiruna is not particularly busy with traffic.

Changes concerning the operational work are usually provided to the controllers at ACC through daily self-briefing. If there are major changes concerning new points, routes and collaborations, there are verbal briefings. At the self-briefing, the information is divided into that which is applicable to all and that which is applicable to certain ratings. The controller carried out a self-briefing just before the shift began.

The controller stated during the interview that Kebnekaise was not marked on the radar chart.

Air traffic controller; ACC-P has stated the following during interviews

The shift in question was the first shift of the day. The controller had been working between 15 and 30 minutes when he received coordination from Bodö that *HAZE 01* was on its way to Kiruna. The flight was at Flight Level 130 towards Kiruna VOR, direct Kiruna. The controller then rang up Kiruna and coordinated with them and asked if it was OK to go towards KRA in order to join the STAR. The controller then gave an estimated arrival to the controller in Kiruna.

According to ACC-P, they could not see *HAZE 01* on the radar and therefore did not know exactly where the aircraft was situated. They gave descent to Flight Level 100, which is not standard procedure to Kiruna. The air traffic controller stated that they usually descend to Flight Level 160 since Kiruna normally borrows air above its TMA up to Flight Level 155.

The controller also stated that the workload goes up and down while sitting at the P position and that it felt very straining when they had the aircraft in question.

With regard to the supplement[24] that became applicable on 15 March 2012, the controller did not know this until after the shift in question and does not remember whether or not it was part of the self-briefing.

At the time of the event in question, the controller had no experience of flights from the west.

The controller stated that he does not know why they did not think of the fact that YKL lower limit up in the north-west corner was Flight Level 125.

Air traffic controller; Control tower in Kiruna has stated the following during interviews.

At the occasion in question, there was not a particularly heavy workload, though according to the controller there was more to do than normal that day. Essentially it was just a matter of *TORCH 03*, *HAZE 01* and *HAZE 02*, as well as a police helicopter. It was "great weather" at Kiruna Airport, though there was a certain amount of wind. The controller maintains that on such a clear day, you can see Kebnekaise from the tower.

The air traffic controller stated that Kiruna has TMA up to Flight Level 95, but usually "borrows" air from Stockholm up to Flight Level 155 to make it easier to deal with meetings at higher altitude as the radar coverage is poor at lower flight levels. This means that traffic usually comes descending to Flight Level 160, according to the controller.

During interviews, the air traffic controller said that when *HAZE 01* requested a *"visual approach, when approaching",* the controller perceived this to mean that *HAZE 01* was VMC in order to continue flying VFR. However, *HAZE 01* never said *"cancel IFR",* and the controller never asked *"confirm you are proceeding VFR from now".* According to the controller, no such clarification took place, and the latter also felt that as the weather was so fine, it was clear that *HAZE 01* would receive permission for a visual approach. However, the controller stated that the pilot is required to report *"field in sight"* before a clearance of this type can be issued, which the pilot on HAZE 01 did not do, according to the air traffic controller.

The air traffic controller stated that, as TORCH 03 was situated at about 5000 feet, the next usable level was Flight Level 70. In order to separate *TORCH 03* from *HAZE 01*, *HAZE 01* thus received a clearance to Flight Level 70. The clearance was an IFR clearance. Had there been no traffic, *HAZE 01* would have been able to receive clear approach directly, according to the air traffic controller.

The controller also explained that outside the TMA it is the pilot's responsibility to maintain obstacle clearance, and the controller can always give MSA *(Minimum Sector Altitude)* as the lowest altitude in to the TMA, if traffic permits this. If traffic is coming to the south sector, descent can be permitted to 5,000 feet, which is the minimum sector altitude. The controller also stated that if the pilot in that case elects to go down to 5,000 feet, 100 NM from Kiruna, it is the pilot's

[24] The supplement related to changes resulting from the Swedish Transport Agency's Regulations and General Advice on Air Traffic Services (ATS), TSFS 2012:6.

responsibility. According to the controller, no confirmatory questions are ever put to the pilot as to whether he is aware that there is any mountainous terrain in the area. The controller also said that there are no procedures in Kiruna for providing separation with respect to Kebnekaise's peak and that Kebnekaise lies far outside the TMA .

The controller stated that he did not know that YKL in the area in question was Flight Level 125, even though from training, he was aware that YKL in the mountain area was higher than in the rest of Sweden.

According to the controller, it is sometimes appropriate to announce *"You will enter uncontrolled airspace below flight level 95"* or something similar, but never when there is no radar contact. The controller states that, had he seen an aircraft at 5,000 feet 50 NM west of the TMA, he would naturally have asked: *"What are you doing?".* If an aircraft leaves controlled airspace for uncontrolled, and it is known that there is no traffic there, "*no reported traffic*" is added, according to the air traffic controller.

The manager of the control tower in Kiruna stated the following during interviews

Kiruna has TMA up to Flight Level 95 and borrows from Stockholm up to Flight Level 155. For military operations, Stockholm takes back the air and issues it to STRI. It is ACC that coordinates with STRI, and Kiruna coordinates with ACC. With regard to the supplement that applied from 15 March 2012, the manager of Kiruna Tower did not see it until 16 March. A few days earlier, Kiruna Tower received an e-mail containing information that the supplement would concern radar vectoring in uncontrolled airspace. Since this is not something used in Kiruna, the manager of Kiruna Tower did not attach any importance to it.

Over the past year, there had been a lack of personnel due to sick leave and parental leave, which had prompted the manager of Kiruna Tower also to perform administrative managerial duties during operative duty or on her time off.

In order for controllers serving in Kiruna to gain a perception of the surrounding terrain and an improved situational awareness, there are occasional instances of their driving around by car in the control zone to look at the geographical points that pilots can make use of. Formerly, they have instead flown around in both the TMA and the control zone, but to save money such flights have ceased. It also emerged during the interview that there has been a transition from double manning to single manning in the tower in order to cut costs.

1.3 Injuries to persons

	Crew	*Passengers*	*Total*	*Other*
Fatalities	4	1	5	–
Serious injuries	–	–	–	–
Minor injuries	–	–	–	N/A
Unharmed	–	–	–	N/A
Total	4	1	5	–

All those killed belonged to the Norwegian Air Force and have been identified through DNA analyses.

The work to collect and attend to the remains of those killed, and to perform identification of the deceased, has been carried out by personnel from the Swedish National Bureau of Investigation and the National Board of Forensic Medicine in Umeå.

1.4 Damage to the aircraft

The aircraft collided with the Kebnekaise massif, just below the ridge between Kebnekaise's south and north peaks at an altitude of 2,014 metres. The aircraft broke up very severely, see Fig. 5.

Fig 5. Parts of the wreckage collected in a hangar in Kiruna. (Picture: SHK)

1.5 Other damage

There was fuel and oil spillage at the accident site. At the time of the accident, there were approximately 8,900 kg (corresponding to approximately 11,100 litres) of aviation fuel JP-8, approximately 50 litres of hydraulic oil and approximately 170 litres of engine oil on board the aircraft.

In addition to this, there was material at the accident site that could pose risks in the form of battery acid, soot, damaged tyres, glass, chemicals, sharp-edged parts, damaged pressure vessels as well as composite materials such as carbon fibre.

The aircraft was equipped with countermeasures in the form of flares and chaff, which due to built-in gunpowder charges constituted a great risk in the salvage work. These were detonated on site.

During the work at the site of the accident, SHK has salvaged a total of approximately 15 tonnes of the aircraft, representing approximately 37 per cent of the empty weight. Measures to clean up the site of the accident have thereafter been taken by the National Property Board of Sweden.

The accident site is situated in an area with very high nature values.

1.6 Flight crew and air traffic controllers

1.6.1 Commander

The commander held the rank of captain, was 42 years old at the time and had a valid Norwegian military licence and ATPL theory.
At the time of the accident, the commander was PM[25].

Flying hours				
Last	24 hours	7 days	90 days	Total
All types	1,5	13	25	6,153
This type	1,5	13	25	5,937
This model	1,5	13	25	742

Number of landings on this type, last 90 days: 17.
Type rating on the type C-130 concluded on 16 June 1994.
Type rating on the model C-130J concluded on 28 August 2008.
Latest renewal of military instrument rating concluded on 3 February 2012 on the C-130J.

1.6.2 Co-pilot

The co-pilot held the rank of lieutenant colonel, was 46 years old at the time and had a valid Norwegian military licence and completed training with regard to ICAO commercial pilot theory.
At the time of the accident, the co-pilot was PF[26].

Flying hours				
Last	24 hours	7 days	90 days	Total
All types	1,5	9	18	3,285
This type	1,5	9	18	243
This model	1,5	9	18	91

Number of landings of this type, last 90 days: 11.
Type rating on the model C-130J concluded on 23 August 2011.
Latest renewal of military instrument rating concluded on 3 January 2012.

[25] PM – Pilot Monitoring – The pilot who is not manoeuvring the aircraft.
[26] PF – Pilot Flying – The pilot who is manoeuvring the aircraft.

1.6.3 Loadmaster 1

Loadmaster 1 held the rank of captain, was 45 years old at the time and had a valid Norwegian military loadmaster certificate.

Flying hours				
Last	24 hours	7 days	90 days	Total
This type	1,5	9	61	1,590
Type model	1,5	9	61	617

Flight mechanic training on the model C-130E completed on 19 September 2004.
Loadmaster training on the model C-130J completed on 11 March 2010.
Latest renewal of loadmaster rating concluded on 21 October 2011.

1.6.4 Loadmaster 2

Loadmaster 2 held the rank of captain, was 40 years old at the time and had a valid Norwegian military loadmaster certificate.

Flying hours				
Last	24 hours	7 days	90 days	Total
This type	1,5	16	67	3,004
This model	1,5	16	67	752

Loadmaster training on the type C-130 completed on 5 June 2000.
Loadmaster training on the model C-130J completed on 20 November 2009.
Latest renewal of loadmaster rating concluded on 05 October 2011 on the C-130J.

1.6.5 The passenger

The passenger was a helicopter pilot from the Norwegian Air Force and was 35 years old at the time.

1.6.6 The crew members' duty schedule during the period in question

The crew was participating in the military exercise *Cold Response*. On 13 March, the crew performed four flight missions in a total of 5 hours and 12 minutes. On the evening of 14 March, a flight mission of 1 hour and 22 minutes was flown. Duty that evening ended at 21.08 hrs, and the crew returned to the hotel at 22.40 hrs. On 15 March, duty began at 09.55 hrs with a planning meeting.

1.6.7 The air traffic controller (E- executive) Stockholm ACC

The controller at the E position (see Section 1.10.4) was 32 years old at the time, had a valid air traffic controller licence since 1 April 2011 and had served from that date with a Z rating.

1.6.8 The air traffic controller (P- planner) Stockholm ACC

The controller at the P position (see Section 1.10.4) was 26 years old at the time, had a valid air traffic controller licence since 20 January 2012 and had served from that date with a Z rating.

1.6.9 The air traffic controller in Kiruna

The controller at Kiruna Tower was 35 years old at the time, had a valid air traffic controller licence since 25 March 2010 with a rating for Kiruna Tower from 8 December 2011. The person in question carried out his latest emergency training on 29 September 2011. The course, held in Umeå, included simulator training.

1.6.10 The air traffic controllers' duty schedule during the period in question

The controller at the E position at Stockholm ACC was off duty between 11 and 13 March and was on duty on 14 March between 14.00 hrs and 21.30 hrs. On 15 March, the shift began at 14.00 hrs and was scheduled to last until 21.30 hrs.

The controller at the P position was off duty on 10-11 March. On 12 March, at 22.00 hrs, the person in question began a shift that lasted until 06.45 hrs the following morning. A corresponding shift was also begun on the evening of 13 March. The subsequent shift commenced at 14.30 hrs on 15 March.

Afternoon shifts for the controllers at Stockholm ACC overlap each other by 15-30 minutes, which according to information from LFV provides time to carry out self-briefing. Shifts during mornings do not have this overlap and the controllers are therefore to carry out self-briefing at the beginning of the shift.

The air traffic controller at Kiruna was scheduled to work on 15 March 2012 from 14.00 hrs to 22.30 hrs. However, the person in question already began his shift at 12.00 hrs as a need arose to relieve a colleague. The controller was stationed in another town but served alternately between this town and Kiruna. Between 8 and 14 March 2012, the controller was stationed in the other town and was off duty on 12-14 March. On 14 March 2012, the controller travelled to Kiruna.

At Kiruna Tower, the time for handover and self-briefing is 30 minutes between the morning shift and the afternoon shift. Those on duty during the morning shift begin work 10 minutes before the airport opens, at which time they acquaint themselves with log entries from the preceding evening shift.

1.7 Aircraft information

1.7.1 General

The *C-130J Super Hercules,* see Fig. 6, is a four-engine transport aircraft, intended for the transport of personnel and materiel. The maximum number of passengers is 128.

Power is supplied by four turboprop engines with six-bladed variable pitch propellers. The engines are equipped with digital control units, *FADEC (Full Authority Digital Electronic Control)*.

The fuselage is divided into the flight station and cargo compartment. The entire fuselage can be pressurised by the cabin pressure system.

In its military configuration, the C-130J has a minimum crew of two pilots and one loadmaster. The commander and the co-pilot sit on the left and the right sides of the cockpit, respectively. A seat for a third crew member is positioned behind the centre console.

Fig. 6. The aircraft that crashed, C-130J-30 Super Hercules "SIV" of the Norwegian Air Force. (Picture: The Norwegian Armed Forces).

1.7.2 *Technical data*

Aircraft				
TC holder	Lockheed Martin Aeronautics Company			
Model	C-130J-30 Super Hercules			
Serial number	5630			
Year of manufacture	2010			
Gross mass	Max authorised take-off/landing mass is 74,390/74,390 kg (164,000 lbs), actual take-off mass was 52,030 kg			
Centre of gravity	At take-off: Threshold 15-30% MAC, actual 23.2%			
Total flying time	856.16 hours			
Flying time since latest inspection	71.29 hours			
Number of cycles	No information			
Fuel loaded before event	4,470 litres JP-8 (NATO ref F-34)			
Engines				
TC holder	Rolls-Royce Corporation			
Model	AE2100D3			
Number of engines	4			
Engine	*Nr 1*	*Nr 2*	*Nr 3*	*Nr 4*
Serial number	CAE-540906	CAE-540918	CAE-540920	CAE-540921
Total operating time, hours	853.53	853.46	853.42	853.43
Operating time since last inspection, hours	853.53	853.46	853.42	853.43
Operating time since last overhaul, hours	68.66	68.59	68.55	68.56
Propeller/Rotor				
TC holder/manufacturer	Dowty Propellers			
Model	R391/6-132-F/3			
Serial number	DAP0901	DAP0786	DAP0951	DAP0953
Total operating time	853.53	820.96	853.42	853.43
Operating time after inspection/overhaul	853.53	820.96	853.42	853.43
Operating time limits	No information			
Remarks on the aircraft				
MEL[27]	None			
Outstanding remarks	See 1.7.5			

The aircraft was delivered from Lockheed Martin to the Norwegian Air Force in June 2010 as the last of four C-130Js ordered.

[27] MEL: Minimum Equipment List, lays down minimum technical requirements and specifies which systems and functions are necessary for flight.

Designation
C-130J-30 is the manufacturer Lockheed Martin's designation for the extended variant of the C-130J. The C-130J-30 is 4.6 m longer than the C-130J. Both variants are referred to as *"Super Hercules"*. The official designation in the U.S. Air Force, among others, is *"CC-130J Super Hercules"*.

1.7.3 *Airworthiness and maintenance*

The aircraft had a valid Certificate of Airworthiness, issued on 1 February 2011 by the *U.S. Department of Defense*. The certificate was issued in accordance with *U.S. Air Force Policy Directive 62-6* and confirms that the aircraft was built in accordance with approved design *(Block 6.0 Upgrade)* and is in a condition that guarantees safe function. Responsibility for continuous airworthiness and the certification of any design changes is stated to be incumbent upon the State of Norway.

The latest inspection, known as A-check, was conducted in January 2012 at the home unit of Gardermoen. The next inspection, a C-check, was scheduled for 28 July 2012.

The *post-flight check* after the latest landing was carried out at 00.30 hrs on the day of the accident. The *pre-flight check* was carried out at 04.20 hrs on the day of the accident.

SHK has found nothing to suggest anything other than that the aircraft was maintained in accordance with the approved maintenance programme and other approved applicable maintenance data.

1.7.4 *Aircraft manual*

The aircraft manual consists of a technical and an air operational section. The technical manual is extensive; the list of current technical publications alone comprises about 35 A4 pages.

The flight operations manual includes system descriptions, instructions and checklists for crew members. The section of the manual constituting the *Flight Manual* comprises over 2300 pages.

1.7.5 *Outstanding remarks*

At the beginning of the flight, the aircraft had two outstanding remarks, noted on the handover sheet.

Remark 1 relates to a broken spring of the locking device for the left cargo door: *"L/h aft cargo door downlock spring is broken"*.

Remark 2 relates to an error when setting IAS *(Indicated Air Speed)* on the *Reference Set Panel* (speed hold mode in the autopilot): *"IAS on REF. SET. PANEL will not stay on selected setting, unstable"*.

SHK has had access to the aircraft MEL, dated 8 December 2009. The outstanding remarks in question did not affect the airworthiness of the aircraft.

1.7.6 External dimensions of the aircraft

The external dimensions of the aircraft are shown in Fig. 7.

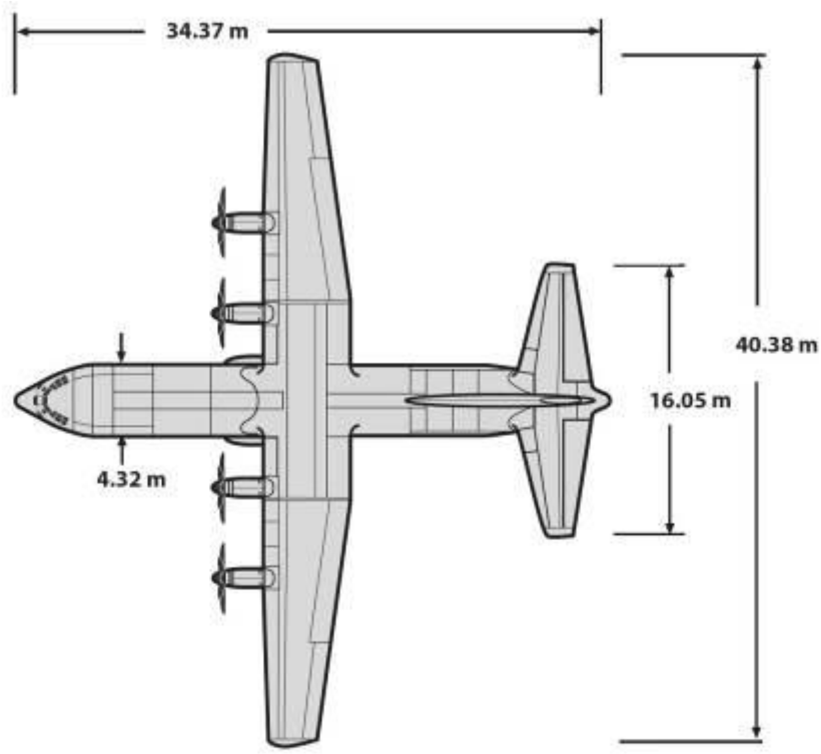

Fig. 7. External dimensions of the C-130J Super Hercules.

1.7.7 Avionics

The cockpit is equipped with four multifunction screens (known as a glass cockpit) for flight instrumentation and navigation systems, see Fig. 8, and each pilot also has a line-of-sight indicator, known as a *HUD (Head-Up Display)*.

Fig. 8. Cockpit C-130J. (Photo: Norwegian Air Force.)

On the multifunction screens, also known as HDD 1-4 *(Head Down Display)*, pilots can select different presentations, such as PFD *(Primary Flight Display)*, engine instruments, system status, digital map, information from the aircraft's weather and navigation radar or information from the aircraft's systems for ground collision avoidance and terrain avoidance (GCAS/TAWS). Two system computers, *Mission Computers*, operate and monitor the avionics systems.

The C-130J is equipped with an *Enhanced Traffic Collision Avoidance System* (E-TCAS).

1.7.8 Aircraft systems for Ground Collision Avoidance and Terrain Avoidance

Radar altimeters

There are two identical radar altimeters installed in the aircraft, RADALT 1 and 2. Each radar altimeter system is a solid-state pulse system which measures and displays altitude up to 50,000 feet. Radar altitude is presented on the PFD as a boxed digital readout, below and to the left of the altitude scale, with the text AGL above the box. Below the digital readout, a radar altitude reference set value is presented. When the aircraft is at or below the reference value, the digital readout changes from white to amber. The radar altitude readout can also be shown whenever the radar altitude is 5,000 feet or below. The altitude is presented as a digital readout after the letter R, directly below the altimeter (see Fig. 9).

Fig. 9. Picture of the Head Up Display, HUD, with the current radar altitude circled in yellow. (Picture: Norwegian Air Force)

GCAS/TAWS

The aircraft systems for ground collision avoidance and terrain warning avoidance consist of two integrated subsystems, GCAS *(Ground Collision Avoidance System)* and TAWS *(Terrain Awareness [28] and Warning System)*. GCAS works with

[28] The expression Terrain Avoidance and Warning System is also used in parts of the aircraft documentation.

the aircraft's radar altimeter and “looks” down, while TAWS sees forwards/downwards along the direction of flight by means of terrain databases.

GCAS/TAWS works in two different modes, *Normal* and *Tactical*. Mode selection is made by the pilots in the GCAS/TAWS menu in the AMU *(Avionics Management Unit)*, centrally placed in the cockpit in front of the pilots. The mode selection *Normal*/*Tactical* in the AMU simultaneously controls the GCAS and TAWS. On power up, the default value is *Normal*.

The sound recording on the CVR revealed that the pilots acknowledged the switching of TAWS to the “*Tactical*” mode while flying in the holding pattern at 13.59 hrs (about 1 hour before the collision).

Normal mode gives an advance warning to the crew, equivalent to about 40-60 seconds of flight before the impending collision, which is comparable to the warning characteristics of similar systems in civil aircraft. In *Tactical,* the warning thresholds are modified so that the aircraft can be flown tactically without giving unwarranted warnings, such as in controlled tactical low-level flight. The *Look Ahead Distance (*LAD) in *Tactical* is about 50% shorter than in *Normal,* which entails reduced margins for the avoidance of ground collisions. The width of the area covered by TAWS is dependent on the current estimated navigational error, but is in the forward section at least around 190 m (0.1 NM).

When GCAS/TAWS is in *Tactical*, the TAWS *Minimum Operating Altitude* (MOA) can be adjusted by the pilot. MOA can be described as the height of the forward-facing box in which the warning system operates. The choice of MOA dramatically affects the margins for terrain warning so that lower values give a later warning. The MOA setting is limited to 0 to 2,500 feet AGL. For the flight in question, a MOA of 200 feet was chosen, according to audio recordings of commands.

At the time of the accident, there was no operational restriction within the Norwegian Air Force relating to the use of *Tactical*, but the decision as to the appropriateness of using this mode selection had been left to the commander.

The aircraft MEL permits flight without GCAS and TAWS, though with certain restrictions. Flying without GCAS presupposes that no passengers are being carried; flight without TAWS is accepted if the mission does not require this function, and it presupposes considerations regarding, among other things, terrain, flight altitudes, route characteristics and the crew's experience of the route.

TAWS display:
The TAWS system provides a visual representation of terrain and obstacles, ”TAWS display”, which can be displayed on the pilots' HDD. The TAWS terrain and obstacle video image is displayed on the TAWS display. The terrain and obstacles appear as variable density dot patterns in black, green, yellow, or red. Areas with “unknown terrain” are marked with magenta-coloured blocks.

For terrain or obstacle warnings, the TAWS display appears automatically on the *Head Down Display 3*, known as *TAWS Pop-Up*. According to what emerged in the interviews conducted, it was not common for the TAWS display to be selected in the basic configuration of the cockpit, but crews are reported to rely on the TAWS Pop-Up function.

In *Tactical* mode, the function TAWS Pop-Up can be switched off ("POPUP INHIBIT") in the GCAS/TAWS menu in the AMU.

Warnings:
Visual and audible warnings are presented jointly to GCAS/TAWS. Audible warnings are provided through the internal communication system (ICS) in the form of voice messages and in some cases a "whoop, whoop" warning tone. The visual warnings are presented in the special alert box at the top centre of the HUD displays and at the top centre of the HDD PFD.

Warnings are given on two levels, *Cautions* and *Warnings*. TAWS *Cautions* are given as "TERRAIN AHEAD" or "OBSTACLE AHEAD" and require prompt but moderate adjustment of the flight controls within 3 to 5 seconds to return to safe flight conditions. TAWS *Warnings* can be given as "TERRAIN PULL-UP" or "OBSTACLE PULL-UP", combined with a warning tone ("whoop"). This level requires an evasive manoeuvre with *immediate and aggressive action* within 1 to 2 seconds in order to avoid a collision. Calculated action for such an evasive manoeuvre requires full aircraft performance, that is, maximum allowable G-load and thrust.

In Tactical mode, the terrain warning system can be switched off ("TERRAIN INHIBIT") in the GCAS/TAWS menu in the AMU. Terrain inhibit is intended to be used, for example, in tactical low-level flight in mountainous terrain where the terrain warning would otherwise be given continuously and constitute a distracting element.

TAWS databases:
TAWS utilises two different levels of Terrain data, delivered in different formats. In *Normal* mode, a commercial database with lower resolution is used. In *Tactical* mode, a high resolution tactical database is used. Both databases are built on a terrain database *(DTED, Digital Terrain Elevation Data)* and an obstacle database *(DVOF, Digital Vertical Obstruction File)*.

- TAWS in *Normal mode:* Commercial database.
  - Terrain and obstacle database from *Honeywell*.
  - Standard resolution terrain data: *Honeywell DTED level 1 =* 1,000 m x 1,000 m, level 2 = 500 m x 500 m.
  - Coverage: Terrain and obstacle data is worldwide.

- TAWS in *Tactical mode:* Tactical database.
  - Terrain database from *NGA, US National Geospatial Intelligence Agency*.
  - High resolution terrain data: *NGA DTED level 1 =* 100 m x 100 m, level 2 = 30 m x 30 m.
  - Coverage of terrain data: From latitude 60˚ N to 56˚ S. No terrain data is available north of 60˚ N or south of 56˚ S.
  - Obstacle database from NGA.
  - Coverage of obstacle data: Worldwide.

The 60th parallel north passes just outside Oslo and Uppsala, see Fig. 10. At the accident site, the aircraft with TAWS in *Tactical* mode has no forward-facing terrain avoidance function due to the limitation in tactical terrain data. North of 60° N, the warning system is thus limited to “downward-looking” GCAS, while the forward-looking capability only covers obstacles such as masts and towers with a height above ground level ≥ 100 feet (about 33 metres).

Fig. 10. Map of Scandinavia. In the red area, TAWS in Tactical mode has no terrain warning function. The crash site is marked with a red star (Map view from Google Maps)

According to information to SHK, the tactical databases in the Norwegian Air Force's C-130Js have not been updated since the aircraft were delivered.

<u>*Text message TAWS TACTICAL VOID*</u>*:*

The limitation in TAWS is announced by a warning at the lowest level *(advisory message)* in the warning system *ACAWS (Advisory, Caution And Warning System)*. The advisory message is presented as a text message on the ACAWS panel, *TAWS TACTICAL VOID*, accompanied by an audible signal (ping).

According to the aircraft's emergency checklist, included in the flight manual, the message *TAWS TACTICAL VOID* arises for three different reasons:

a. No TAWS database data is available due to operations at latitudes greater than 60 degrees North or 56 degrees South.

b. The database has insufficient terrain data, i.e., the system perceives that terrain cells along the flight path contain voids, compare fig. 11.

c. TAWS is transitioning from *Normal* mode to *Tactical* mode. The message is visible for the time it takes for the system to load the high resolution database. According to the flight manual, this can take about 30 seconds, but reportedly, loading normally takes just 10-15 seconds in practice.

Under *"Crew action"* for the present low-level warning, the emergency checklist states that no action is expected to be taken by the crew and that no terrain or obstacle warnings are given as long as any of the criteria are fulfilled:
None. No alerts will be provided while any of these conditions exist.

None. No alerts will be provided while any of these conditions exist.

TAWS TACTICAL VOID is displayed for a certain time on the ACAWS panel on the *Head Down Display* that displays engine instruments. According to the flight manual, the message is to be visible until the criterion for the warning disappears or until it is stored on the *"ACAWS OVERFLOW page"* on any other *HDD*. However, the message also disappears north of 60˚ N when the aircraft enters an area with input obstacles in the form of masts or towers. Obstacles are common even north of 60° N. When the text message disappears, this happens without any audible signal being given.

Areas that are completely without data are presented by the TAWS display in magenta, see Fig. 11. The picture presents areas with input obstacles, but having non-existent terrain data, in black. Depending on the flight altitude in question, there are also instances of a blue background in such areas.

According to the flight manual, black means that the terrain separation is more than 2,000 feet. Blue represents sea level (MSL).

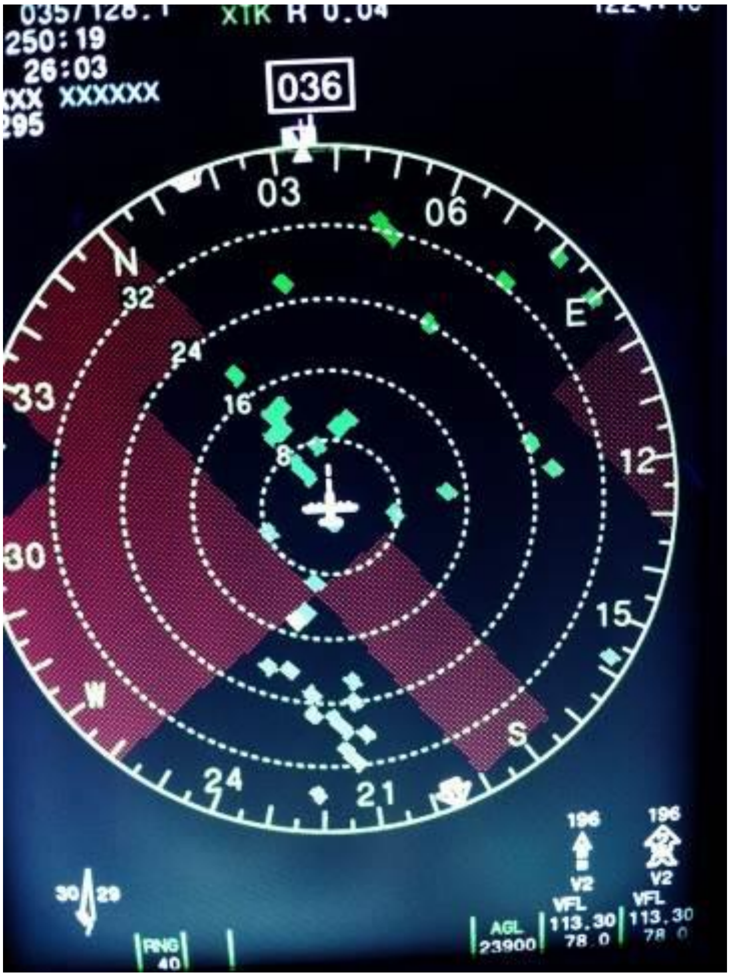

Fig. 11. Photo of the TAWS display at a position north of 60° N. Areas with “voids” appear in magenta. The green dots show obstacles. When flying in black areas, the VOID message is off. (Picture: Norwegian Air Force)

There are no obstacles on the Kebnekaise mountain or in the surrounding area to its west. The two masts in the area are located south-east and east of the accident site.

For the flight in question, CVR data shows that the message TAWS TACTICAL VOID occurs in connection with the selection of *Tactical*, as is evident from the acknowledgement tone from the ACAWS system as well as the comment “TAWS void” from a crew member. About 25 minutes after the selection of *Tactical*, the presence of the message is noted once again in a question from the loadmaster in the cockpit. The explanation then given by the commander is that the warning has been activated *“fordi vi er so høit” [“because we are so high”]*. High latitude (>60˚ N) is a criterion for the displaying of the “VOID” message, but current flight altitude is not a criterion.

The flight manual states that flying in rugged mountainous terrain may give too many terrain warnings due to the lack of resolution in the tactical database. The information about the limitation in the tactical database north of 60° N is found neither in the flight manual's system description nor in the chapter on Limitations, but has been made known through a supplement to the flight manual from 1 September 2008 *(“Supplement – Flight Manual, RNoAF C-130J”).* The supplement presents ten limitations of the aircraft's various systems. The TAWS limitation is one of these and is described using the following wording:

> “[---] Coverage of DTED in TAWS Tactical Mode is from 60°N latitude to 56°S latitude. Obstacle data, DVOF (Digital Vertical Obstruction File) is also published by NGA and is World Wide. TAWS Tactical Mode may be used, however, TAWS may not give proper terrain warning and display terrain as described in the Flight Manual outside the coverage area mentioned above.”

The emergency checklist provides a number of other ACAWS messages linked to TAWS. One example is the message *“TAWS TACT NOT AVAIL”,* which is described as follows:

> TAWS alerts […] are not available in TACTICAL mode due to external faults or corrupted database, or the TAWS Tactical database cartridge is not inserted.

Error issues:
False alerts from GCAS/TAWS have been reported from all four Norwegian C-130J aircraft. The false alerts have, in all but one of the cases known to SHK, occurred in the *Normal* mode. Among the probable causes of error that have been stated are interference between the two radar altimeters, a too low presentation of radar altitude in relation to reality as well as possible measurement error due to snow-covered ground.

A *Material Deficiency Report Category II*, relating to error issues on the radar altimeters on all four Norwegian C-130J aircraft, was submitted by the C-130J unit *(135 Air Wing)* on 5 January 2011. The grounds for this report are stated to be problems with a GCAS false alert in various flight regimes and conditions. The problem is classified as a serious flight safety issue linked to the risk of lower confidence in the Ground Collision Avoidance System.

The log attached to the error report shows that the crashed aircraft (5630) had a higher number of false alerts compared with its three sister aircraft.

To prevent false alerts, the Norwegian Air Force had at the time of the accident introduced a procedure initiated by Lockheed and the U.S. Air Force. The procedure involves both pilots selecting the same radar altimeter at flight altitudes above 10,000 feet AGL.

Training:

Type rating on the C-130J, which was the pilots' first contact with GCAS/TAWS, was carried out by the U.S Air Force at Little Rock (Arkansas, United States) in areas well south of 60° N. The theory part of the training involves, according to information SHK has received from the U.S. Air Force, one hour of tuition on TAWS. The training documentation is dated 2012, and SHK has not been able to see the documentation that was valid at the time of the C-130J training for the commander and co-pilot (2008 and 2010 respectively).

The theory parts of the training also encompass a computer-based course offering. The material to which SHK has had access includes a lesson on TAWS, which covers about 60 pages. The lesson includes an image of the VOID message, and the 60° N limitation is described as a “key point” concerning the *Tactical mode*.

None of the check questions that conclude this lesson deal with the limitation. Nor does the summary of the lesson do this.

Several of the pilots at the squadron in question have stated that before the accident, they had certain limitations in their knowledge of TAWS functions north of 60° N. Several pilots also state that they perceive the occurrence and significance of the text message *TAWS TACTICAL VOID* as difficult to interpret. Similarly, it is stated that the training taught without closer explanation to put GCAS/TAWS in *Tactical* in conjunction with the *Combat Entry checklist* and at the same time also select both POPUP INHIBIT and TERRAIN INHIBIT.

System tests:
The TAWS function was part of the aircraft's Block 6.0 Upgrade that was installed in all C-130Js delivered to Norway. Prior to delivery, acceptance tests were performed on the individual aircraft in question by both the U.S. Air Force and the Norwegian Air Force.

The tests performed included flight tests of GCAS/TAWS, which included implementing tests of warning functions and the random check of the databases' function. All the tests were performed in the United States, in an area north of Atlanta, well south of 60° N. No specific flight tests of the system were carried out in Norway.

Registered alerts

Registered data shows that no terrain or obstacle warnings from aircraft systems for ground collision avoidance and terrain avoidance had been received before the collision.

During the flight in question, the CVR has a number of audible signals (pings) which mark the appearance of advisory messages, but which are not commented on by the crew. When advisory signals are not stored on the DFDR, the presence of advisory messages such as *TAWS TACTICAL VOID* cannot be read from the DFDR data.

1.7.9 Other

SHK has obtained information on the existence of pirate components in US-built aircraft. An investigation carried out by the Defence Committee of the U.S. Senate also indicates the existence of non-certified electronics parts in the C-130J, among others. SHK has obtained a written statement from the US Air Force to the Royal Norwegian Air Force which clarifies that pirate components on board the Norwegian C-130J meet the specifications and do not constitute a flight safety risk. There is nothing in SHK’s investigation that gives cause to suspect that these types of components would have had any significance in the incident.

1.8 Meteorological information

1.8.1 General

SHK has obtained information from several meteorological authorities and from several flight crews which had flown in the area in question at the time of the accident. The information was concordant and is therefore presented in brief.

The following meteorological units have contributed information:

- Swedish Meteorological and Hydrological Institute (SMHI)
- Swedish Armed Forces Meteorological and Oceanographic Centre (METOCC)
- SMHI's research group for meteorological analysis and prediction (FoUp)
- Weather Section of the Norrbotten Wing F 21 at Kallax, Luleå
- Norwegian Meteorological Institute
- Nansen Environmental and Remote Sensing Center, Bergen

Weather reports have been obtained from crews on the following aircraft:

- A pair of JAS 39s from the Swedish Air Force
- HAZE 02, C-130J Super Hercules from the Norwegian Air Force
- TORCH 03, C-160 Transall from the German Air Force
- SAINT 41, P-3 Orion from the Norwegian Air Force
- M515, M504, Merlin helicopters from the Danish Air Force
- SAVER 20, Sea King MK43 rescue helicopter from the Norwegian Air Force
- Swedish civil helicopter that was situated in the area.
- Swedish police helicopter, see Fig. 12.

Fig. 12. Picture taken from police helicopter at about 14.50 hrs in the direction south-west towards the crash site at a distance of approximately 30 kilometres. (Photo: Swedish Police)

1.8.2 *Swedish Meteorological and Hydrological Institute (SMHI)*

Weather on 15 March 2012, at 15.00 hrs local time at Kebnekaise according to SMHI's analysis:

Wind (Kebnekaise peak):	250° / 60-70 kts, possibly 80 kts.
Visibility:	<1 km in cloud and possible snow showers.
Cloud:	8/8 with the cloud base at 1 000-4 000 ft, cloud top Flight Level 90-100 with local peaks at Flight Level 160.
Temp. /dp:	-3 to -5°C/-3 to -5°C
QNH:	1000-1002 hPa.

Icing

There was a general risk of icing in convective clouds above 3,000 feet QNH (zero degree level). Model data indicated a high risk of icing on the west side (the windward side) of Kebnekaise. This, in conjunction with updraughts and the presence of supercooled cloud droplets, should have been able to give rise to moderate or possibly severe icing, most pronounced from 1,000 feet AGL to the peak of Kebnekaise.

Turbulence:
In the area, there was mechanical turbulence associated with strong southwesterly winds, assessed as moderate or locally severe from ground level to Flight Level 80, most pronounced over and on the leeward side of the mountain tops. Model data indicated turbulence mainly leeward of the border mountains towards Norway and the area over and just east of the Kebnekaise massif from GND to Flight Level 70. According to SMHI, the models probably underestimated the turbulence over the sharp mountain peaks.

Mountain waves:
Satellite images suggested that mountain waves were forming in the area to a certain extent. Model data showed that the mountains were generating a wave pattern but that the temperature stratification was not favourable for the formation of pronounced mountain waves.

Current weather (METAR) at 13.50 hrs UTC (14.50 local time):
Harstad/Narvik Airport (Evenes):
ENEV 151350Z 22023G40KT 9999 BKN042 BKN062 OVC092 06/M00 Q0998 RMK RMK WIND 1400FOT 23039G56KT

Kiruna Airport:
ESNQ 151350Z 21021KT CAVOK 02/M02 Q1000

From the above "current weather" information, we can gather that there was a strong, gusty south-westerly wind with medium and high clouds at Harstad/Narvik airport and that there was a somewhat weaker wind and no clouds below 5000 feet at Kiruna Airport. Visibility was good at both airports.

Synoptic observations (SYNOP) 15 March at 14.00 hrs UTC (15.00 local time):

Tarfala	Wind:	170° / 16 kts, gusting 43 kts
	Temp:	-1.5° C
	Dp:	-5.0° C
	Atmospheric pressure (QFF): 1002.1 hPa	
Nikkaluokta	Wind:	250° / 14 kts, gusting 25 kts
	Temp:	4.5° C
	Dp:	-3.5° C
	Atmospheric pressure (QFF): 1001.0 hPa	
	Visibility:	26 km
	Cloud (15 UTC):	FEW 800 ft, SCT 3,400 ft
Katterjåkk	Wind:	250° / 14 kts, gusting 29 kts
	Temp:	3.6° C
	Dp:	-2.5° C
	Atmospheric pressure (QFF): 999.5 hPa	
	Visibility:	30 km
	Cloud (15 UTC):	FEW CB 2,500 ft, BKN 4,000 ft

1.8.3 *Weather on the route between Evenes and Kiruna*

The Significant Weather Chart (SWC) at the time of the incident, see Fig. 13, stated the following on the route between Evenes and Kiruna:

- The presence of broken cloud cover between 2,000 feet and 9,000 feet along the Norwegian coast and eastwards to a point halfway to Kiruna.
- The presence of moderate to severe turbulence from ground level up to 8,000 feet, where the southern edge of the area was on a level with Kiruna.
- Scarce presence of mountain waves.
- The isotherm for 0° C was between 2,500 feet and ground level.

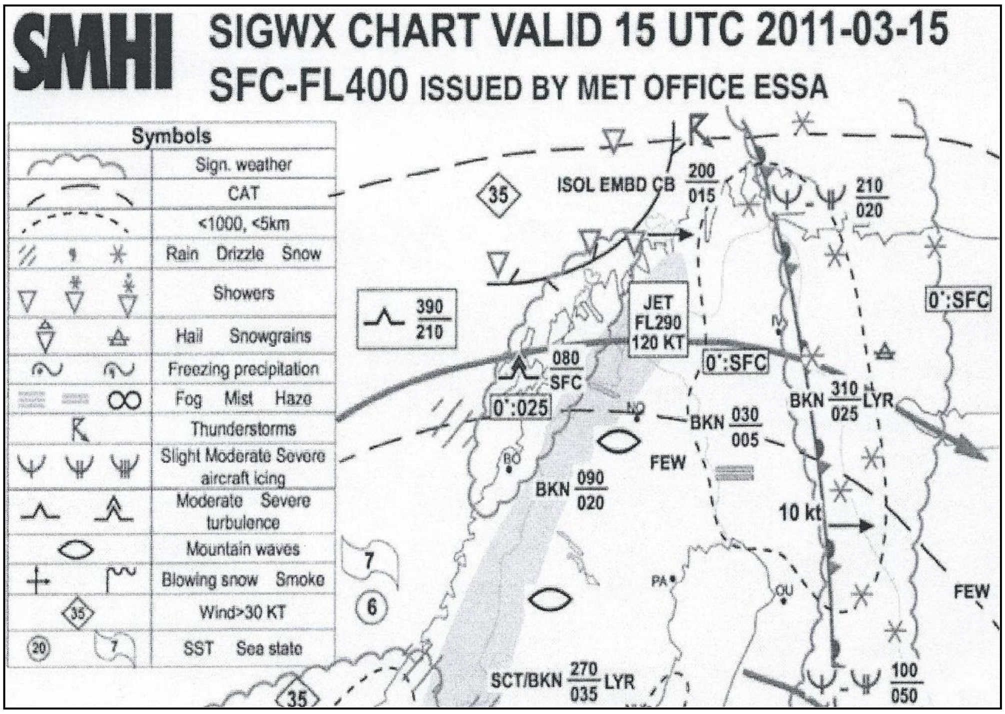

Fig. 13. Significant Weather Chart, SWC.

1.8.4 *Expert opinion on current weather conditions*

SHK has performed quality assurance on all information received by obtaining the opinion of a meteorology expert. Below follows a summary of this opinion:

> *The weather assessments provided by SMHI, the Swedish Armed Forces and Flymet Tromsö essentially describe the weather conditions at the crash site in a correct manner.*
>
> *In order to describe the wind conditions at the crash site, a more detailed analysis is required of the topography associated with the gradient wind field than has been performed in the documentation studied so far.*
>
> *The cloud base is assessed to have been about 4,000 feet MSL; that is, the upper parts of Kebnekaise were mostly in cloud. During the afternoon, the cloud base has locally and at times been up to 6,500-6,800 feet MSL. In connection with the crash, there were snow showers with reductions in visibility down to 1-2 km, and the clouds that were in the area entailed the risk of moderate to at times severe icing.*

The average wind speed at the peak of the mountain massif has been around 50-60 knots; at times, it has probably blown up to 80-100 knots; the wind direction was about 250 degrees.

With regard to the wind at the crash site, it is difficult to exactly predict which flow pattern was prevailing without access to weather observations associated with the valley where the crash occurred and in close proximity to the time of the crash.

It is not possible to rule out that there were severe wind conditions at the crash site with severe updraught and downdraught areas and complicated flow patterns.

1.8.5 Space weather

SHK has investigated whether current space weather may have had any influence on the incident. Analyses from METOCC have demonstrated that no abnormal activity of this kind has occurred at the time in question. However, such activity did occur in the evening that same day.

1.9 Aids to navigation

The aircraft was equipped with a communication and navigation system *(CNI-MS, Communications/Navigation/Identification Management System)* that allowed flight under IFR. The system consists, among other things, of a global navigation system (GPS) integrated with an inertial navigation system (INS), an instrument landing system (ILS), a receiver for directional radio beacon (VOR), distance measuring equipment (DME), a receiver for non-directional radio beacon (ADF) and TACAN (tactical navigation system, military version of VOR/DME).

The aircraft was equipped with a weather and navigation radar with a range of 250 nautical miles/approximately 460 km, as well as a function that could display ground contours (*Ground Map Mode*).

The aircraft was also equipped with a *Moving Map* that could be presented on any *Head Down Display,* see Fig. 14. The map could be used to display the aircraft's current position in relation to the terrain, stating terrain elevation, obstacles, latitude, longitude and obstacle-free altitudes with a margin of 200 feet. The lower part of the map could present the map scale, current latitude and longitude as well as heading angle and distance.

The Norwegian Air Force has stated that the moving map could be set to the scales 1:250,000, 1:1,000,000 and 1:2,000,000 during the flight in question.

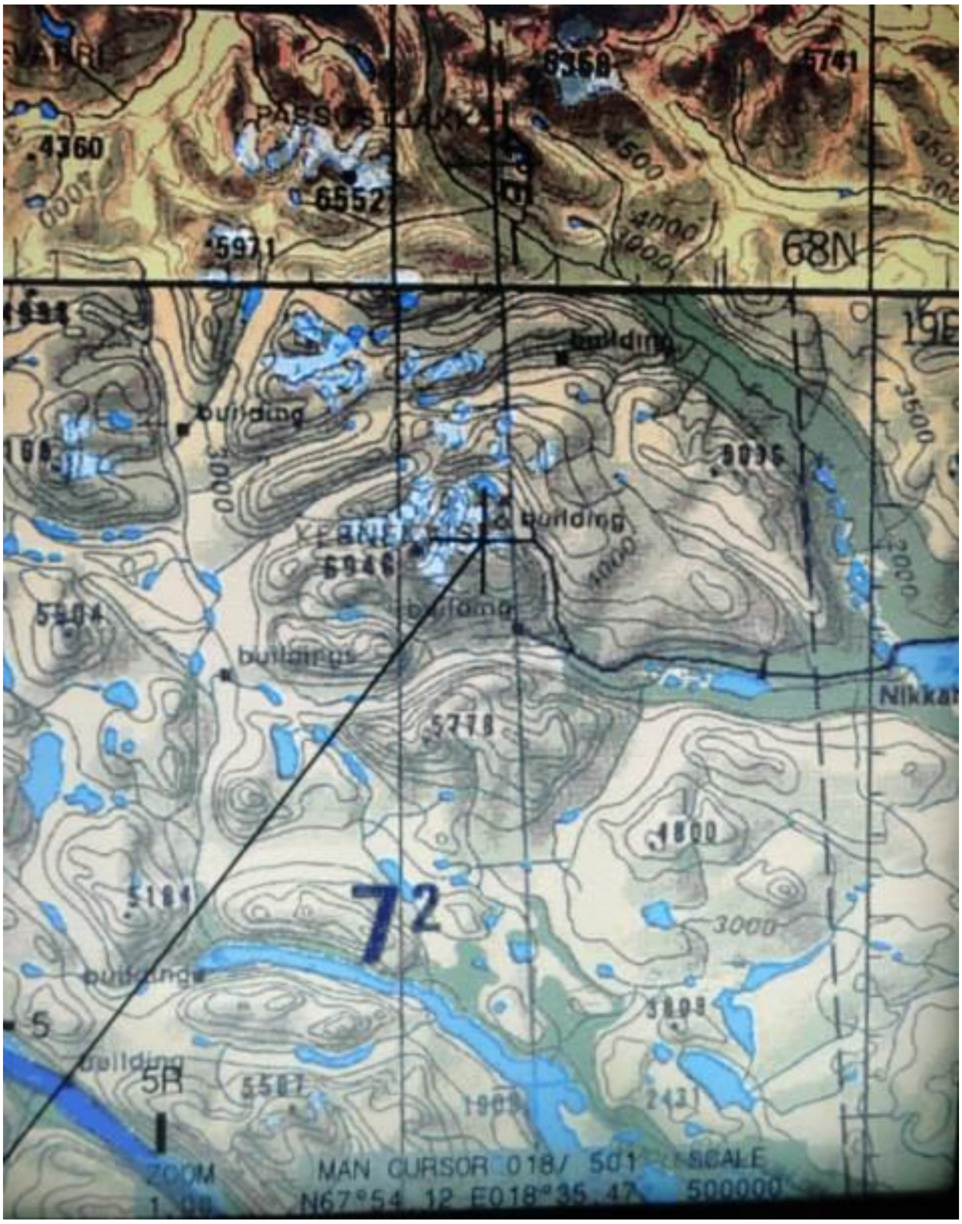

Fig. 14. Moving map. However, the cursor line and the scale are misleading in relation to the sequence of events. (Photo: Norwegian Air Force.)

1.10 LFV and the Norwegian Air Force

1.10.1 LFV's organisation

LFV (Luftfartsverket) is a government agency and a public utility which provides air navigation services in Sweden for civilian and military clients. The business area Production Terminal provides local air navigation services at 34 civilian and military airports, including two civilian and three military terminal control units.

Operations at the control centres ATCC Stockholm and ATCC Malmö ATCC are conducted by LFV through the co-owned Swedish-Danish trading company NUAC HB that commenced operations on 1 July 2012, i.e., after the accident involving *HAZE 01*. The aim of the company is mainly to identify efficiency improvements in operations and support so as to achieve savings that contribute to lower en route charges, that is, the charges that airlines pay to fly in the two countries, but also to reduce environmentally hazardous emissions by facilitating and streamlining flight planning and the utilisation of the airspace.

Formally personnel are employed by the parent companies with the employment conditions that are applicable in each country. The operational personnel, however, are on loan to NUAC until further notice, but a few individuals in management positions are employees of NUAC. During the investigation, it has emerged that personnel have stated that it has been unclear as to where exactly they have been formally employed.

1.10.2 Changes to Air Navigation Services

Over the last decade, air navigation services in Sweden have undergone a significant transformation that has brought sweeping changes to LFV's role and responsibilities. Among other things, the local air traffic services have been exposed to competition and state airport operations have been corporatised. Certain agency tasks were transferred from LFV to the newly created agency, the Swedish Civil Aviation Administration (Luftfartsstyrelsen), in 2005, which in turn was dissolved in connection with the creation of the Swedish Transport Agency in 2009. The Air Navigation Services Inquiry report Flight Plan for the Future – enhanced air navigation services (SOU 2012:27) provides a more detailed description of the above-mentioned changes.

In this context, it may be noted that the Parliamentary Committee on Transport and Communications proposed that the Riksdag make a declaration to the Government that no further steps regarding the deregulation of air traffic services may be taken until the ongoing preparatory work on the Air Navigation Services Inquiry report has been concluded and the Government has reported back to the Riksdag on what measures have been taken to ensure that continued excellence in aviation safety has the highest priority and that the needs of the Swedish Armed Forces are taken into account (Committee on Transport and Communications report 2011/12: TU15). On 7 June 2012, the Riksdag approved the Committee's proposal for a parliamentary decision (Riksdag Communication 2011/12:248).

1.10.3 Air traffic controller training[29]

The LFV air traffic controller training conducted at *Entry Point North (EPN)* is approved by the Swedish Transport Agency and shall be in accordance with Commission Regulation (EU) No 805/2011 and TSFS series ANS. All students undergoing the air traffic controller training at EPN complete the following course stages: Basic, APS and TCL. After this, the training is divided into two different specialisations; those who will be working as ACC controllers complete ACS and ACP. Those who will be working as TWR/APP controllers complete ADI and APP training.

Basic

In the Basic ATC module, students practise simulator exercises in airspace classes C and G. They learn all the airspace classes and associated rules as well as about ATS routes and airspace classification in accordance with Eurocontrol CCC. They also train to manage traffic in the areas bordering the different classes of airspace. Exercises with respect to YKL 125 are not practised specifically as this is a Swedish method and is stated to come under the national training component that students receive after concluding Initial Training, i.e. when Basic, APS and TCL have been completed.

[29] An explanation of the below abbreviations can be found at the bottom of page 12.

Students also learn that when an air traffic controller instructs an aircraft to fly into or leave controlled airspace, standard phraseology shall be used in accordance with ICAO Doc 9432 *Manual of Radiotelephony.* Air traffic controllers are also taught that they have the responsibility for pilots' receiving a clear boundary where clearance ceases to apply and for their being informed about the boundary to controlled airspace.

As regards the content of training in Basic for LAF (lägsta användbara flygnivå, lowest usable flight level) and AMA (area minimum altitude), EPN states that students learn *MSA (minimum sector altitude), MVA (minimum vectoring altitude)* and to vector aircraft in their airspace.

ACS

According to EPN, the following types of airspace are used in the simulator training:

- The fictitious airspace used in simulator training (Horn airspace) is, in Horn FIR, divided into airspace class G up to Flight Level 95 and airspace class C above this.
- Around airports, CTR with airspace class C is used up to 1,500 feet and TMA with airspace class G to 1,500 feet and above this class C to Flight Level 95.
- Around airports with AFIS, TIZ and TIA class G are used to 4,500 feet.
- In adjoining FIRs, students practise with the classes G, D and C.

According to Annex 11 to the Chicago Convention, it is not part of air traffic control's task to prevent collision with the terrain. Furthermore, it states that air traffic control shall provide advice and information for a safe and efficient conduct of flights. According to EPN, this is treated during training as follows:

- In controlled airspace, it is the air traffic controller who is responsible for a safe and efficient traffic management.
- Students are trained to clear traffic to the lowest safe altitude. In Horn airspace, there are no mountains, but the same methodology is used for R area/D area or other military activity with bordering areas to take into consideration.
- In G airspace, the pilot is responsible for obstacle clearance and is informed, for example, in the approach to an AFIS airport, about possible obstacles and other known traffic.

As regards ACS training content for LAF (lägsta användbara flygnivå, lowest usable flight level) and AMA (area minimum altitude), EPN stated the following:

- In certain simulator exercises, there are two active areas to 18,000 feet or 12,000 feet. Students are trained to calculate LAF using the current QNH.
- Students practice the use of areas in which the air combat command borrows areas for military traffic on exercises. Here too, students take into account the lowest usable flight level both in vertical separation minima (VSM) and reduced VSM (RVSM) airspace.

ADI & APP

Students are trained in airspace classes C and D. As regards training content for LAF (lägsta användbara flygnivå, lowest usable flight level) and AMA (area minimum altitude), EPN stated the following:

- This is not a specific “goal” of these courses, but is trained in a simulator to follow up on knowledge acquired in the Basic course.

Emergency training

As regards emergency training for the controllers at ATCC Stockholm, LFV has informed SHK that emergency training is part of the local basic training, for which reason there is no specific documentation for emergency training in particular, other than that it is included in the training plan for operational controllers at ATCC Stockholm.

1.10.4 *Stockholm ATCC*

The two controllers at the E and P positions at Stockholm ATCC had what is known as a Z rating, which meant that they were approved for service in four different sectors, namely 4, F, N and K. The sectors for which they were responsible at the time of the incident in question were sectors K and N (at the time combined). Sector K is the north sector and sector N the south.

The E and P positions, which are located adjacent to each other, are identical with regard to equipment and design, see Figs. 15-16. The E position is always open, and the P position is regularly open when there is military traffic, and otherwise depending on traffic intensity.

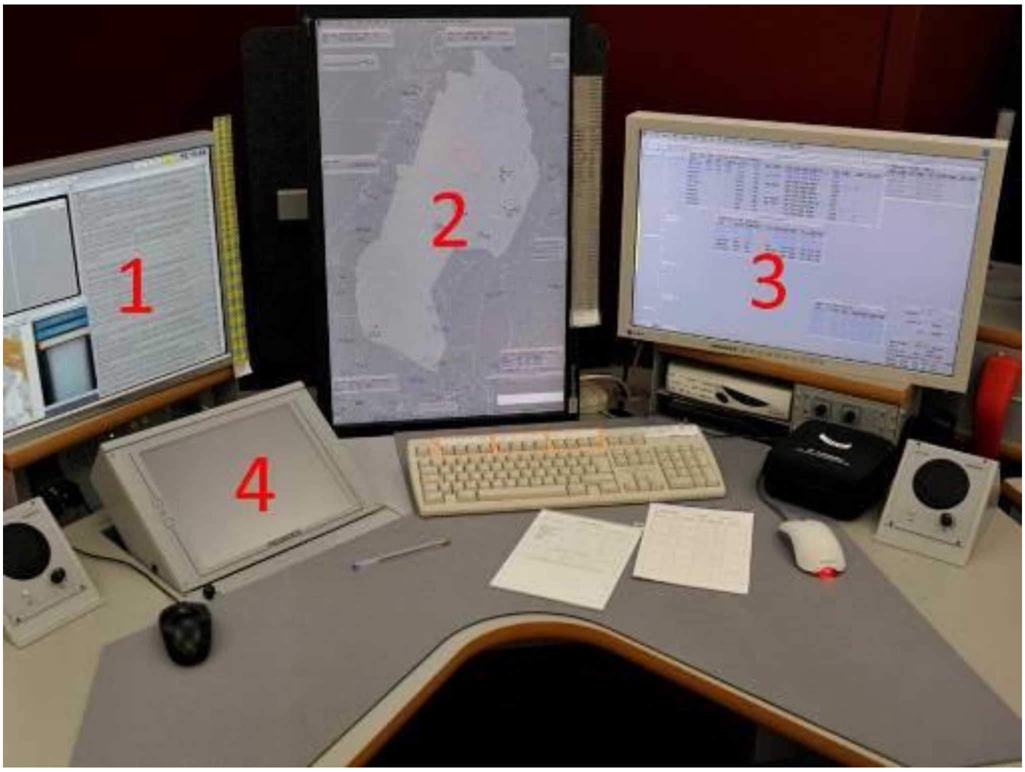

Fig. 15. The E position for Z rating at Stockholm ACC. Immediately next to this, outside the picture, is the identical P position. The figures mark the following equipment: 1=weather information, 2=radar screen, 3=planning tool for incoming traffic, 4=VCS (radio panel).

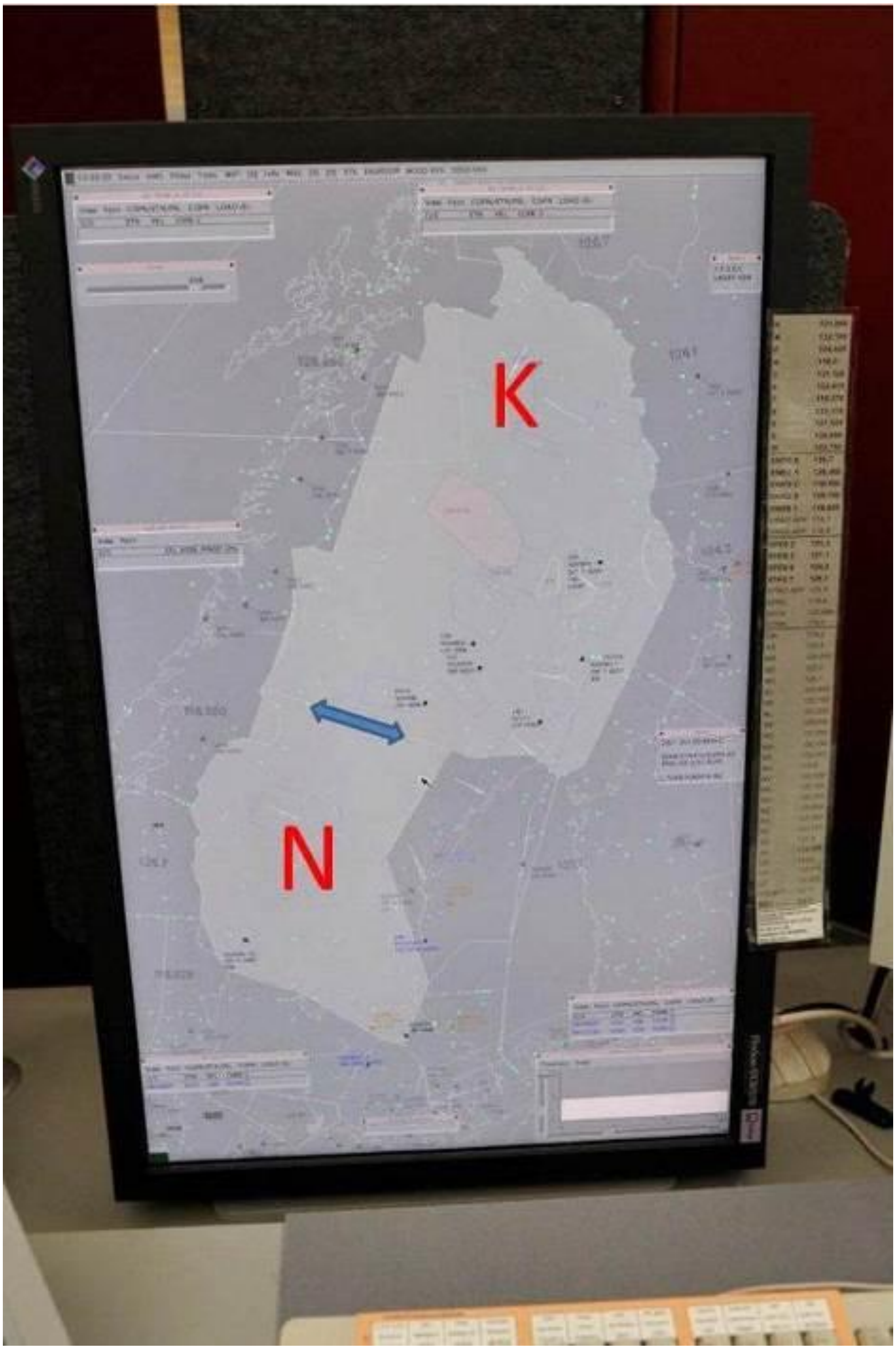

Fig. 16. The P position's radar screen. The letters K and N illustrate the different sectors, the letter K positioned where Kiruna TMA is located. The blue arrow marks the division between the sectors (the red letters and the blue arrow have been inserted by SHK). The list outside the screen to the right contains frequencies for various air traffic services units. At the time of the incident, Kebnekaise was not marked on the radar chart.

Rating course

ATCC Stockholm has stated that their simulator exercises change over time, but that traffic from the west in northern Sweden is not included in the simulator exercises. It has further emerged that various procedures are practised as they arise and that various exercise examples may be issued by an instructor when the student is at a position during a rating course.

ATCC Stockholm implements theory lessons with all students (3 days for airspace and methodology) in which airspace and methodology are reviewed. ATCC Stockholm has notified SHK that both controllers have undergone such lessons. It has also emerged that there are no exam questions for students concerning traffic from the west, but that there are, however, questions on procedural separations (which are used for traffic from the west because the radar coverage is deficient) and airspace status, questions that the two controllers answered correctly. They also correctly answered the exam questions on the fact that YKL lower limit was flight level 125 in the area in question. A picture of the area with the divisionof airspace can be seen in Fig. 17.

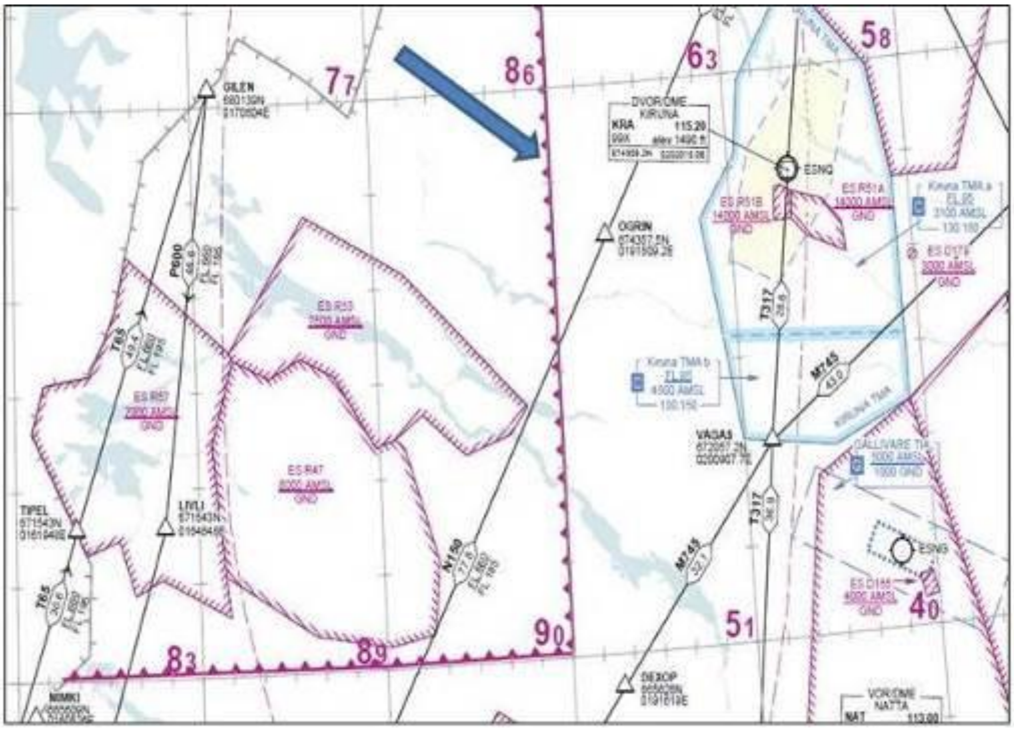

Fig. 17. En route chart with the boundary line for YKL 125 marked with a blue arrow by SHK. (Picture from IAIP[30])

Self-briefing

The ATS Operations Manual Part 3, Section 1, Ch. 1 for Stockholm ATCC states, among other things, that before operational duty, all operational personnel shall apprise themselves of “Today's briefing” that is available on the ATCC Intranet.

Debriefing

With reference to the incident in question, the two air traffic controllers carried out a debriefing in the late afternoon of 15 March 2012. The debriefing was organised by an aviation medical examiner. The two controllers then completed their shifts on 15 March and continued their duty the next day according to the planned schedule.

[30] Integrated Aeronautical Information Package.

1.10.5 *The control tower in Kiruna*

Kiruna Tower applies single person operations, which means that one controller at a time is on duty. The measure for certain control towers to apply single person operations was implemented as a savings measure in the early 2000s.

A normal shift is 9 hours. The controller in question has stated that in good weather it was possible to see Kebnekaise from the tower. In the course of the investigation, it has also been found that Kebnekaise was one of the geographical points that the controller in question was tested on during the rating stage, for which an approved result was obtained. The controller had very little experience of managing traffic from the west. However, the person in question is reported to have practised the management of traffic from the west in a simulator during his rating stage. The design of the work position is shown in Figs. 18-19.

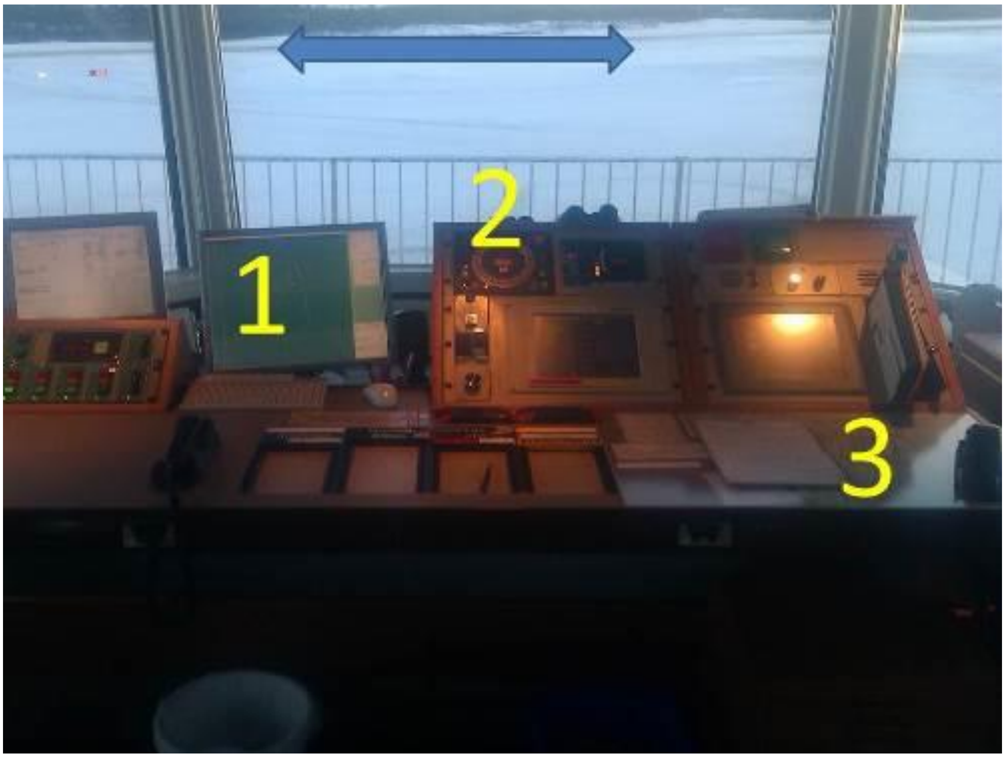

Fig. 18. The air traffic controller's work position at Kiruna Tower. The figures mark the following equipment: 1=radar screen, 2=direction finder, 3=chart. The horizontal arrow marks the runway location, the direction of which is 03/21. At the time of the incident, Kebnekaise was not marked on the radar screen.

Fig. 19. Turning the head to the right from the previous picture shows the approximate (westerly) direction towards Kebnekaise (not visible in the picture). Kirunavaara is visible in the background and a chart table in the foreground.

According to information from LFV, traffic from the west is managed in the same way as traffic from all other points of the compass, which according to LFV means that air traffic services in Kiruna issue clearance that applies in controlled airspace down to the minimum sector altitude. Traffic information is provided regarding any traffic in uncontrolled airspace. This was in force both before and after 15 March 2012.

Debriefing

The controller on duty at the time of the incident was withdrawn from duties on the evening of 15 March 2012. The next day, the person in question was instructed by the manager of Kiruna Tower to visit the occupational health service, which he did. Since the serving behavioural scientist was on holiday, the controller was instead examined by a doctor. On Sunday 18 March 2012, that is, three days after the crash, the controller was back on operational duty at Kiruna Tower and then directed, among other things, the air traffic to and from the airport which was caused by the crash on 15 March 2012. The controller has stated that he did not feel any need to be away from operational duty longer than that which came to be the case.

According to the Kiruna ATS Local Operations Manual Part 2, Ch. 1, *ATS aviation safety policy*, it is incumbent on the controller in question to report to his supervisors himself if the controller for some reason does not consider himself fit for operational duties.

Kiruna terminal control area (TMA)

The terminal control area, see Fig. 20, is long and narrow in the runway direction and is, like the other TMAs in Sweden, designed for traffic in the primary directions. Traffic from the west is not such a direction. Air traffic controllers from both Stockholm ACC and the tower in Kiruna state that traffic to Kiruna from the west is very rare. There is no ATS route from the west.

Fig. 20. Area chart of Kiruna TMA marked with a brown border. Within the terminal control area, the control zone (CTR) is represented by the light yellow field.

The TMA extends up to Flight Level 95. The *Minimum Sector Altitude (MSA)* is 5,500 feet in the TMA's northwestern part and 5,000 feet in its southwestern part. The *Transition Altitude (TA)* is 6,000 feet.

The Upper Controlled Airspace (YKL) is flight level 95 at the lowest. However, furthest west in the *"Mountainous Area",* the lower limit is flight level 125, see Fig. 21. Kiruna TWR normally borrows a block of airspace from *Sweden Control* above the TMA between flight level 95 and flight level 155, where there is normally radar coverage, in order to able to resolve traffic problems. This block of airspace may, in that case coordinated with *Sweden Control*, also be used by Swedish military combat command.

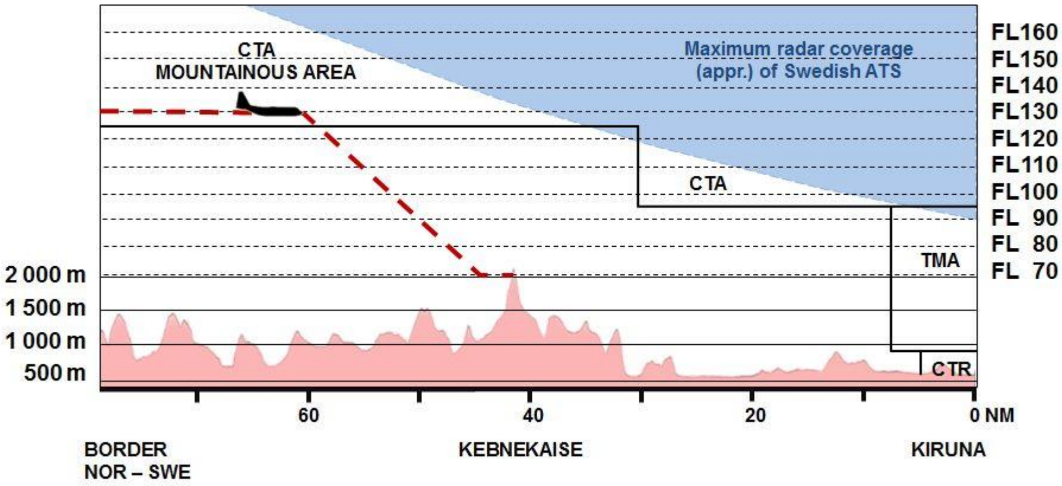

Fig. 21. Airspace and terrain profile along the route of the aircraft. The area shaded in blue shows approximately the radar coverage of the Swedish Air Traffic Services in optimal conditions. The broken red line shows the route of HAZE 01 in schematic form. Note that the altitude scale in the picture is greatly exaggerated. (Terrain profile: Google Earth)

Radar coverage and radar

The radar coverage of Swedish Air Navigation Services varies with weather conditions and the type of transponder the aircraft is equipped with, but over Kiruna Airport reaches down to around Flight Level 90 at best and westwards towards the Norwegian border down to around Flight Level 200-230.

In order to improve radar coverage along the mountain chain in the western part of Sweden, LFV applied in 2007 for access to two radar stations in Tromsø and Kletkov. However, according to information from LFV, Avinor[31] did not propose any agreement, upon which LFV decided in 2009 to initiate another project with a similar purpose, a project designated WAM[32].

Procedural traffic control

Procedural traffic control is used in areas where there is no radar coverage (and is a back-up procedure in cases where radar stops working) and is based on the aircrafts' own information on e.g. altitude, position, speed and intentions. Air traffic control then separates the traffic and clears the aircraft in accordance with applicable regulations.

Release procedure

Incoming traffic is handed over to *Kiruna TWR* at the time agreed in each particular case. This often coincides with the time of contact. When an aircraft has reached the release point, the control responsibility passes from the unit handing over to the unit receiving. Normally, *Sweden Control* gives clearance to the traffic to descend to Flight Level 160 since *Kiruna TWR* normally disposes over Flight Level 155 and below.

[31] Provides, among other things, services for air traffic control in Norway.

[32] Wide Area Multilateration.

Visual approach

For *visual approach* to Kiruna, there are no restrictions, either from an environmental or an obstacle point of view. However, military jet traffic is not permitted over the city of Kiruna.

1.10.6 LFV's incident investigation

After the accident, LFV conducted an internal incident investigation, *Investigation of ATS function associated with the crash of a Norwegian Hercules in the Kebnekaise massif on 15-03-2012.*

According to LFV, internal investigations must fulfil three different purposes: to clarify and describe the sequence of events, to identify causes and contributing causes of the occurrence and to formulate recommendations aimed at reducing the risk of a similar occurrence happening again.

The investigations undergo quality assurance by means of the investigators who conducted the investigation presenting a draft to other investigators at the unit to obtain views on the content. The investigation is subsequently referred to individuals concerned. The severity classification is determined by a Safety Manager at a special classification meeting.

The report was finalised on 28 September 2012, and the following was stated in connection with applicable regulations and analysis of the incident. The numbering of each header and the sections in italics are taken from the incident investigation.

5.5.1 Phraseology

The section presents the interpretation of the expression "descend". As the meaning is not specified in the regulations or in the Operations Manual's section on phraseology, the following interpretation is made.

> *This means that the pilot can commence descent directly but also remain at altitude for the present; the controller can thus not expect immediate descent. In other words, the phrase can be used when, from air traffic control's perspective, it is immaterial whether or not descent is commenced immediately. If it a clarification is required, one of the examples g or j below can be used.*

In the examples g and j, the phraseology "When Ready" and "Immediately" is used in combination with "descend", with the respective explanations that the altitude change is commenced at the pilot's discretion and that the altitude change must be commenced immediately.

> *8.2 Stockholm's management*
>
> *The clearance, "When ready descend to Flight Level 100" meant a clearance which allowed the commander to descend at his own discretion, even through the lower limit of the controlled airspace on his way towards Kiruna TMA, where re-entry into controlled airspace would take place in accordance with the clearance (Flight Level 70).*

8.3 Kiruna's management

Overall, it can be said that AD was not aware that the derogation had been removed and that clearance down into uncontrolled air cannot be given, but the derogation was de facto removed. Assuming the regulations that the controller thought were in force, he acted correctly except for the fact that no traffic information was provided, which may possibly have indicated to the pilot that he was situated in uncontrolled airspace.

With the rule change, there is now no direct requirement, but according to the old regulations, traffic information was to be provided, even when there is no traffic to provide information about, in the form of the phrase "No reported traffic outside controlled airspace".

8.4 Relevant regulations

AIP Sweden also states that clearance can be given if the pilot requests, including via a submitted flight plan, to go direct even if descent from Suecia CTA may then come to be executed in uncontrolled airspace. In this incident, there was a flight plan via two coordinates followed by Kiruna. The controller in Sector K also received coordination from Bodö that HAZE01 wished to fly direct Kiruna for landing. From that perspective, a clearance under Flight Level 130 is not incorrect since it is interpreted as if the pilot is requesting descent.

10 Conclusions

- *HAZE01 was cleared "when ready" to Flight Level 100, which is below the lowest usable flight level in Suecia CTA in the area. This meant that the flight entered uncontrolled airspace, which may possibly be seen as initiated by air traffic control and therefore not correct according to the regulations in force at the time, SUPP12/12.*
  But at the same time, the phrase "when ready" means that air traffic control leaves the decision and initiative to the commander to determine when he will commence his descent.
- *According to AIP Sweden, a flight can be cleared down from Suecia CTA if the pilot requests this, which it was interpreted that HAZE01 did.*
- *It is not the task of air traffic control to prevent collision with terrain, but it is the pilot's responsibility to make sure that all clearances from that perspective are safe if the flight is not under radar vectoring or direct routing (initiated by air traffic control). Since the pilot was flying on a GAT flight plan, it is assumed that he was aware of the provisions described in AIP.*

1.10.7 *The Swedish Transport Agency's control of LFV's operations*

With reference to the crash in question, the Swedish Transport Agency carried out a control of the operations of LFV/Stockholm ATCC on 4 May 2012. The previous control of the same site was carried out on 9-11 March 2010. A control of the ATS function in Kiruna was carried out in early September 2013. The most recent control of operations in Kiruna before the accident was carried out on 17 November 2009.

On 23 March 2012, a meeting was held between the Swedish Transport Agency and LFV. According to the Swedish Transport Agency, the following emerged during the meeting:

> *Meeting with LFV regarding the incident, information about LFV's immediate measures and further handling of the incident (investigation, etc.). LFV reported the measures taken in the form of published OMA at ATS Kiruna (regarding the fact that clearance to MSA may not be given outside the distance 25 NM KRA VOR), published OI at ATCC Stockholm (that ATC may not initiate clearance down into uncontrolled air and that if the pilot requests it, traffic information shall be provided, alternatively "No reported traffic"). LFV also reported that they had held an "aviation safety meeting" and decided that the air traffic controller training at EPN will be revised, the phraseology for uncontrolled airspace will be revised and the practical management of DHB SUPP will be revised. LFV notified that the business area Terminal will perform an analysis of which TMA airspaces need to be revised and will gather all its COs in Gothenburg and will then, among other things, discuss clearance involving uncontrolled airspace.*

In the report after the control of operations carried out on 4 May 2012, the following emerges, among other things:

> *Working methodology:*
> *The working methodology used by the Executive Controller at ATCC Stockholm at the time of the crash does not appear to be used by the three Z-rated controllers interviewed by the Swedish Transport Agency. Together with the Swedish Transport Agency's Regulations and General Advice (TSFS 2012:6) on Air Traffic Services (ATS), and the clarification of this in the form of LFV SUPP 12/12, LFV SUPP 13/12 and ATCC Stockholm OI 20/2012, the management at ATCC Stockholm has done what it can to ensure that the operators do not initiate a clearance that leads an aircraft out of the controlled airspace and that flight crews continue to always be informed if they are given a clearance that leads them out of the controlled airspace (after this has been initiated by the flight crew).*
>
> *Dissemination of information within the organisation:*
> *During the interview with the management, it emerged that the official in charge of safety at ATCC Stockholm has received e-mail information from the head office regarding AMA and LAF/YKL and what these altitudes mean to the operators. This was one of the measures taken that LFV presented to the Swedish Transport Agency after the meeting on 23 March 2012 with reference to the measures taken by the organisation after the crash. This information had not been disseminated further to the personnel (in accordance with (EU) No 1035/2011 Annex II 3.1.4b), but the management said that it had been discussed previously and therefore already known by the personnel. Of the personnel interviewed, the Swedish Transport Agency was able to establish that not all were aware of*

the problem of AMA versus LAF. None of the interviewed controllers had received any specific information about this from the management. Thus it is not established that the controllers are aware of the requirements of the international regulations ICAO doc. 7030 6.6.1.2 Obstacle clearance, 6.6.1.2 (A2-Chapter 5; P-ATM-Chapters 4 and 8) 6.6.1.2.1 Unless an IFR aircraft is receiving navigation guidance from ATC in the form of radar vectors, the pilot is responsible for obstacle clearance. Therefore, the use of RNAV does not relieve pilots of their responsibility to ensure that any ATC clearance or instruction is safe in respect to obstacle clearance. ATC shall assign levels that are at or above established minimum flight altitudes.

On 26 June 2012, the Swedish Transport Agency published what is known as an MFL (Message from the Civil Aviation Department), which included, among other things, the following text:

> *<u>Background</u>*
> *The Swedish Transport Agency has noted an increased number of incident reports regarding outgoing and incoming traffic flown in uncontrolled airspace. The incident reports describe problems experienced by controllers after the Swedish Transport Agency's Regulations and General Advice (TSFS 2012:6) on Air Traffic Services (ATS) entered into force on 15 March 2012. TSFS 2012:6 entails that a previous Swedish derogation from the international regulations has been removed. The derogation meant that an aircraft that was departing from or arriving at a controlled aerodrome was allowed to be cleared so that the aircraft was flown in uncontrolled airspace before entry into controlled airspace/terminal control area if this procedure facilitated the expediting of traffic.*
>
> *<u>Analysis</u>*
> *Air Traffic Control (ATC) including vectoring may be exercised only within the controlled airspace (ref. Chapter 1, Section 4 TSFS 2012:6). The clearances issued by ATC are valid only in the controlled airspace (ref. point 4 of Annex II to the Commission Implementing Regulation (EU) No 1035/2011 of 17 October 2011). The meaning of the former Swedish derogation was that ATC was, in specific situations, allowed to issue a clearance (climb/descend) that under the flight crew's own navigation resulted in uncontrolled airspace being entered. The flight crew would just as today be informed that they are entering uncontrolled airspace because flight information service shall be exercised for traffic in the uncontrolled airspace (reference Chapter 1, Section 4 TSFS 2012:6). If ATC were to perform vectoring in the uncontrolled airspace, this may result in flight crews believing that ATC is assuming an air traffic control responsibility (obstacle clearance, separation from other aircraft, etc.) – things that ATC cannot guarantee in the uncontrolled airspace.*
>
> *If there is a problem of the airspace being designed in such a way that incoming and outgoing traffic cannot be expedited without entering uncontrolled airspace, the Swedish Transport Agency interprets this as an indication that the airspace is not designed in accordance with the needs of the airspace users and therefore needs to be revised. Changes in the airspace are to be developed by an approved airspace designer and*

application for approval of the changes shall be sent to the Swedish Transport Agency in accordance with the Swedish Transport Agency's Regulations and General Advice (TSFS 2009:11) concerning the design and use of airspace.

1.10.8 The Royal Norwegian Air Force

The Royal Norwegian Airforce's organisation is structured so that the Inspector General of the Air Force (GIL) has the highest ranking position. Via the Norwegian Aviation Act, the GIL is an independent military aviation authority in Norway. GIL provides the framework for all military aviation via the Provisions for Military Aviation (BML). GIL also issues Provisions for the Norwegian Air Force (BFL) for the specific operative flight systems. The GIL exercises responsibility and supervision via the Air Operations Inspectorate (LOI). LOI distributes a series of publications called Håndbok for Luftforsvaret [the Royal Norwegian Air Force Handbook] (HFL). HFL contains guidelines and standard procedures for the Air Force's operative flight systems. GIL is responsible for flight safety in the Air Force and exercises this responsibility via Flytryggingsinspektoratet [the Norwegian Flight Safety Inspectorate].

GIL is responsible for producing combat-ready divisions, which means that GIL is responsible for training flight crews. GIL exercises this training responsibility via the Air Force Training Inspectorate (LUI). GIL exercises its administrative management of the Air Force via the Air Force Staff (LST). LST administers the air force's allocated resources. These resources consist of personnel, material, infrastructure and economy. GIL manages the Air Force's stations (Luftvinger [Air Wings]) via subordinate Wing Commanders.

The Royal Norwegian Air Force consists of six air bases, two combat command centres, two training centres, nine squadrons and two battalions of anti-aircraft artillery. The Air Force also has rescue helicopters stationed at three different locations. 135 Luftving with 335 Squadron is located at Gardermoen with a total of C-130J-30 Hercules, and carries out missions across the world. The primary tasks consist of providing transport support to Special Forces and Norwegian units serving abroad, but they also perform ambulance missions and medical evacuation and participated both in the efforts after the earthquake in Iran in 2003 and after the tsunami in South East Asia in 2004. At 335 Squadron, an upgrade from C-130E to C-130J was carried out. The co-pilot for the flight in question with *HAZE 01* also held the position of Squadron Leader for 335 Squadron and as such was relatively new at his post.

All commanders have a reporting obligation with respect to incidents that have occurred. All employees also have access to a reporting system in which it is possible to make reports anonymously.

1.11 Regulations

1.11.1 Provisions on traffic rules for civil aviation etc.

The military flight in question was performed according to GAT (General Air Traffic), which means that ICAO civil aviation rules shall apply. This is consistent with Section 9 of the Admission Ordinance (1992:118), see 1.11.2.

Under Chapter 8, Section 1 of the Aviation Ordinance (2010:770), the Swedish Transport Agency may, following consultations with the Armed Forces, issue regulations on aviation traffic rules. The traffic rules shall correspond in the main to the traffic rules adopted by the International Civil Aviation Organisation (ICAO) (Rules of the Air). These are found in Annex 2 to the Chicago Convention.

The Swedish Transport Agency has in Regulations and General Advice on aviation traffic rules (TSFS 2010:145) issued such regulations as are referred to in Chapter 8, Section 1 of the Aviation Ordinance. The regulations shall, pursuant to Chapter 1, Section 1, first paragraph, be followed by personnel at aerodromes, personnel performing air traffic services and pilots flying aircraft within a Swedish area, unless otherwise specified.

Chapter 2, Section 11 of TSFS 2010:145 states that the regulations do not exempt the commander from the responsibility to take action that averts collisions in the best manner. This also applies to manoeuvres based on Resolution Advisories (RA) from ACAS systems. Monitoring in order to prevent potential collisions is to be performed on board aircraft, regardless of the type of flight in question and the class of airspace in which the aircraft is situated. Monitoring on board is also to be performed when the aircraft is moving in an aerodrome's movement area.

Here, the following provision in *ICAO Doc. 8168, Volume I, Part 3, Section 1, Chapter 4* may also be noted.

> **4.1.1 Pilot's responsibility**
> The pilot-in-command is responsible for the safety of the operation and the safety of the aeroplane and of all persons on board during flight time (Annex 6, 4.5.1). This includes responsibility for obstacle clearance, except when an IFR flight is being vectored by radar.

With respect to controlled flights, that is, flights requiring clearance and that can only be performed within controlled airspace, Chapter 2, Section 51 of TSFS 2010:145 states that before a flight or a part of a flight is performed as a controlled flight, clearance shall be obtained. The air traffic control unit receives the basis for the clearance through the submitted flight plan. If the commander considers a received clearance not to be appropriate, he or she may request an amended clearance. Even if a clearance is issued for a flight from the departure airport to the destination airport, it is only applicable for those parts of the flight that are performed within controlled airspace.

Chapter 4, Section 2, first paragraph of TSFS 2010:145 states that only when it is necessary for take-off or landing, or when the authority in question has granted or prescribed otherwise, may IFR flight be performed at a lower altitude than the minimum altitude established by the State whose territory is being overflown, or if such does not exist, below: 2,000 feet (600 metres) above the highest obstacle within 8 kilometres of the estimated position of the aircraft if the flight takes place over high terrain, or otherwise 1,000 feet (300 metres) above the highest obstacle within 8 kilometres of the estimated position of the aircraft. The second paragraph of the same provision states that in Sweden, 'high' denotes terrain that is higher than 6,000 feet (1,850 metres) above mean sea level.

In order to satisfy international requirements concerning the making available of aviation information, the Swedish Transport Agency publishes *AIP (Aeronautical Information Publication)* Sweden. The publication, produced by Luftfartsverket (LFV) under the supervision of the Swedish Transport Agency, includes information about the rules that apply for aviation within Swedish territory. It is thus designed to be a manual that contains details on regulations, procedures and other information relevant to the conducting of aviation in the country to which it relates. The text of AIP is both in Swedish and English. AIP is available both in paper form and online, IAIP.

AIP Sweden GEN 3.3, concerning air traffic services, under the heading "5 Minimum flight altitude", states the following [translation from the Swedish version for the purpose of this report].

> a) Information on current QNH values and temperatures will be provided by ATS units on request and for some aerodromes also in the meteorological broadcasts according to GEN 3.5.7 and 3.5.9.
> b) Within SUECIA CTA, the lowest usable flight level is
> – FL 100 where CTA lower limit is FL 95
> – FL 130 where CTA lower limit is FL 125.
> c) Within "L3" CTA the minimum IFR cruising level is 4000 feet MSL. The lowest usable flight level is determined by the appropriate ATS unit.
> d) The above does not relieve the pilot-in-command of his responsibility to ensure that adequate terrain clearance will exist at all times, except when an IFR flight is vectored by radar (cf. ICAO Doc. 4444 PANS-ATM 4.10.3 note 3.
> e) For an IFR flight outside controlled airspace, the pilot-in-command himself shall determine the lowest available flight level with regard to obstructions along the route and to the actual or forecast QNH and temperature values.
> f) As regards "minimum vectoring altitude", see ENR 1.6 para 2.4.

It may be noted that the English translation of b) in the same document has the following wording.

> Within SUECIA CTA, the lowest *available* [SHK's italics; Swedish *användbara*, literally *usable*] flight level is
> – FL 100 where CTA lower limit is FL 95
> – FL 130 where CTA lower limit is FL 125.

AIP Sweden ENR 1.1 para 3, where there are some general regulations, under the heading "3 SUECIA lower/upper control area (CTA/UTA), states the following.

> SUECIA CTA/UTA includes the airspace between FL095 and FL660 within Sweden FIR/UIR. In the northwest part of Sweden FIR lower limit SUECIA CTA is FL125.
>
> Air traffic service within SUECIA CTA/UTA is provided by Malmö ACC and Stockholm ACC.

AIP Sweden ENR 1.3 para 1, concerning instrument flight rules, under the heading "10 Flight within SUECIA CTA/UTA", states the following.

> 10.1 In order to facilitate the air traffic services, flight within SUECIA CTA/UTA shall be flight planned via published ATS routes where reasonable.

10.2 When traffic situation permitting, ATC may clear aircraft to fly a shorter route than the one flight planned or previously assigned to the aircraft.
Note. Normally, ATC will not initiate any reclearance that would bring the aircraft outside controlled airspace from SUECIA CTA/UTA.
[- - -]
10.6 If indicated in the filed flight plan that an aircraft is requesting a direct route (i.e. not via published exit or entry points in TMA), or if so requested by the aircraft by radio, the aircraft will be cleared accordingly, if traffic permitting. This applies even if the climb to or descent from SUECIA CTA may partly be carried out in uncontrolled airspace.

1.11.2 Regulations for foreign state aviation under the Admission Ordinance

The Government has in Section 9, first paragraph of the *Ordinance concerning the Admission to Swedish Territory of Foreign State Vessels and State Aircraft (1992:118) (the Admission Ordinance*) prescribed that within Swedish territory a foreign state aircraft shall comply with the provisions for civil aviation and be operated in accordance with directions from Swedish air traffic control.

1.11.3 Regulations and manuals for Air Traffic Services

General

Under Chapter 6, Section 10 of the *Aviation Ordinance,* the Swedish Transport Agency may issue regulations on the tasks, scope and organisation of air traffic management, information services for aviation, meteorological services, communication, navigation and monitoring services, and on search and rescue services, as well as issue the necessary flight safety regulations for the activities.

The Swedish Transport Agency has, in part pursuant to that provision, issued *Regulations and General Advice on Air Traffic Services (ATS) [TSFS 2012:6]*. These entered into force on 15 March 2012. In force prior to this were Luftfartsverket's regulations (LFS 2004:30) *Provisions for Aviation – Air Navigation Services (BFL-ANS) 7* with appendix and the *Swedish Civil Aviation Administration's Regulations and General Advice (LFS 2007:51)* on special provisions for Air Traffic Services (ATS).

The general requirements prescribed under both the previous provisions and those in force at the time of the crash, state that the one performing air traffic services shall comply with the provisions that are applicable for the services and the airspace in question and that are set out, among other places, in *ICAO Doc. 4444 Procedures for Air Navigation Services – Air Traffic Management,* (PANS-ATM), provided that this is possible with reference to Swedish conditions and unless otherwise pursuant to these or other regulations.

Chapter 6, Section 13, third paragraph of the *Aviation Act (2010:500)* states that air traffic management of the airspace surrounding an airport may be conducted by the entity running the airport or by an entity which has been commissioned for the purpose by the entity running the airport.

The general requirements that must be met by those who want to become certified as air navigation service providers are stated in Annex I to the Commission Implementing Regulation (EU) No 1035/2011 of 17 October 2011 laying down common requirements for the provision of air navigation services. Article 3.3 of the Annex states that air navigation service providers shall provide and keep up-to-date operations manuals relating to the provision of their services for the use and guidance of operations personnel. Furthermore, the provider shall ensure that operations manuals contain the instructions and information required by the operations personnel to perform their duties; relevant parts of the operations manuals are accessible to the personnel concerned; the operations personnel are expeditiously informed of amendments to the operations manual applying to their duties as well as of their entry into force.

LFV is a certified air navigation service provider and runs operations at Kiruna Airport, among other places, through the Air Traffic Services unit ATS Kiruna. It is also active at Arlanda via Stockholm ATCC.

LFV has produced such operations manuals as are referred to in the above-mentioned EU Regulation. In the present case, it is a question of a central operations manual *(Dhb ANS)* and a local operations manual *(Dhb ESNQ).* As a rule, Dhb ANS is updated 2-3 times a year, and in between, changes and additions are made through the publication of supplements (SUPP). The operations manuals are normally not available to the public or others outside LFV due to the fact that they contain information covered by secrecy pursuant to Chapter 19, Section 1 of the Public Access to Information and Secrecy Act (2009:400).

Air traffic control's duties

According to Dhb ANS Section 2, Chapter 1, point 3, air traffic control's duties are to:

- prevent collisions between aircraft;
- prevent collisions between aircraft in manoeuvre areas and with obstacles in this area;
- promote well-organised traffic;
- provide advice and information of significance for the safety and efficiency of aviation;
- inform the concerned unit when an aircraft requires Fire and Rescue Services and assist the unit where necessary.

This text corresponds to Chapter 2.2 in Annex 11 of the Chicago Convention.

> The objectives of the air traffic control service as prescribed in Annex 11 do not include prevention of collision with terrain. The present provisions do not therefore relieve commanders of their responsibility to ensure that any clearance issued by air traffic control units is safe in this respect, except when an IFR flight is vectored by radar or is given direct routing.

The corresponding text is found in *Note 3 to 4.10.3 "Minimum cruising level for IFR flights"* in *ICAO Doc. 4444.*

Division of airspace

An airspace class indicates whether airspace is controlled or uncontrolled airspace. Classes A – D are controlled airspace for both IFR and VFR, class E is controlled airspace for IFR and uncontrolled for VFR, whilst classes F and G are uncontrolled airspace. In Sweden, only airspace classes C and G are used. ACC is responsible for the flight information service in airspace class G. It is common, however, for VFR flights to contact the nearest ATS.

Clearance in uncontrolled airspace

A difference between the older provisions (LFS 2007:51) and those in force at the time of the crash (TSFS 2012:6) is that under the old provisions, it was permitted to clear an aircraft departing from a controlled aerodrome so that the aircraft is flown in uncontrolled airspace before entry into controlled airspace if this procedure facilitates the expediting of traffic (Section 121 LFS 2007:51). Under Section 122 of LFS 2007:51, an aircraft arriving at a controlled aerodrome was also allowed to be cleared so that the aircraft is flown in uncontrolled airspace before it passes into the terminal control area if this procedure facilitates the expediting of traffic.
Regarding the possibility that existed under the old provisions, the following is stated in Dhb ANS, Section 2, Ch. 2, para 11.

11 [S] Flight that temporarily enters or can enter uncontrolled airspace

In the case of a flight at cruising altitude within SUECIA CTA/UTA, the following may be applied if this facilitates the expediting of traffic or if it entails a shortening of the route and provided that the pilot has not requested otherwise by means of a flight plan or via RTF.

a) an outgoing flight from a controlled aerodrome, with a flight-planned cruising altitude within SUECIA CTA/UTA, may be given clearance which entails that the aircraft is briefly flown in uncontrolled airspace before climbing up into SUECIA CTA.

Note. This may denote continuous climb through uncontrolled airspace up into SUECIA CTA or temporary level flight in uncontrolled airspace for a limited period when the aircraft due to other traffic is not yet able to be cleared to climb up into SUECIA CTA.

b) an incoming flight to a controlled aerodrome may be given clearance which entails that the aircraft is temporarily flown in uncontrolled airspace (descending below SUECIA CTA) to later enter the TMA.

c) traffic information is to be provided. When ATS is not aware of any traffic outside the controlled airspace that might affect the flight, traffic information is to be provided in the form of the following phrase:

NO REPORTED TRAFFIC OUTSIDE CONTROLLED AIRSPACE	INGEN RAPPORTERAD TRAFIK UTANFÖR KONTROLLERAT LUFTRUM

With reference to the fact that TSFS 2012:6 was to enter into force on 15 March 2012, LFV published a supplement with validity from the same day as TSFS 2012:6 entered into force. In the supplement, the following was stated:

Clearance in uncontrolled airspace
The Swedish derogation, with the possibility to issue clearance in uncontrolled airspace in order to facilitate the expediting of traffic and to shorten the route, which is described in Dhb ANS Part 3 Sect 2, Ch 2 para 11 + 14.2 is removed in its entirety.

TSFS 2012:6 was published on 8 February 2012 on the Swedish Transport Agency website. On the same day, an e-mail was sent from the Swedish Transport Agency to LFV, among others, with an invitation to an information meeting about the new regulation to be held on 8 March 2012.

On 9 March 2012, a summary of the Swedish Transport Agency's presentation of the new regulation was published on the LFV intranet. There, a report was given of the major changes, among other things. The removal of the Swedish derogation was part of this. It was also stated that a supplement was forthcoming. The supplement was published on the LFV intranet on 13 March 2012.

On 14 March 2012, the head of Production Terminal at LFV sent an e-mail to all operations managers within the business area Terminal that had the following content:

> There is some uncertainty as to what applies to radar guidance in G air with reference to the change in the previous wording.
>
> Due to the risk that this has not been correctly understood, I advise you to apply this as follows:
>
> 1. Vectoring in G air can be performed for the purposes of guidance into C air. This should be evident from the clearance.
>
> 2. Vectoring that entails that traffic is guided down below the TMA is not to be carried out. That is, do not guide tfc down under the additional TMA. Apply 500 feet to the lower limit as the minimum vectoring altitude.
>
> Hope I have not created new confusion with this! This will probably occasion overhauls of some TMAs.

On 23 March 2012, LFV published a clarification of the above-mentioned supplement that had the following wording:

> **Supplement 13/12**
> **Operational information**
> **Clarification of SUPP 12/12, para 3.1**
>
> **Background**
> The derogation that has now been removed existed in Sweden for over 10 years. This amendment does not affect how air traffic control or flight information service is to be exercised.
>
> Prior to the amendment (TSFS 2012:6), the controller had the possibility to initiate a clearance that brought the aircraft out into uncontrolled airspace, provided that “this facilitates the expediting of traffic or if it entails a shortening of the route”.

This possibility no longer exists. **The controller may not initiate flight in uncontrolled airspace.**

What does the change mean?

What is new is that a controller may **NOT** initiate a change in the flight plan (to e.g. DCT routing) that entails that the flight finds itself in uncontrolled airspace. If the pilot submits a flight plan, or requests a change to this (for example, via radio), that means that the flight will enter uncontrolled airspace, it is permitted to grant this, and the flight will be managed by means of air traffic control or flight information service according to the airspace class in which the pilot is flying.

Bear in mind that this applies to the entire flight, not only in your area of responsibility.

Examples:

- For an outgoing flight from a controlled aerodrome, with a flight plan within controlled airspace, the controller may **NOT** initiate clearance which entails that the aircraft is flown in uncontrolled airspace.

- For an incoming flight to a controlled aerodrome, with a flight plan within controlled airspace, the controller may **NOT** initiate the issuing of clearance which entails that the aircraft is flown in uncontrolled airspace.

For the part of the flight that is performed in uncontrolled air, flight information service is to be provided.

Note. About flight information service, see Dhb ANS Part 3, Sec 9.

Clearance close to uncontrolled airspace

LFV Dhb ANS Part 3, Section 5, Chap. 1, paragraph 6 states the following:

6 Flight close to the boundary to uncontrolled airspace or to the area of responsibility of another air traffic control unit

6.1 Laterally
Clearance may be issued close to the boundary to uncontrolled airspace.
Note. Bear in mind that for vectoring, the minimum distance of 1 NM to uncontrolled airspace applies.

6.2 Vertically
An IFR flight may not be issued clearance at a flight altitude closer to the boundary to uncontrolled airspace than:

- below Flight Level 290 (8 850 m STD): 500 feet (150 m);
- at or above Flight Level 290 (8 850 m STD): 1000 feet (300 m),

except when the pilot specifically requests this, for example, for meteorological reasons, or when this is necessary to expedite the flight according to flight plan.
Note. Where appropriate, the aircraft should, if deemed warranted, be informed that the requested flight altitude is too low or too high relative to the minimum/maximum usable flight altitude.

Provisions concerning phraseology for the changing of flight altitude

According to the Swedish Civil Aviation Administration's Regulations and General Advice on radio telephony and phraseology (LFS 2007:13), the following phraseology, among others, applies to the changing of flight altitude (the same text is found in Dhb ANS section 18):

English	**Swedish**	**Note, if any**
CLIMB (or DESCEND) *followed as necessary by for example* TO FL 100	STIG (el SJUNK el PLANÉ) *efter tillämplighet följt av till exempel* TILL FL100	
WHEN READY, CLIMB (*or* DESCEND) TO *(level)*	NÄR REDO, STIG (*el* SJUNK *el* PLANÉ) TILL *(flyghöjd)*	The altitude change is commenced at the pilot's discretion
CLIMB (or DESCEND) IMMEDIATELY TO (*level*)	STIG (*el* SJUNK el PLANÉ) OMEDELBART TILL (*flyghöjd*)	The altitude change must be commenced immediately

It can be noted that in DOC 4444, Section 1 2.3.1.2, concerning phraseology for the changing of flight level, there is a supplement in connection with the phrase CLIMB (or DESCENT) which reads:

> *… instruction that a climb (or descent) to a level within the vertical range defined is to commence*

Visual approach

LFV Dhb ANS section 6 states the following, among other things, with regard to visual approach.

> 2.5.1 On the following conditions, clearance for an IFR flight to execute a visual approach may be requested by the aircraft or initiated by the controller.
>
> 2.5.2 **[S] [C]** An aircraft is considered to request clearance for visual approach if it reports "field in sight".
>
> 2.5.3 Caution should be observed in the initiation of a visual approach when there is reason to believe that the aircraft does not have knowledge of the aerodrome and surrounding terrain. Account is also be taken of prevailing traffic and weather conditions.
>
> 2.5.4 **[S] [C]** An IFR flight may be cleared for visual approach if the pilot has the aerodrome in sight and can maintain visual reference to the ground and:
>
> - the reported cloud ceiling is not less than the flight altitude approved for the aircraft for initial approach; or
> - the pilot, either at the flight altitude for approach or at another time during the instrument approach procedure, reports "field in sight".

2.5.5 **[M]** An IFR flight may be cleared for visual approach if the pilot reports "recognized" or "field in sight".

2.5.6 Separation shall be maintained between aircraft that have been cleared for visual approach and other controlled aircraft.

The provision is the same as the international rules apart from the exception that in Sweden "field in sight" is required. PANS-ATM requires the pilot to have visual reference to the terrain: "An IFR flight may be cleared to execute a visual approach provided the pilot can maintain visual reference to the terrain ..."

Lowest usable flight level

Under the Chicago Convention's *Annex 2 – Rules of the Air, Chap. 3, 3.1.3 b):*

The cruising levels at which a flight or a portion of a flight is to be conducted shall be in terms of:

a) flight levels, for flights at or above the lowest usable flight level or, where applicable, above the transition altitude;

b) altitudes, for flights below the lowest usable flight level or, where applicable, at or below the transition altitude.

The subject is also treated in *PANS-ATM, chap. 4, 4.10.1.3,* which states:

For flights en route, the vertical position of aircraft shall be expressed in terms of:

a) Flight levels at or above the lowest usable flight level; and

b) Altitudes below the lowest usable flight level;

except where, on the basis of regional air navigation agreements, a transition altitude has been established for a specified area, in which case the provisions of 4.10.1.1 shall apply.[33]

PANS-ATM chap. 4, 4.10.3.2 also states the following:

ATC units shall, when circumstances warrant it, determine the lowest usable flight level or levels for the whole or parts of the control area for which they are responsible, use it when assigning flight levels and pass it to pilots on request.

Note 1. — Unless otherwise prescribed by the State concerned, the lowest usable flight level is that flight level which corresponds to, or is immediately above, the established minimum flight altitude.

Note 2. — The portion of a control area for which a particular lowest usable flight level applies is determined in accordance with air traffic services requirements.

Note 3.— The objectives of the air traffic control service as prescribed in Annex 11 do not include prevention of collision with terrain. The procedures prescribed in this document do not relieve pilots of their responsibility to ensure that any clearances issued by air traffic control units are safe in this respect. When an IFR flight is vectored or is given a direct routing which takes the aircraft off an ATS route, the procedures in Chapter 8, 8.6.5.2 apply.

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33 *PANS-ATM Chapter 4.10.1.1* For flights in the vicinity of aerodromes and within terminal control areas the vertical position of aircraft shall, except as provided for in 4.10.1.2, be expressed in terms of altitudes at or below the transition altitude and in terms of flight levels at or above the transition level. While passing through the transition layer, vertical position shall be expressed in terms of flight levels when climbing and in terms of altitudes when descending.

The counterpart of the above in Swedish provisions is *LFV Dhb ANS, 1.4,* which states:

> For flight en *route*, the flight altitude of aircraft is to be expressed as follows, unless otherwise prescribed:
>
> IFR flight:
>
> a) flight level at or above the lowest usable flight level (lägsta användbara flygnivå, LAF):
>
> b) height above sea level below the lowest usable flight level.

However, Chapter 3, Section 7 of TSFS 2010:145, under the heading *Altimeter setting and cruising altitude,* states the following.

> VFR flight in level flight at altitudes exceeding 3000 feet (900 m) above the ground or water shall be performed at a flight level according to appendix 6. Exceptions can be made in clearance or by the appropriate ATS authority.

Chapter 4, Section 6 of TSFS 2010:145, under the heading IFR flight within controlled airspace, states the following.

> For IFR flight in controlled airspace, cruising altitudes are to be selected in accordance with the tables in appendix 6. This also applies to levels that are selected for the application of a cruise climb technique.
>
> However, the correspondence between the flight altitude and the magnetic track as described in the table is not to be observed unless otherwise stated in the clearance or in the State's AIP.

Chapter 4, Section 7 of TSFS 2010:145, under the heading IFR flight outside controlled airspace and sub-heading Cruising altitudes, states the following.

> IFR flight in level flight outside controlled airspace shall be performed at cruising levels based on the magnetic track in accordance with the applicable table in appendix 6.
>
> The appropriate ATS authority may prescribe otherwise for flights at or below 3 000 feet (900 m) AMSL.
>
> [S] Exceptions to the first paragraph within the Swedish area are published in AIP.

That which is stated in Swedish *AIP, GEN 3.3, para 5* regarding the lowest usable flight level is reproduced in section 1.11.1. above.

Duty following an incident

According to Chapter 2, Section 9 of TSFS 2012:6, when an incident has occurred where aviation safety has been adversely affected, the official responsible for safety shall expeditiously make an assessment as to whether a lack of expertise has contributed to the incident. A lack of expertise in air traffic controllers or AFIS personnel is to be notified to the Swedish Transport Agency.

According to Chapter 4, Section 4 of TSFS 2012:6, the person who has had involvement in a crash or a serious incident during his/her operational service shall be withdrawn from duties as soon as possible. Duties may be resumed when it is the assessment both of the appointed official in charge of safety at the Air Traffic Services unit and of the person concerned that this can take place without an adverse effect on aviation safety.

The LFV operations manual ANS states the following on measures following an incident:

> 7.6 Measures following an incident
>
> 7.6.1 A person who has been involved in an accident or serious incident during operative duty must be removed from duty as soon as possible. Duty may be resumed once both the operations manager and the concerned individual feel that this can take place without an adverse effect on flight safety.
> Note: At a single-manned ATS unit, this may involve the temporary closure of the unit.
>
> 7.6.2 ATS personnel who are to be interviewed in connection with an incident may not be on duty in an operative position on the same day as the interview. The personnel may only return to operative duty after the operations manager has made an assessment.
>
> 7.6.3 The operations manager shall produce checklists for routines for incidents or accidents. Recommendations of measures that should be included:
> - only supportive elements; no discussion on the matter of culpability
> - the concerned individuals should write down the sequence of events as soon as possible, before recordings or radar data are reviewed
> - a supervisor should be present when recordings and radar data are reviews
> - if a trainee is involved in the incident, the training officer should be informed.
>
> Other measures are adapted in accordance with available resources in consultation with operative personnel.

The local operations manual for ATS Kiruna, Part 3, Section 1, *Duty following an incident*, states:

> ATS personnel who, when on duty in position, are affected by an air traffic incident or other serious incident, such as violence or the threat of violence, personal tragedies etc., shall be withdrawn from operational duties without undue delay.
>
> If another member of personnel is on duty, this person shall be responsible for initiating action as described above. If another member of personnel is on duty, it is incumbent on the person in question, independently and according to the circumstances, to ensure that he or she is relieved.
>
> The manning problems arising from the measures described above are to be resolved in the best manner according to prevailing circumstances and judgement. The following alternative measures may be relevant:
> – Personnel with office duties relieve the person concerned - suitable personnel are called to duty - where necessary, notification is made of traffic restrictions e.g. PPR - if there is no other solution, the ATS shall close.
> The person affected by a more serious incident shall be attended to in the first instance by workplace management or other suitable person.
> In the event of an incident, crisis management/dialogue shall be carried out with [name] behavioural scientist [company], before duty in position is resumed.

1.11.4 *Regulations for flight operational duty*

Documents and publications that concerned the air operations of the Norwegian Air Force

SHK has, in addition to the aircraft's flight operations and flight technical manuals, had access to extensive material in the form of documents and regulations that applied to the Norwegian Air Force's air operations at the time of the incident.

General provisions are found in *Lov om luftfart (Luftfartsloven) [Act relating to Aviation (Aviation Act)]*, which among other things regulates which civil provisions apply to military aviation, and *Bestemmelser for Militær Luftfart, BML(D) [Regulations for Military Aviation],* which lays down special provisions for military aviation. BML describes additions and exceptions to civil provisions of a permanent nature. BML states that military personnel associated with flying duties shall have knowledge of civil provisions which, according to the Aviation Act, apply to military aviation. It also states that flight personnel shall have good knowledge of *Bestemmelser for Sivil Luftfart, BSL [Regulations for Civil Aviation]*, published by the CAA Norway; AIP Norway and AIC Norway.

In addition to this, among other documents, are *Bestemmelser for Luftforsvaret, BFL [Regulations for the Air Force], Håndbok for Luftforsvaret, HFL [Manual for the Air Force] and Ordrebok for Lufttjeneste, OFL [Order Book for Air Service]*. The last-mentioned is published by the head of 335 Squadron and contains internal orders and provisions for air service at the squadron.
There are also a variety of manuals and *SOP, Standard Operating Procedures,* containing provisions and guidelines to abide by.

SHK has studied the material and divided the information into four subject areas that are considered relevant, as per the following.

Periodic checks

OFL describes how the crew's periodic checks should be performed. The checks, which are performed every six months, consist of a theoretical part and a practical part.

The theoretical part is divided into an *Open Book Test*, whereby the candidate has access to relevant reading materials, and a *Closed Book Test* in which they do not. Each test consists of 25 questions taken from the aforementioned reading materials. SHK has reviewed the question banks for the tests and has not found any questions concerning the definition of the lowest usable flight level or correction of minimum altitude in the event of low atmospheric pressure when the altimeter is set to 1013.2 hPa. The practical part is carried out in a flight simulator.

Altimeter settings, altitudes and terrain separation

BML 9.6 states that the minimum safe cruising altitude (flight level) must be calculated for every flight mission at low altitude, and must be a flight level that ensures at least 2,000 feet clearance above the highest obstacle within 10 nautical miles of the track.

BFL 120-30 2.3.2 states that the rules in BSL F 1-5 must be applied in IFR-flying outside of established routes. BSL F 1-5 could not be found.

Altimeter corrections for current meteorological conditions (temperature and/or wind) are explained in 2-4.2 and 2-4.2.1 of *HFL 100-65*.

Basic Employment Manual C-130J, BEM covers terrain conditions within 10 nautical miles of the track, as well as the descent corridor during descent under instrument meteorological conditions.

Air Force Manual, AFM, Flying Operations Instrument Flight Procedures, (the US Air Force), as well as *Air Force Instruction, AFI, Flying Operations, C-130J Operations Procedures (US Air Force)* explains the following terminology:

- *MEA (Minimum Enroute Altitude)*
- *MOCA* (*Minimum Obstruction Clearance Altitude)*
- *MIA* (*Minimum IFR Altitude)*
- *ORTCA (Off Route Terrain Clearance Altitude)*
- *ESA (Emergency Safe Altitude)*

Point *9.2* of *AFM 11-217V1* explains that the air traffic control's clearances likely have a larger impact on when descent commences than any other individual factor. It also states that distance, desired rate of descent, weather, terrain and fuel consumption at low altitude should be taken into account before a request is made for descent.

Point 8.1.5.2. of *AFM 11-217V3* states that obstacle clearance over the terrain can be a real problem when flying with the altimeter set to QNE[34].

It can be noted here that ICAO Doc. *8168, Volume I, Part 3, Section 1, Chapter 4* states the following:

> **4.2.1 Flight levels**
> When flying at levels with the altimeter set to 1 013.2 hPa, the minimum safe altitude must be corrected for deviations in pressure when the pressure is lower than the standard atmosphere (1013 hPa). An appropriate correction is 10 m (30 feet) per hPa below 1013 hPa. Alternatively, the correction can be obtained from standard correction graphs or tables supplied by the operator.

Flight preparations

According to Annex 6 of the Chicago Convention, an operational flight plan is defined as follows:

> The operator's plan for ensuring the safe conduct of the flight based on considerations of the aeroplane performance, other operating limitations and relevant expected conditions on the route to be followed and at the aerodromes concerned.

BML point 10.9.4 states that pilots responsible for the navigation of military aircraft, before and during a flight, must maintain an operational flight plan on the log sheet established by a head of department in accordance with *BSL D 2-1*.

[34] Corresponds to an atmospheric pressure of 1013.25 hPa

Point 4.3.3.1, *BSL D 2-1* stipulates that the minimum safe altitude for the distance to be flown must be recorded in the operational flight plan.

BEM explains under *point 4.2.5.8* the minimum essential details that the symbol for navigation information (*doghouse)* must provide: course, distance, cruising altitude and *ESA*. *Point 4.2.5.10* explains that the recorded *ESA* must be clearly visible.

BEM point 4.2.5.11.2 suggests that the position of a descent corridor under instrument meteorological conditions should be marked with a decision point.

SOP states under *point 1.9* that Jeppesen flight plans *(Jetplans)* must be used where possible, and that the planning can be done without wind data concerning fuel and route.

CR-12, Cold Response, Airspace Rules and Regulations stipulate that all pilots should understand the structure of the civil airspace in which the exercise takes place.

Execution of the flight

SOP describes under *point 1.5* which duties the loadmaster can be expected to carry out:

- When a call-out is made and one of the pilots needs to look at the instrument panel (head-down), the loadmaster must pay greater attention in terms of keeping a lookout, as well as the monitoring of activities and communication in the cockpit.
- Radio communication
- Updating take-off and landing data with the latest ATIS information.
- Handling fuel panels in accordance with SOP and Flight Manual
- Keeping a fuel and flight log
- Checking that RADALT SAME ACAWS are disengaged before passing 10,000 feet AGL during descent
- Confirm that the correct handle/switch is manipulated upon order from the PM and check which situations require confirmation in accordance with the emergency checklist

SOP describes under *point 1.7* that the functions of the GCAS/TAWS system are modified when in tactical mode in order to allow for manoeuvres close to the terrain, and explains that this mode is most suitable for modified contour flight and approaches at low altitude in accordance with Visual Flight Rules. It also explains that tactical mode can be used in all tactical operations, subject to the Commander's appraisal of the situation.

SOP point 1.9.6 explains that the scope of the navigation/radar display must be set so as to prioritise weather/terrain avoidance, and that the digital chart must be used as a tool in order to increase awareness of terrain/obstacles.

SOP point 6 explains that terrain features must be reviewed with the help of the digital chart or paper charts before descending in unfamiliar territory.

SOP point 6.3 describes how the Top of Descent (TOD) can be established by means of a backup calculation: "*Distance from TOD to airfield = Twice height to lose + Distance required from field at BOD + 10 nm + PLUS/MINUS wind allowance*".

SHK has performed a backup calculation of the *TOD* from Flight Level 130, the result of which was a point located around 38 nautical miles from the airport.

1.12 Flight recorders

In the tail of the aircraft, the crash-protected flight recorders were located; the *Digital Flight Data Recorder (DFDR)* and *Cockpit Voice Recorder (CVR).* The *DFDR* records data from the various aircraft systems, while the *CVR* records audio from the cockpit, communications and auditory system indications. The units were equipped with an underwater transmitter which is activated when it makes contact with water. This makes them easier to locate if they end up at sea or in lakes and other watercourses. The units were therefore not equipped with a transmission function that would facilitate location if they end up on land. They are however painted orange and fitted with reflectors.

In August 2012, the DFDR and CVR were recovered from the site of the accident. The memory units had separated from their chassis – see fig. 22 – but still had their underwater transmitters.

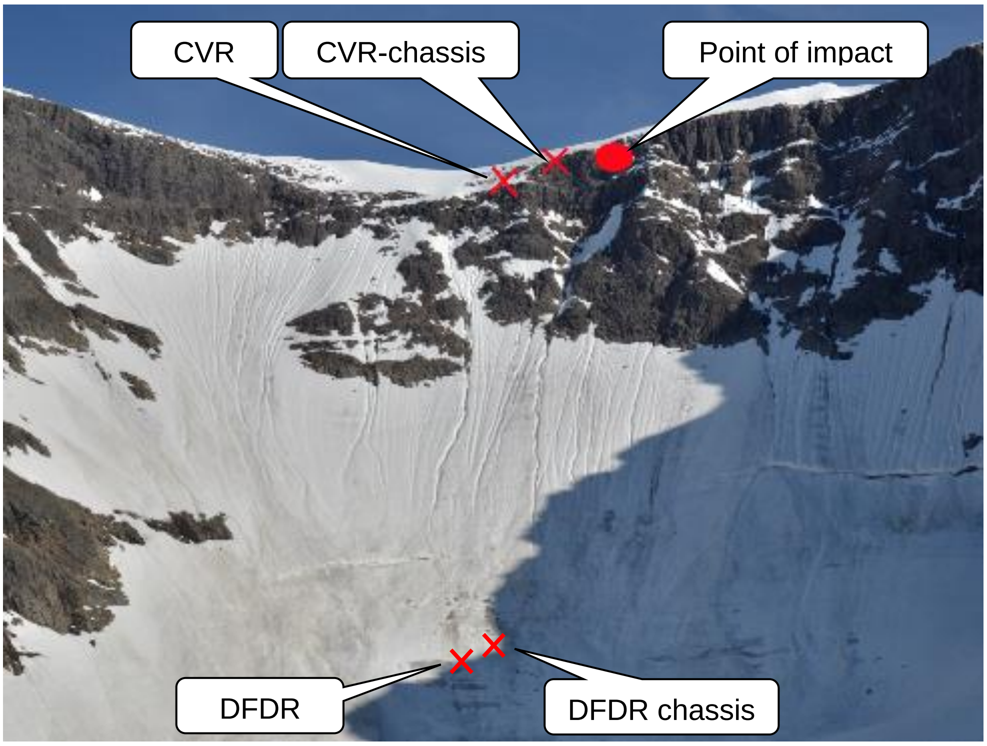

Fig. 22. Sites where DFDR and CVR and their chassis were discovered. (Image SHK.)

The DFDR and CVR with their chassis, see figs. 23-24, transported by SHK to the British *"Air Accidents Investigation Branch"* (AAIB), where the memory cells were removed and examined.


Fig. 23-24. The crash-protected memory units from DFDR and CVR. (Image SHK.)

The memory units' contact wiring had been torn away, but new wiring could be soldered and the units' binary data could be read.

1.12.1 *Data from the Digital Flight Data Recorder (DFDR)*

The DFDR is operational when the aircraft is powered. Its memory capacity is capable of maintaining a continuous record of the last 25 hours of aircraft systems operation and flight data. Data are stored on digital memory units in a shock and heat resistant crash protector, mounted on a chassis. The crash protector is designed to enable the memory units to retain their memory at accelerations up to 3,400 g.

Via the aircraft systems computers, data are recorded from 20 different aircraft systems. 104 separate parameters are recorded, including acceleration (vertical, lateral and longitudinal), rudder, aileron and elevator position, level, airspeed, heading, pitch attitude, bank angle, pitch trim, flap position, landing gear position, radio settings, engine status (EGT, torque, propeller speed, and fire warning) and time. Acceleration is measured by a single tri-axis accelerometer. Rudder, aileron and elevator positions are measured by transducers mechanically connected to the individual torque tubes. The other parameters are measured and reported by the individual controlling system.

The data in the DFDR were stored in a compressed format. This means that a so called *”End of File”* (EoF) was written every time the DFDR was shut off during normal operation. When reading the data, it was possible to decompress them once the correct position of this EoF was identified and an EoF was written in. The binary data file that was then obtained was converted in the software environment *FlightScape* and has since been used for analysis and animation of the sequence of events.

1.12.2 *Data from the Cockpit Voice Recorder (CVR)*

The CVR is operational when the aircraft is powered. It stores a continuous record of the most recent 120 minutes of communications, audio from the commander's and co-pilot's intercom microphones, audio from what is known as an *Area Microphone* in the cockpit as well as the current time from the DFDR. Data are stored, as with the DFDR, on digital memory units in a shock and heat resistant crash protector, mounted on a chassis.

1.12.3 *Non crash protected recorders*

<u>*Dual Slot Data Transfer System (DSDTS)*</u>

The DSDTS is a digital memory unit that records mission data from the aircraft's various electronic systems. Various parameters that are needed to assess the status of the aircraft and enable error analysis are recorded, such as error indications, withdrawn error indications, alerts, response from the crew, engine trend data, the aircraft's serial number, the engines' serial numbers, engine operating time, flight time and crew codes.

During flight, system status and error information is recorded on one of two removable memory modules (RMM cards) installed in the DSDTS. Mission data is written to an installed RMM card.

The aircraft's DSDTS unit was found at the crash site in damaged condition, containing a memory card labelled *"MAINTENANCE"*.

<u>*External Mass Memory Unit (EMMU)*</u>

An EMMU is used to transfer map information for the aircraft's digital mapping system *(Moving Map)*.

The aircraft's EMMU unit was found at the crash site in damaged condition, containing two memory cards.

1.12.4 *Evaluation of recorded data*

Preparations had been made to enable a quick reading of the CVR and DFDR once these had been found. Conversion of the DFDR's binary data to engineering units was made more difficult, however, because a necessary data file was made inaccessible by the aircraft manufacturer. The Norwegian Armed Forces did not possess this conversion file and neither did it receive access to it. In civil aviation, according to ICAO regulations, the accident investigation authority investigating an accident shall have unrestricted access to this type of document. In addition, the operator must ensure that the conversion document is updated with the latest system calibrations.

The manufacturer agreed to perform the conversion and animation itself with representatives from SHK and from the Norwegian Armed Forces present. The conversion was performed in *FlightScape*. After this, SHK received the animation in the form of a data file which was only compatible with *FlightScape.* Due to quality deficiencies in the recorded data, it was necessary to redo the animation. This, as with the analysis of data, was conducted by FDR/CVR experts at SHK.

Analysis of the DFDR data revealed certain limitations in the system. The aircraft's registered position resolution was 15 minutes of arc in longitude and 30 minutes of arc in latitude, and both Caution and Advisory messages from ACAWS were not registered. Furthermore, there were no parameters to determine the status of the recording unit itself *(Flight Data Acquisition Unit Status Word)*.

The reading of the CVR resulted in four audio files, all with a duration of 2 hours and 4 minutes.

The audio was recorded continuously until the moment of impact. The two files with audio from the pilots' headsets proved to be of good quality. The sound recording from the *Area Microphone*, which records general noise in the cockpit, had high noise levels, which reduced the audibility of speech and audio alerts.

The content of the memory cards from the DSDTS and EMMU units has not been read, as the potential information from these units is not considered to contribute any conclusive information to the investigation, beyond the other recordings evaluated.

1.13 Accident site and aircraft wreckage

1.13.1 Accident site

The aircraft collided with terrain around 170 metres from the south peak of Kebnekaise and the sloping part of the ridge that runs between the north and south peaks. The point of collision is located just below the dividing line between the ridge's sloping surface and the nearest vertical rock face; see figs. 25-26. The distance to Kiruna is around 42 NM (77 kilometres). The area is very inaccessible.

Fig. 25. Photo of Kebnekaise. The photo is taken in the direction of approach at the same altitude as the point of impact (marked). (Photo: SHK)

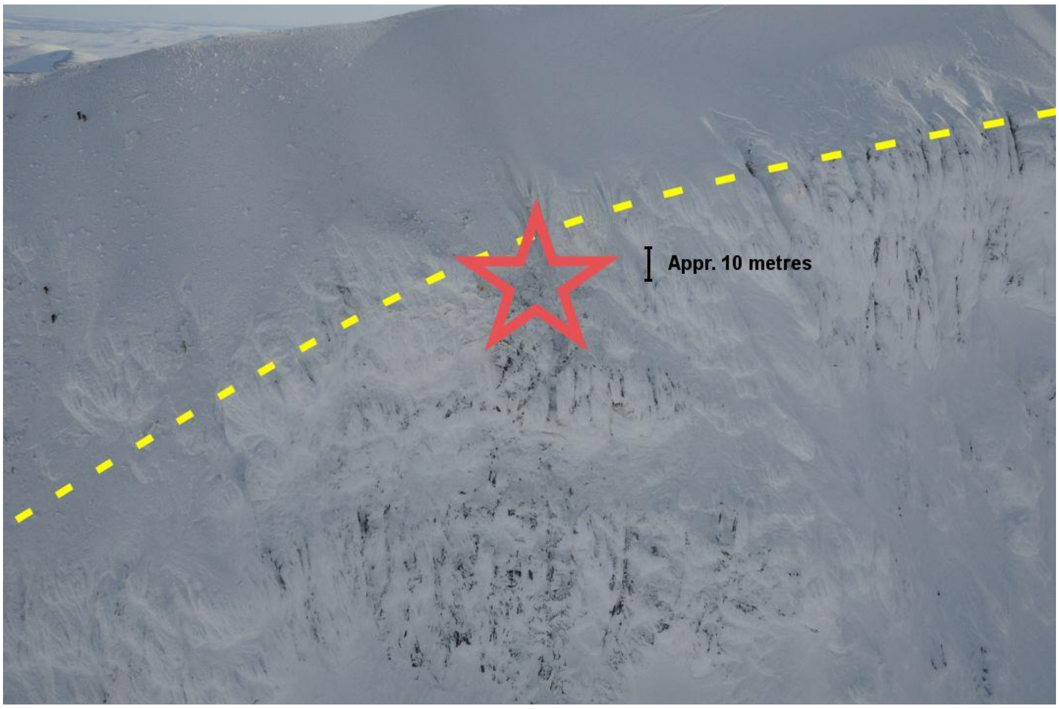

Fig. 26. Photo of the point of impact on the west side of Kebnekaise. The dividing line between ridge and vertical rock wall is marked by a dotted yellow line. Note the salvage crew on the left side of the image. (Photo: SHK.)

The aircraft's heading was approx. 095° when it collided with the terrain. The principle bearing of the ridge is approx. 045°, which meant that the aircraft hit the mountainside at an angle – see fig. 27.

Fig. 27. Photo montage of the point of impact, as seen from above. The contour line at the point of impact is marked with a yellow line, and the aircraft's approach with a thick orange line. (The picture is based on a satellite image from Google Earth.)

The height of the point of impact's centre has been measured at 2,014 m using GPS. The highest point of the ridge in the direction of flight is roughly 2,060 metres.

The aircraft's speed at the time of collision, obtained from flight recorders and radar information, would have entailed a very fast collision sequence. Time from the moment at which the first parts of the aircraft touched ground until the final parts impacted can be estimated at around 0.5 seconds.

The collision caused an avalanche, whereby much of the wreckage was buried and carried down to "Rabots glaciär" (Rabot's glacier). The avalanche area of the glacier was around 800 metres long and about 200 metres wide at its widest point.

The parts of the wreckage were spread across a very large area, even up on the ridge. The strong westerly wind at the time of the accident caused a strong upward wind, which was a contributing factor in lighter parts of the wreckage being pushed over the edge, landing on the east side of the ridge – see fig. 28.

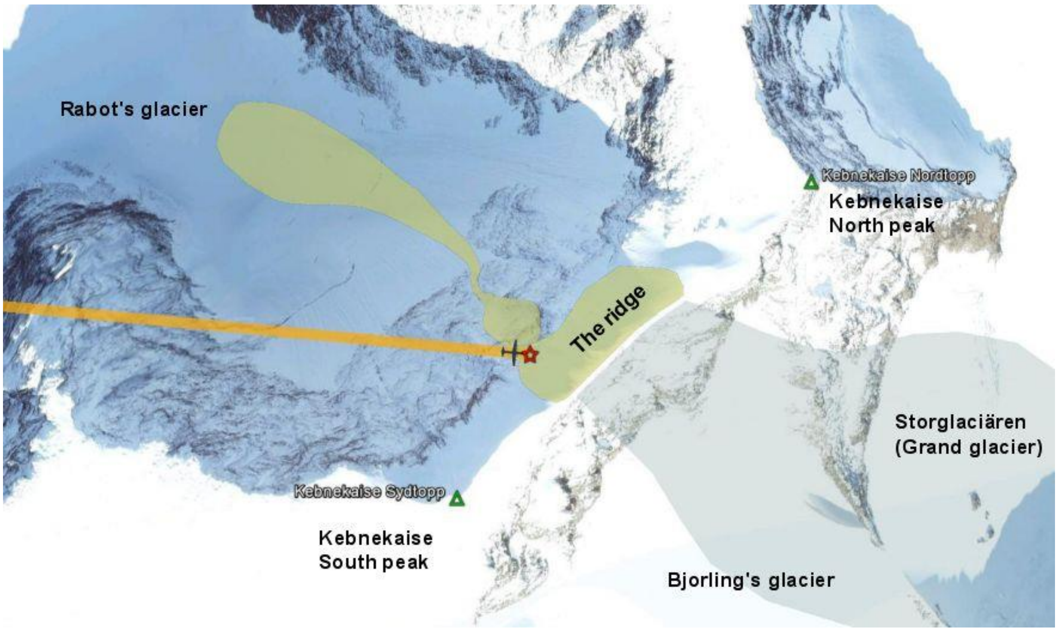

Fig. 28. Approximate spread of the various parts of the wreckage, most parts having been discovered on the ridge and on Rabot's glacier. (The picture is based on a satellite image from Google Earth.)

1.13.2 Salvage of the aircraft wreckage

A first salvage operation under SHK's supervision commenced immediately after the wreckage had been located and the rescue operation was over. The salvaging lasted up until 13 April 2012. The work was carried out under very difficult and risky conditions and was strongly affected by weather conditions such as snow, strong wind, low temperatures and poor visibility. The salvage crew, consisting of personnel from Norway and Sweden, also had to take into account risks such as steep terrain, glacial rifts and high risk of an avalanche. The primary task was to find the CVR and DFDR and to salvage and investigate parts of the wreckage that could provide information on the sequence of events and the flight status at the time of the collision with the mountain

No clear pattern of distribution could be discerned during the initial salvage operation. Large parts were found both down in Rabot's glacier (e.g., loading ramp) and up on the ridge between the north and south peaks (e.g., upper part of the tail fin). The work at the site of the accident had to be stopped after a month of very difficult weather conditions.

A second salvage operation was carried out from 31 July to 13 August with the purpose of finding both CVR and DFDR. Once these had been found, SHK's salvage of the aircraft wreckage ceased.

The salvaged parts were transported to the Arena Arctica hangar at Kiruna Airport, where they were cleaned, identified, weighed and sorted. Some parts were laid out in the formation of the aircraft, others were sorted according to the system to which they belong (electronics, fuselage panels, engine parts, etc.), see fig. 29 below. Additional parts considered to be of less importance to the investigation were sorted directly onto pallets. Personnel from the aircraft manufacturer assisted SHK in this work.

Fig. 29. Overview of the Arena Arctica hangar. (Photo: SHK.)

Following analysis of the parts, they were packed into containers and put in storage pending further investigation.

The great majority of the salvaged parts are very small parts of the wreckage. Parts of the tail section, the upper part of the tail fin and parts from the left side of the aircraft are some of the few larger parts of the wreckage seized, see fig. 30.

Fig. 30. Some of the larger parts of the wreckage in the hanger. Parts of the tail section in the foreground. (Photo: SHK.)

1.14 Medical information

1.14.1 The crew

According to *Bestemmelser för militaer luftfart, BML(D)* [Regulations for Military Aviation], flight personnel must undergo annual flight physical examinations, but the *director of the Norwegian Association of Aviation Medicine* can grant exemption from this under special circumstances.

According to information received during an interview with an aviation medical examiner, the Commander had been exempted from flight physical examination up until June 2012.

When reviewing the last 72-hours of medical records, it was discovered that two days prior to the accident the Commander had symptoms of a sinus infection, and therefore did not wish to undertake HAHO missions (which involve flying at high altitude without a pressurised cabin). There has been nothing to suggest that the problem was so severe as to necessitate contact with an aviation medical examiner or that he had refrained from undertaking flights due to his symptoms.

According to information obtained in the interviews, the crew's shifts allowed for a normal night's sleep.

Other members of the crew had approved flight physical examinations in accordance with the rules and regulations. Over the course of the investigation, there has been no indication that their general state of health was impaired on the day of the accident or the days leading up to it.

1.14.2 Air traffic controllers

At the time of the incident in question, all three air traffic controllers valid medical certificates without limitations. During the course of the investigation, there has been nothing to suggest that the air traffic controllers' psychological or physical health has been impaired in connection with or during the shift in question.

1.15 Chance of survival

1.15.1 Fire

Some parts of the wreckage show signs of fire, though with a very limited spread. Isolated and localised incidences of charred carbon fibre have been established.

1.15.2 Physical impact on the human body

An individual using a safety belt is subject to major trauma in the event of a collision at speeds above 70 km/h. For an individual without a safety belt, the corresponding speed is 50 km/h.

In collisions at high speeds, the human body is damaged both via direct force and the increase in pressure resulting from the sharp deceleration at the moment of collision. With this type of trauma, energy is transferred and leads to the disintegration of the body's tissues.

The speed of the aircraft at the moment of collision was approx. 520 km/h (280 kts). Those on board at the time of the collision were therefore subject to major trauma and had no chance of survival. All were killed instantly.

1.15.3 *Emergency Location Transmitter*

The aircraft was equipped with an *ELT (Emergency Locator Transmitter)*, mounted in the tail. The ELT system is part of the satellite based rescue system *Cospas-Sarsat*. ELT signals received are forwarded to the Swedish air and sea rescue centre, *JRCC (Joint Rescue Coordination Center)* in Gothenburg.

The on-board ELT equipment consisted of a *Cobham C406-2* with associated antenna. The ELT is designed to be activated at G-forces in excess of 2.3 G, at which point it starts transmitting on all three emergency frequencies: analogue signals at 121.5 and 243 MHz, and digital signals at 406 MHz.

The ELT unit has an internal battery for operation without an external power source for 50 hours (121.5 and 243 MHz) and for 24 hours (406 MHz), and is certified for operation in the temperature range -20° – +55° C. In addition, the unit according to specification has a crash resistance of 500 g for 4 ms and 100 g for 23 ms. Moreover, the standard DO-182, referenced in the ELT manual from Cobham, states a recommendation for the ELT attachment points in the aircraft to be such as to guarantee the operation of the ELT at force stresses up to +/- 100 g in the direction of travel. Attachment of the transmitter unit and the antenna unit, according to the same standard, should be as close to each other as possible, on the same structure section, in order to maximise the likelihood of function after an accident.

No signals from the aircraft's ELT system were received after the accident. The ELT unit was found in damaged condition during the second salvage operation (August 2012), see Figure 31. The antenna section has not been found.

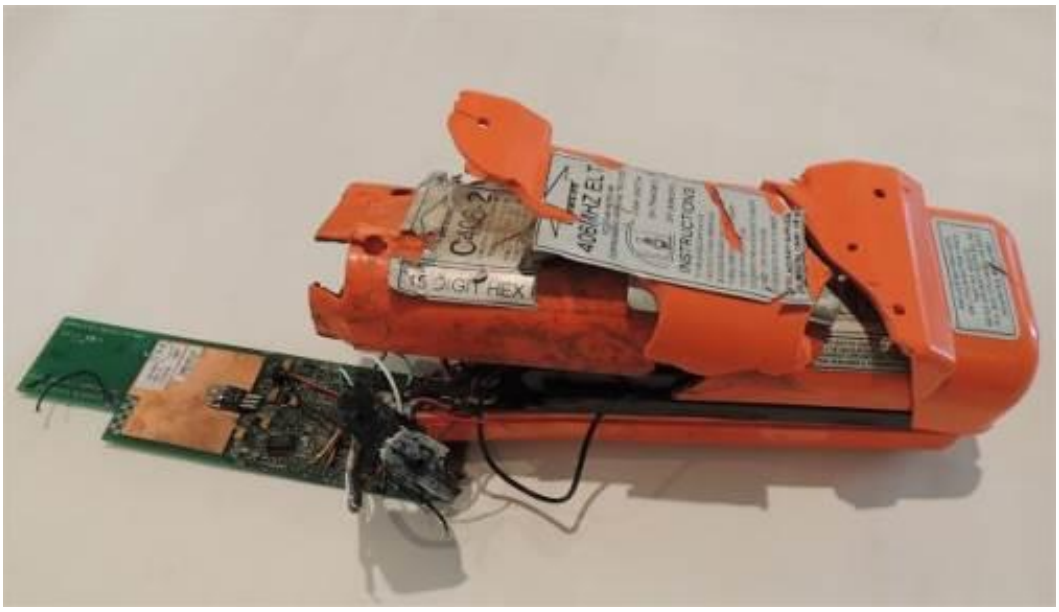

Fig. 31. Photo of the aircraft's ELT, Emergency Locator Transmitter. The damage to the unit is greatest in the forward part, on the left of the picture, where the antenna connection is located. (Photo: SHK)

1.16 The rescue operation

The following section provides a summary of the rescue operation. A more detailed report of the rescue operation can be found in Appendix 1 (available only in Swedish).

<u>*General*</u>

When the aircraft was reported lost, a search operation began which went on for around 36 hours before the site of the accident was discovered. Thereafter, it took a further eight hours or so before it was established that none of the five individuals on board had survived.

Those responsible for the rescue operation – the Swedish Maritime Administration in collaboration with the Joint Rescue Coordination Centre (JRCC), under which the air rescue centre, the Norrbotten County Police and the rescue services in Kiruna cooperated with one another and with other units and other management functions from organisations in Norway. Resources for the rescue operation were provided by the Swedish and Norwegian armed forces, among others. Military air forces from other countries within NATO also participated. Due to the extensive military presence in the region at the time owing to the *Cold Response* exercise, there were also various types of land and air units immediately available to assist in the rescue operation.

Also assisting in the operation was the National Bureau of Investigation, SOS Alarm in Luleå, the rescue services in Gällivare municipality, Norrbotten County Council and the County Administrative Board of Norrbotten. Volunteers with a good knowledge of the area were enlisted as guides for the search on land.

The management of participating operative units required collaboration with partners which were in some cases not previously known. Resource management for efforts in inaccessible terrain under difficult weather conditions are examples of situations that arose, in terms of both practical difficulties on the terrain and difficulties in management. One particular area was the collaboration that took places on all levels between Swedish and foreign participants in the rescue operation.

<u>*Thursday 15 March 2012*</u>

The air traffic controller at Kiruna Airport alerted the municipal rescue services in Kiruna at 15.30 by means of an accident alarm that was sent to the rescue service's alarm centre. One minute later, the air traffic controller also alerted JRCC. They received information that an aircraft of type Hercules was reported missing when it did not land at Kiruna Airport as expected. At JRCC, an air rescue operation commenced which continued until the morning of Saturday 17 March 2012.

The work at JRCC involved the management and coordination of various rescue units in order to locate the missing aircraft. During the rescue operation, JRCC received information that several units from different organisations were assisting or offering to assist in the search. The collaboration expanded and covered a number of different organisations and units, and cooperation was established at an early stage between JRCC and the Joint Rescue Coordination Centre Northern Norway (HRS NN).

On its own initiative, the municipal rescue services in Kiruna commenced an operation that lasted for approximately 48 hours, from Thursday afternoon to Saturday afternoon. The operation was not carried out as a municipal rescue service in accordance with the Civil Protection Act (2003:778); it was instead primarily a support to the air rescue services, as well as to police preparations for and execution of the mountain rescue service. The work at Kiruna rescue services was characterised by preparations for the extrication of any individuals who may be trapped inside the aircraft wreckage and to assist with the transportation of injured persons across the terrain. Continuous managerial and staff efforts were also underway at the fire station in Kiruna. An investigation was also made into whether the accident had entailed damages from emissions into the environment that could necessitate municipal efforts in the rescue operation as per the Civil Protection Act. The municipal rescue units were first transported to Nikkaluokta and later arrived at Kebnekaise Mountain Lodge around midnight (between Thursday and Friday).

On Thursday evening at Norrbotten County Police, it was decided that the operation would be classed as a “special event”. A commanding officer was appointed and a team put together at the police station in Luleå. The work of the county police was characterised primarily by preparations leading up to efforts for the mountain rescue service that was to be performed once the site of the accident had been located. A Police Incident Officer (PIC) was appointed on Thursday afternoon, who initially also assisted as a collaborator in the team at the fire station in Kiruna.

From the very beginning of the search for the missing aircraft, both Swedish and foreign military air and land units assisted on their own initiative. Special units with special expertise in working under winter conditions in inaccessible mountain terrain assisted, from both Sweden and Norway, and worked in difficult weather and terrain conditions.

Friday 16 March 2012

During the night, between Thursday and Friday, the Air Rescue Coordinator at JRCC directed the search towards a designated area in the Kebnekaise massif. A large number of flying resources were at the Air Rescue Coordinators disposal. However, the prevailing weather of strong wind and poor visibility meant that the search could not be conducted from helicopters in the area in question.

The search on the ground was conducted with Kebnekaise Mountain Lodge as a starting point, where personnel from Kiruna rescue services, Swedish and Norwegian military units, paramedics, mountain rescuers from the police, a number of civilian guides, and later the police as well, were situated.

The local coordination of the units conducting the search on the ground was carried out by means of a field team/outdoor team at Kebnekaise Mountain Lodge. The field team consisted of representatives from the municipal rescue services, Swedish and Norwegian military and, from the Friday evening onwards, the police's PIC. Communication between the field team and JRCC in Göteborg took place via telephone and e-mail.

Late on Friday afternoon, the first discoveries of wreckage were reported.

Saturday 17 March 2012

On Saturday morning, the Air Rescue Coordinator gave the PIC[35] responsibility for the ground units. Around seven in the morning, the site of the accident had been localised to the west side of the Kebnekaise's highest ridge and Rabot's glacier. For this reason, a decision was made at 09.00 at JRCC to discontinue the air rescue service.

At the same time, the Norrbotten County Police decided to commence a mountain rescue service in order to attempt to find and rescue any survivors from the aircraft. Taking into account the parts of the wreckage and body parts discovered during the day, it became clear that no-one had survived the accident. The mountain rescue service was therefore discontinued on Saturday afternoon at 17:30. Roughly half an hour later, the municipal rescue services also discontinued their supporting efforts.

1.17 Tests and research

1.17.1 Radar data

The Swedish Air Navigation Services had no radar coverage in the area in question, but the actual flight could be followed at lower levels by six military radar stations in both Norway and Sweden.

From each radar station, the last ten registered radar responses prior to impact have been used to produce a reconstruction of the flight path. The aircraft's point of impact has been used as the final point in each "track" registered by radar.

Figs. 32-33 show each of the tracks from the respective radar station, leading up to the point of collision.

Radar station	**Colour of the flight path as registered by radar**	
Njunis, Norway	(blue line)	Blue
Senja, Norway	(red line)	Red
Evenes, Norway	(yellow line)	Yellow
Kletkov, Norway	(purple line)	Purple
Bodö, Norway	(pink line)	Pink
Swedish Armed Forces	(black line)	Black

35 Police Incident Officer

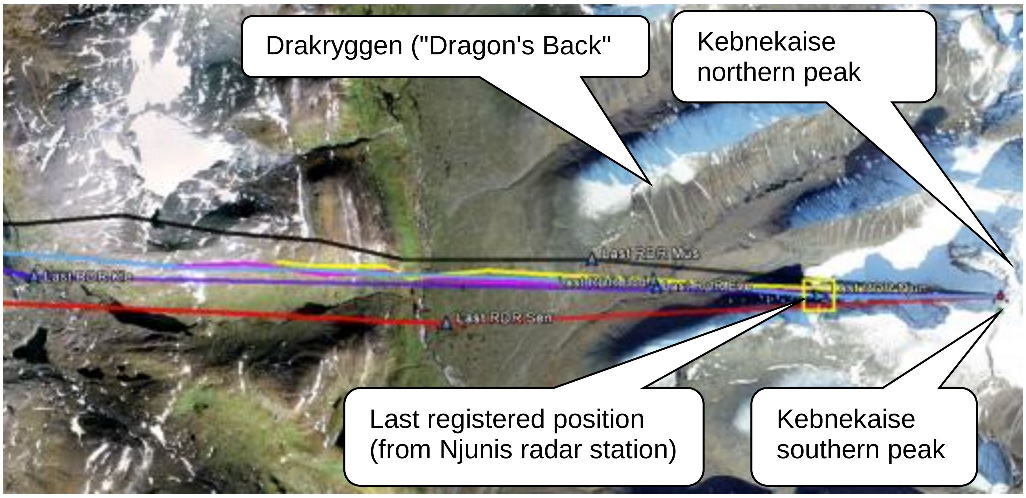

Fig. 32. View from above: final stages of the radar tracks.

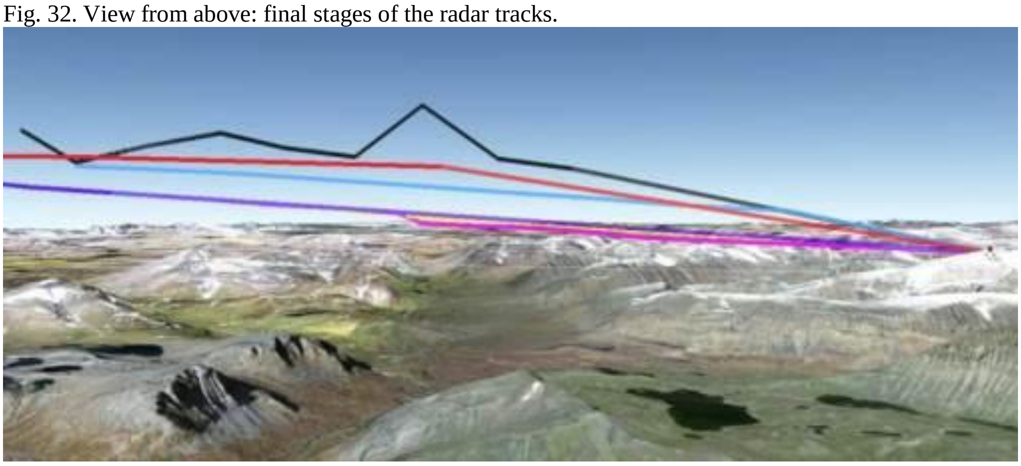

Fig. 33. Perspective view from the south.

The precision of the positions registered by radar depends on the radar station's distance from and alignment with the object, ground conditions between the station and the object, the object's height above ground, atmospheric conditions and the type of radar.

1.17.2 Seismic data

The Swedish National Seismic Network at Uppsala University's Department of Earth Sciences registered signals with a seismic energy corresponding to a quake of 0.01 on the Richter scale which are most likely attributable to the accident. The determination of the time is quality-assured, and according to these observations the time of the collision was 14:57:29.

1.17.3 Altimetry

<u>*General*</u>

The altimeter is a flight instrument used to display the height above a reference pressure area. The reference pressure area used depends on whether the aircraft is flying at *Flight Level* or *Altitude*.

Flight Levels refer to the pressure surface 1013.2 hectopascals (hPa) or 29.92 inches of mercury (in Hg) and has a nominal altitude difference of 500 ft based on the International Standard Atmosphere (ISA). Flight level zero shall therefore correspond to the pressure surface 1013.2 hPa. Flight levels for IFR flying are numbered 010, 020, 030, etc. thereafter, whilst flight levels for VFR are numbered 035, 045, 055, etc. IFR flight levels have a nominal altitude difference of 1,000 ft.

Flight altitude normally refers to the pressure surface QNH, which is an atmospheric pressure within a certain defined area adjusted to mean sea level. An altimeter set to QNH will display the airport's elevation above sea level when the aircraft is on the ground at the airport's altimeter checkpoint.

The transition from *flight level* to *altitude* is made within the transition layer, the lower limit of which is called the "transition altitude" and the upper the "transition level". During take-off and initial climb, the altimeter is set to the QNH value of the departure airport. During the climb, the altimeter is switched to standard (1013.2 hPa) when passing the transition altitude. Thereafter, level is expressed in flight level. During descent, the altimeter is switched to the QNH value of the landing airport when passing the transition level. Thereafter, the altitude is expressed as height above sea level.

The altimeter is calibrated to be accurate in conditions corresponding to the *International Standard Atmosphere* (ISA). Where conditions deviate from ISA in terms of low temperatures and high wind speeds, the displayed value must be corrected. To obtain the height above sea level when flying at flight level with the altimeter set to the standard atmospheric pressure of 1013.25 hPa, the displayed value must be corrected for the local atmospheric pressure.

Altimeter settings during the incident in question

The aircraft was equipped with an altimeter at each pilot seat and one backup altimeter. Each one had an adjustable scale used to set the atmospheric pressure in millibars (mb) and inches of mercury (in Hg). One millibar is equivalent to one hectopascal.

SHK has calculated that Flight Level 70 corresponded to the altitude of the point of impact for the accident, at 2,014 metres. The calculations have been performed as follows:

- Flight level 70 corresponds to 7,000 feet above the pressure surface 1013 hPa
- The prevailing atmospheric pressure (QNH) in the area was the equivalent of 1000 hPa
- The difference of 13 hPa * 30 feet = 390 feet.
- 7,000 feet – 390 feet = 6,610 feet
- 6,610 feet x 0.3048 = 2,015 metres

The resulting height only takes into account the atmospheric pressure. It is not possible to calculate an exact height with regard to prevailing local wind speeds and temperatures as these values are not recorded in the area of the incident. However, the calculated value corresponds to a high degree with the altitude of the aircraft's point of impact according to GPS.

Calculation of the lowest usable flight level in the prevailing atmospheric conditions

The prevailing meteorological values that could potentially have affected the values displayed by the altimeter were:

- Lowest forecast pressure in the area: 998 hPa (Kiruna)
- Lowest temperature in the area: 2°C (Kiruna)
- Highest forecast wind speed: 60 knots

Based on the fact that the highest terrain along the flight path was 6,900 feet (rounded up to the nearest 100 feet) and that the lowest altitude must be 2,000 feet higher, there is a nominal minimum altitude of 8,900 feet, which gives a nominal minimum flight level of 90.

As the lowest atmospheric pressure along the flight path is 998 hPa, the altitude must be corrected as follows:

- 1013 hPa – 998 hPa = 15 hPa
- 15 hPa x 30 feet = 450 feet

Flight level 90 corresponds to 9,000 feet in the standard atmosphere. When the altitude is corrected for the lower atmospheric pressure, we calculate as follows:

- 9,000 feet – 450 feet = 8,550 feet

Flight level 90 therefore does not fulfil the requirement for an obstacle clearance of 2,000 feet; see fig. 34.

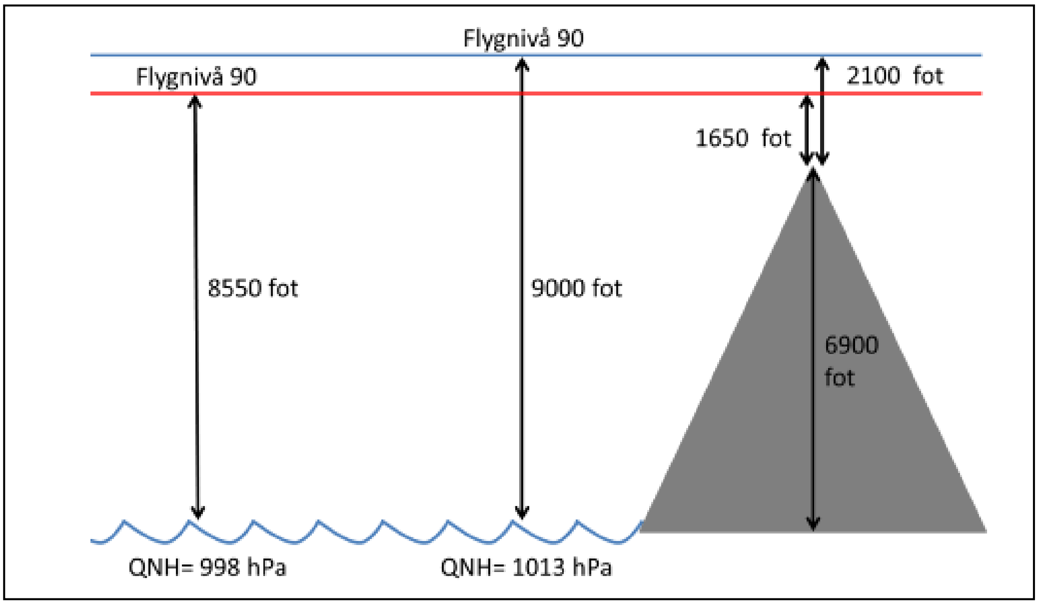

Fig. 34. The upper blue line shows the height above the terrain with the altimeter set at 1013 hPa for a local atmospheric pressure of 1013 hPa. The red line shows the height above the terrain with the altimeter set at 1013 hPa for a local atmospheric pressure of 998 hPa. N.B. Flygnivå = Flight Level, fot = feet.

According to ICAO, temperature corrections only need to be made if the temperature is considerably lower than ISA. According to ISA, the temperature at sea level is 15° C and decreases as altitude increases, by 2° C every 1,000 feet. As Kiruna Airport lies 1,509 feet above sea level, the temperature according to the standard atmosphere is 12° C at the airport's height. The prevailing temperature in Kiruna was +2° C, meaning no temperature correction is necessary.

The wind correction is made on account of the wind speed. The higher the wind speed, the greater the correction. At 60 knots, the correction is 455 feet in accordance with ICAO's correction tables.

If we add these corrections together we get:
- 450 + 455 = 905 feet
- 8 900 + 905 = 9,805 feet

The lowest usable flight level is the first flight level above the minimum safe altitude. In this case, it is Flight Level 100, which corresponds to 10,000 feet above the pressure surface 1013 hPa.

From an obstacle clearance perspective, Flight Level 100 was the lowest usable IFR flight level for the flight in question, according to the documentation available when the flight was planned. In order to perform the flight in controlled airspace, however, Flight Level 130 was the lowest usable.

1.17.4 *Examination of parts found in the wreckage*

Some of the parts found in the wreckage have markings such as impact damage that can provide information on the flight status and the configuration of the aircraft at the time of the collision. More detailed information on these parameters is available from the aircraft's flight recorder.

Rudder/ailerons/elevator

An aileron with part of its mounting were found at the site of the accident. A cursory inspection carried out on-site indicated that the rudder was either in or very close to neutral position at the time of collision.

The aircraft's rudder was examined in the hangar. The damage to the rudder, including impact damage, indicated that it was in its neutral position at the moment of collision.

The aircraft's elevator was also examined in the hangar, both with regards to the elevator cylinder and the impact damage to the aircraft's tail section made by the arms of the respective elevator counterweights. Both right and left elevators had separated from the stabilizer. Parts of the elevator remained on the elevator axle, which is how the elevator position could be examined. The examination was carried out on both sides, and revealed that the elevator was in or very close to its neutral position.

Landing gear

One of the landing gear legs from the main landing gear was examined in the hangar. The examination reveals that the landing gear was in the stowed position at the time of the accident.

1.17.5 *Investigation of standby instrument height/speed*

At the site of the accident, one standby instrument was found; a combined altimeter and airspeed indicator. The instrument was damaged, but the values for both altitude and airspeed could be read. The value for the altitude, with three fixed zeros, was 17,000 feet STD. The value for the *Indicated Air Speed (IAS)* was around 220 knots – see figs. 35-36.

Fig. 35. Standby instrument for altitude and airspeed. (Photo: SHK)

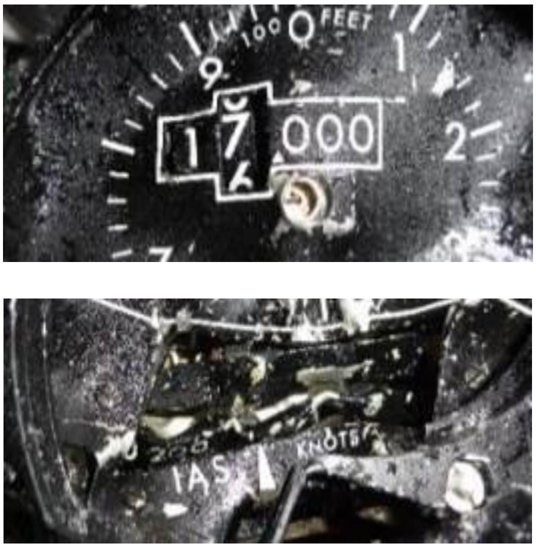

Fig. 36. Instrument values for altitude (in feet) and airspeed (IAS in knots). (Photo: SHK)

A more thorough examination of the instrument was prepared in order to ascertain whether the leftmost (ten thousand) digit of the indicated altitude may have been altered in connection with the collision. The point of collision is at an altitude that with the prevailing atmospheric pressure corresponds to 7,000 feet STD. This examination was however deemed unnecessary once the aircraft's CVR and DFDR were recovered.

1.17.6 *Examination of fuel*

Fuel samples from a petrol truck and fuel tanks at Evenes Air Station, which was used for the final refuelling of the aircraft, were analysed at the Norwegian *”Forsvarets laboratorietjeneste”* [defence lab]. A full specification analysis was performed.

The reports on the fuel samples reveal that none of the samples contain contaminants, that the fuel fulfils the quality standards and that the results of the tests are consistent with previously conducted certification tests.

1.17.7 *Reference flight*

In order to check the quality of radar data from the accident and to examine the function of the aircraft's systems for Ground Collision Avoidance and Terrain Avoidance (GCAS/TAWS) in the terrain in question, reference flights were performed using a C-130J from the Norwegian Air Force.

Using registered radar information from the time of the incident (see *1.17.1 Radar data),* radio traffic, the position of the crash site, the course from the crash site towards Kiruna and the procedures normally applied with C-130J, the likely route that the aircraft was following at the time of the incident was reconstructed.

Fig. 37. Flight path for the reference flight.

This flight path was then used as a basis for the reference flights; see fig. 37 above. In order to follow this flight path during the reference flight, the following values were aimed for at the points noted in the figure.

- *TEST START Pt:* Start point of the reference flight path. Level: Flight Level 130. Airspeed: Appropriate, when taking into account the mass of the aircraft, etc.

- *TEST TOD (Top Of Descent):* Start point for descent to Flight Level 70. Airspeed: 315 kts GS. Visual view from the cockpit in this point; see fig. 38.

- *TEST 10K:* Control point for passing Flight Level 100. Airspeed: 295 kts GS.

- *TEST 7K:* Cut-off point for assuming level flight at Flight Level 70 and airspeed 275 kts GS. The pilot then continued level flight and checked that the speed vector symbol in the aircraft's HUD was at the point of impact.

- *1 NM from the point of impact:* The reference flight was interrupted by pulling up, so that the aircraft flew freely over the ridge between Kebnekaise's south and north peaks.

- *IMPACT:* The aircraft's point of impact on the rock face.

Fig. 38. View from the cockpit at the point TEST TOD during the reference flight (that is, in good visibility). Point of impact marked with a red star. (Photo: SHK)

A total of 14 reference flights were carried out, seven of which with GCAS/TAWS in *Normal* mode and seven in *Tactical* mode. Initially, flights were conducted with a maximum altitude of 7,200 feet at the local QNH in order to fly over the entire profile of Kebnekaise with safe terrain clearance. Following this, an altitude of 7,000 feet was used, with the same difference to QNH as that prevailing at the time of the incident. The altitude was verified by checking that the speed vector symbol in the test aircraft's HUD in level flight was level with the impact point of the aircraft involved in the accident.

GCAS/TAWS in Normal mode

Some false GCAS alerts ("*TERRAIN"* and "*PULL UP"*) were observed in *Normal* mode, partly on the way from Kiruna to Kebnekaise at Flight Level 90 and partly at Flight Level 130 over mountainous terrain. After descent no false alerts were observed.

Otherwise, the system in *Normal* mode appeared to operate as intended. *Caution* and *Warning* came at an early stage, audibly as well as visually through the pop-up of TAWS presentations on the *Head Down Display No. 3*. Already at an altitude of 500 feet above the terrain before the reference flight path started, a continuous *Caution/Warning* was received. The warnings were very clear, both aurally and visually.

GCAS/TAWS in Tactical mode

No relevant GCAS/TAWS alerts were observed during any part of the reference flight path after descent. The message *TAWS TACTICAL VOID* was active both leading up to and when passing over the accident site. A terrain warning occurred first when passing the point of impact following interruption of the reference flight path and climbing over the ridge between the peaks.

MOA (*Minimum Operating Altitude*) was set partly to 150 feet and partly to 1,000 feet on the radar altimeter. The value set in the aircraft involved in the incident, 200 feet, was not known at the time of the reference flight. With these settings, no warning was generated when falling below MOA before passing the point of impact. The aircraft's flight path in the last 5 NM during the reference flight only went below 1,000 feet ground clearance in the very last instant before the point of impact.

1.17.8 The term CFIT

The term CFIT stands for *Controlled Flight Into or Toward Terrain*, according to *CAST/ICAO Taxonomy Team*, and is defined as follows: *"In flight collision or near collision with terrain, water, or obstacle without indication of loss of control"*.

1.17.9 The pilots' basic training, refresher training and previous experience

The pilots had undergone their basic training and certain parts of the refresher training on C-130J in the USA. According to information obtained in interviews, the simulator programmes followed US Air Force training programmes and were also carried out by their instructors. It has not been possible to programme Scandinavian airports into the simulators.

According to information from the Norwegian Air Force, both pilots had several years' experience of flying in Northern Norway.

1.18 Special or effective methods of investigation

1.18.1 Investigation of the site of the accident and search for CVR and DFDR.

The site of the accident was in high alpine terrain. Upon impact, the aircraft was torn apart with great force, and many small fragments were covered with snow in an avalanche caused by the crash. The area of distribution on Rabot's glacier was split into a grid by means of staves planted in the snow to act as a central line, see fig. 39.

Fig. 39. Stave for marking zone F and central line. (Photo SHK)

The work at the scene of the accident was prioritised with a view to finding the CVR and DFDR. These units were assumed to be buried under the snow, with no possibility of locating them other than working through the snow masses and identifying them visually. So as to focus the searches on areas more likely to hold objects the size and density of the CVR and DFDR units, the kinematics[36] of the avalanche were studied and there were discussions with mountain guides from the Swedish Armed Forces.

Ground radar, modified for the purpose, was initially used to identify objects in the snow, then primarily to locate rifts and springs in the glacier, whereby the areas of the glacier could be secured much faster than with conventional sounding. The radar images were analysed by glacier experts from Stockholm University and the research station in Tarfala.

Initially, the search for the CVR, DFDR and other parts was conducted by hand; see fig. 40. This was very demanding and resulted in a great number of small excavation sites.

[36] Snow Avalanches, Christophe Ancey, Cemagref, unite Erosion Torrentielle, Neige et Avalanches, Domaine Universitaire.

Fig. 40. A search team digs its way along Rabot's glacier. (Photo SHK)

In order to cover the largest possible area, SHK decided to make use of a small piste machine to scrape away layers of snow thin enough for the DFDR and CVR not to be shovelled away with the snow as the personnel looked on; see fig. 41. In this way, large volumes of snow could be worked through quickly and pushed to the side. The areas examined were checked over with ground radar and metal detectors, whereby only a few smaller parts could be located.

Fig. 41. Piste machine and search team. (Photo SHK)

The work at the scene of the accident entailed a high degree of risk due to a number of factors such as very high risk of avalanches, hidden glacial rifts, fall hazards and poor weather in the form of low temperatures, wind and snowfall. The mountain safety work was the responsibility of the Swedish Armed Forces' mountain guides, and in consultation with these a decision was made as to where, how and when the work would be carried out.

Work at two different areas within the site of the accident proved effective; in lower sections with a piste machine and 5-10 people, in higher sections with around 10 people digging. In each team, at least one person was tasked with keeping an eye out for falling objects and avalanches from above. Uncovered parts were marked with zone numbers in order to investigate the distribution pattern.

Initially, the search efforts were concentrated to the area in which the rear ramp was found and on the ridge between the north and south peaks. Occasionally, a high concentration of parts was discovered from the rear structure of the aircraft on which the CVR and DFDR were mounted, so the search was then focused on this area.

On 14 April 2012, the search operation was brought to a standstill due to recurrent snowfall and periods of poor weather conditions, with the intention of continuing once the melting of snow in the area was maximal; i.e., early autumn.

During the second search operation, a large number of parts had appeared with the melting of the snow. The concentration of parts from the wreckage was very high on the north-west face in the area north of the point of impact, and there was a particularly high concentration of parts on the rock ledges. A great many parts had also been revealed along the ridge. This meant that the search for the DFDR and CVR was concentrated to the ridge and ledges along the rock faces surrounding the point of impact.

The ridge, the north-west face and the area of the glacier were photographed with a camera capable of taking high resolution pictures. These were then pieced together to make a panoramic image. The next stage was to filter the colours so that the red of the CVR and DFDR units would stand out, thus allowing them to be identified. The photographs were taken from a helicopter at specific GPS coordinates. Creating a panoramic image proved to be a time-consuming process, as did analysing the image content of the hundreds of high definition pictures taken of the area. Before the analysis was complete, the CVR chassis was discovered by the Swedish Army Ranger Battalion during the process of securing the ridge for the work ahead. When studying the photographs after the fact, the CVR chassis is clearly visible. The DFDR was found one week later in the avalanche area on the Rabot's glacier.

1.19 Measures taken after the event

1.19.1 The Norwegian Air Force

The Norwegian Air Force has informed SHK that the following measures have been taken in response to the incident:

- The crews of the Air Force's squadrons have been informed of the actual circumstances of the accident.
- Flytryggingsinspektoratet (FTI, the Norwegian Flight Safety Inspectorate), through its contacts in the flight squadrons, has emphasised pilots' responsibilities in relation to terrain separation and IFR flight in all types of airspace.
- All pilots of the 335 Squadron have had a thorough run through of the GCAS and TAWS systems to increase understanding of their function and limitations.
- The Air Force has obtained an updated terrain database for TAWS NORMAL MODE.
- Limitations in the use of GCAS/TAWS in TACTICAL mode have been introduced in the crew’s checklists for the Norwegian C-130J-30.

- A new HFL 121-13 C-130J Hercules Standard Operating Procedure has been issued and takes effect from 5 July 2013. The document states the following:

  GCAS/TAWS Tactical mode shall only be selected when needed for VFR Tactical low level operations. There is no terrain data north of 60° north latitude and south of 56° south latitude in the TAWS Tactical database. Therefore no TAWS terrain warnings will be given outside the coverage area of the TAWS Tactical database.
- A new BML will be introduced on 1 September 2013, which includes new provisions for terrain separation and the pilots' responsibility for this.

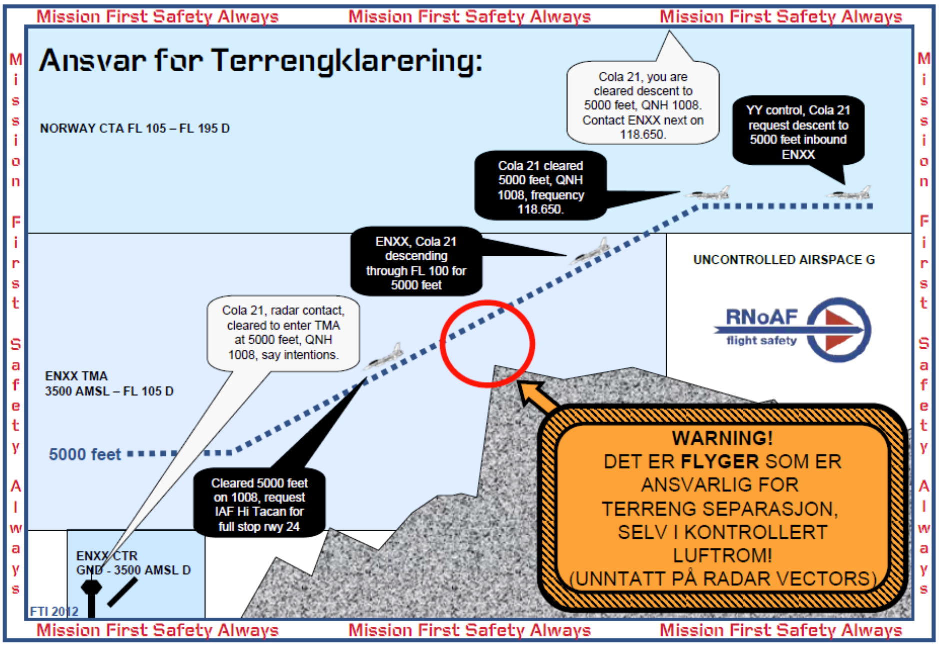

Fig. 42. FTI's Safety Poster sent to squadrons in May 2012. Title: Responsibility for terrain clearance. Bottom right: “Warning! The pilot is responsible for terrain separation in controlled airspace! (Except for radar vectors)”.

In order to notify the crews of the Norwegian Air Force, the following Red Marker has been produced:

> **RED MARKER text** **Date:** **04.06.2012**
>
> There have been discussions about the use of the GCAS/TAWS system. It has become clear that in "Tactical mode" the system has an inadequate or limited database north of 60 degrees N and south of 56 ° S. For this reason, a limitation has been introduced on the use of "tactical mode". **"Tactical mode" should only be used for tactical flight in VMC conditions.** This also underlines the importance of using the COMBAT ENTRY/EXIT checklist and that the checklists should be completed before a "predetermined" entry/exit point (CEP), unless the tactical flight starts and stops at departure/arrival RWY. No checklists or procedures have been drawn up for this as yet, but for the acquisition of an aircraft by ERCC procedures, it is particularly important to ensure that the GCAS/TAWS system is in the correct mode depending on weather conditions and the nature of the flight. Also check that the system is always in the correct mode after power-up before the flight commences.

1.19.2 *The Swedish Transport Agency*

The Swedish Transport Agency has reported to SHK the following measures that were taken in response to the accident:

- By following up OMA / SUPP, inter alia, and in dialogue with LFV, we have ensured that the incident was handled in a manner which we consider satisfactory. We have also carried out special supervision in order to confirm that the measures taken by LFV's management were implemented in the operative plan for our organisation.
- We are following up on the measures promised by LFV via the ongoing supervision.
- Arrangements are also being made to meet LFV's management for a follow-up discussion on matters such as their internal investigations.

1.19.3 *LFV*

LFV has reported to SHK the following measures that were taken in response to the accident:

- Internal investigation of ATS function
- OMA Kiruna
- Operative Instruction (OI) ATCC[37] Stockholm
- ATCC Stockholm and Kiruna ATS have changed their working methods in accordance with the published SUPP 12/12 (OI 20/2012 published 16/03/2012).
- ATCC Stockholm has had recurring discussions with personnel at our team meetings (team meetings are scheduled every quarter).
- ATCC Stockholm has introduced a chart into TopSky which indicates the minimum vectoring altitude.
- ATCC Stockholm and Kiruna ATS have gone through LFV´s internal investigation with all personnel in autumn 2012.

1.19.3 *Lockheed Martin*

SHK has been informed of the following measures taken by Lockheed Martin in relation to the systems in question :

- A new chapter entitled *“Terrain Awareness and Warning System (TAWS) Limitations”* has been added to *“Section 1 Limitations”* of the manual.
- A new measure for the crew has been added to the emergency checklist when the message *“TAWS TACTICAL VOID”* is activated; *Crew Action: 1. Maintain safe altitude or visual contact with the ground. 2. Select NORMAL mode if alerts are required.*
- A new limitation has been added to the flight manual’s system description of TAWS: *Do not use TAWS TACTICAL mode at latitudes greater than 60°N latitude or less than 56°S latitude.* A note has been added which emphasises that the TAWS system may not be used as an aid to navigation.
- A revision of DFDR parameters is under consideration, and improvements to the aircraft’s DFDR capacity will be developed.
- An overhaul of the ELT installation in the aircraft is planned.

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[37] Air Traffic Control Center.

2. ANALYSIS

Basic underlying principles of the analysis

SHK adopts an outlook on how accidents should be investigated, one which is based on a systems approach. This means that shortcomings in safety within the concerned operation or organisation are sought as an explanation for the accident, instead of attempting to identify errors and mistakes made by individuals. From a safety perspective, what SHK is most interested in is not *who* was at fault but rather *why* there was a mistake made. This means that SHK does not normally point out errors or mistakes made by individuals as the primary cause of an accident.

Instead, an accident is in the first instance considered as an indication that there may have been shortcomings in safety within the company or organisation under which the accident occurred. SHK's perception is that this outlook allows us to identify the primary causes of an accident and thereby arrive at more broadly significant improvements of safety than if explanations were instead sought from individuals. If there are fundamental flaws in a system which are not identified and rectified, there will always be a risk that another individual makes the same mistake or error. An accident investigation should therefore produce an overall picture of the causes of an accident, as well as their consequences and the possibilities for improving safety.

2.1 Flight operations

2.1.1 Take-off sequence and holding pattern

The crew's actions during the preparations in the aircraft prior to take-off, reading checklists and when the engines were started, etc., reveals – according to the information recorded by the CVR – that established procedures were followed. Similarly, the crew's collaboration during taxiing to the take-off position and the take-off itself demonstrated in all material respects a proper conduct. Departure briefing for SID GILEN 1E is read and MSA 7,300 feet is given as the Minimum Sector Altitude for the climb out.

In the holding pattern, the crews activities according to information from the CVR included the rectification of malfunctions and discussions on map scales and the terrain warning system. The Commander's explanation of the indication *”TAWS TACTICAL VOID”* was ”fordi vi er so høit” [”because we are so high”]. This can be interpreted as the Commander's awareness of the system's limitations north of 60 degrees latitude, as this flight was far north of this point. Another interpretation of the Commander's words is that they were at too great an altitude for the TAWS to work as intended. The latter would mean an incorrect interpretation of the reason behind the VOID message. The CVR information provides no further assistance in determining which interpretation is true. Information obtained during the interviews indicates that the Commander had knowledge of the limitations of GCAS/TAWS north of 60 degrees latitude during the training period in the USA. At the same time, with this knowledge, SHK is confused by the decision to use the system in *Tactical* mode under these conditions, as in practice this means that TAWS is rendered non-operational. No explanation has been uncovered as to why the crew would knowingly wish to disengage the terrain warning function, and may thus indicate that the crew had not fully understood the aforementioned limitations of the GCAS/TAWS system. SHK discusses this more in-depth in Section 2.3.

2.1.2 *The flight towards Kiruna*

Just after *HAZE 01* set course for Kiruna, the Commander contacted Sweden Control to request visual approach. *HAZE 01* left the cruising level of Flight Level 130 as soon as clearance for Flight Level 100 was obtained and then descended with the engines idling, which entailed a relatively high rate of descent. The Commander then once more requested visual approach, this time to the Kiruna tower, adding *”when approaching”.* This expression is not part of the established phraseology, but it is in SHK's assessment that the request for a visual approach occurs ”later” in the flight, and in this case when nearing the airport. Had the crew decided to switch to VFR flying, and not simply perform a visual approach under IFR, the IFR flight plan would have been cancelled. Based on interviews, SHK deems it likely that, when planning the flight, the crew aimed to fly IFR and then switch to VFR, during the last part of the stretch between Evenes and Kiruna, weather permitting. The switch to VFR flying never took place.

At the call, their position was pinpointed to 50 nautical miles west of the field, which is confirmed by data from the recording equipment. The crew thereby had the opportunity to geographically orient themselves laterally to Kiruna. In addition, the *moving map* system enabled both lateral and vertical orientation throughout the entire flight.

Flight level 100 was the minimum safe flight level that the crew could accept under this part of the flight – with considering underlying terrain and necessary corrections for atmospheric pressure, temperature and wind speed – without taking into account that this meant that they would leave controlled airspace.

The descent continued uninterrupted towards Flight Level 70, once clearance for this had been received from the tower at Kiruna. Soon thereafter, the warning for icing was activated, which indicates that the aircraft was flying in cloud or precipitation. Once in cloud, it is likely that the peak of Kebnekaise was fully or partly hidden, and if this was not the case, it is likely that the contours of the snow-capped peak could not be discerned against the white background of the clouds. The information recorded by the CVR reveals that the crew were in no way aware of the dangers presented by the proximity to underlying terrain and the terrain ahead. Similarly, the DFDR shows no evidence of evasive manoeuvres employed to avoid collision with the mountainside.

Based on data from the DFDR, SHK has established that the altitude was the equivalent of Flight Level 70 at the time of the accident, with a variation of less than 50 ft during roughly 15 seconds of level flight prior to the accident. The variation is likely attributable to turbulence. The calculated value of the flight level at that time, corrected for atmospheric pressure, corresponds very well with the altitude of the point of impact measured by GPS.

The value of 17,000 feet registered on the standby altimeter is most likely a result of the leftmost (ten thousand) digit being altered in connection with the collision. The indicated airspeed is consistent with the recorded data.

The autopilot was likely disengaged due to the turbulence.

2.1.3 *Why did the crew fail to identify the risk involved in descending to Flight Level 70?*

Introduction

The Commander always has the ultimate responsibility for safe piloting of the aircraft and must ensure that the aircraft is flown in accordance with applicable traffic regulations, including that the flight is conducted at or above the minimum safe altitude or flight level. This means that the primary responsibility for terrain separation is always on the Commander. If an aircraft flies IFR and is vectored by radar, air traffic control is responsible for issuing clearances that ensure obstacle clearance.

The responsibility for terrain separation therefore requires the pilots to always have a clear understanding of the aircraft's position and the minimum safe flight level or altitude that applies under the circumstances. At the same time, the pilots are expected to have a clear picture of the division of airspace into the areas in which a flight is conducted.

The clearances issued by air traffic control – first to Flight Level 100 and then to Flight Level 70, and which the pilots followed – entailed that the aircraft descended into uncontrolled airspace and below the minimum safe flight level for the area. In addition, the Top of Descent for the flight was at a considerably greater distance from Kiruna than what would have been natural. According to SHK, an important question that must be answered is why the crew did not react to and question the issued clearances.

Planning

Good planning generally increases the safety of a flight. The planning constitutes a critical element for the safety of the flight ahead and plays a very important role in matters of improving the crew's situational awareness by means of them being able to identify, discuss and handle the risks involved in the upcoming flight [38]. By studying charts, for example, the crew can familiarise themselves with obstacles in the terrain, and thereby also prepare themselves to react to the clearances given by air traffic control where necessary, by having a good knowledge of the underlying terrain and the various potential obstacles therein.

The fact that the flight was in this case conducted at Flight Level 130, in accordance with the ATS flight plan, and was planned to be conducted at Flight Level 160 during the return journey to Evenes, indicates that the intention was for the flight to be carried out at safe flight levels and in controlled airspace. The planning data provided to the crew by Mission Support have also been determined. It is however impossible to say whether the crew studied the planning data in detail or reviewed other documentation and charts in order to obtain information on the underlying terrain for the intended flight to Kiruna. Nor can it be established as to what concrete planning the pilots carried out prior the flight and what of it was used during the flight. It has therefore not been possible to determine whether the crew went through an operational flight plan of the type Jeppesen, which

[38] Cahill, J. N, McDonald. G, Losa. (2013) Understanding and Improving Flight Crew Performance of the Preflight, Flight Planning, and Briefing Task. The International Journal of Psychology, 23(1), 27-48.

according to SOP must be used where possible. SHK considers it likely that the LFC chart supplied to the crew was never used during the flight. The fact that the LFC chart was brought out for use during visual flight and that the Commander offered the chart to the crew on *TORCH 03*, combined with information from interviews with pilots from the Norwegian Air Force, confirms this.

In terms of the material supplied to the crew and routines for planning, however, SHK believes there is cause to point out certain shortcomings.

The chart of type LFC (see section 1.1.3) with annotations concerning minimum altitudes along the route included information on minimum safe altitude in the flight information boxes. MEF were also indicated, which could be a source of confusion. These lower MEF values could easily be interpreted as referring to the entire coordinate box in which a large part of the area is on the Swedish side of the border. Two such MEF values (4.9 and 4.4) lie in direct connection with the planned route on the LFC chart. In addition, very little information is reported on the Swedish side of the border. The possibility cannot be eliminated that the MEF may have given the impression of a considerably lower terrain on the Swedish side (an effect which would have been enhanced when nearing Kiruna) than was actually the case (fig. 1).

During the investigation, it has emerged that the content of the chart's *Doghouse* is not standardised. According to SHK, this constitutes a flight safety risk if the material is given to a crew that is unaware of what the input values represent.

During SHK's investigation, it has been difficult to create a clear picture of how the planning prior to the flight was intended to work. BML point 10.9.3 states that navigators or pilots responsible for the navigation of military aircraft must keep an ”operational flight plan” on the log sheet, established by a head of department in accordance with BSL D 2-1. BSL D 2-1 point 4.3.3.2 states the minimum required information to be included in the ”operational flight plan”. SHK has not found any such log sheet established by a head of department that contains all of the information required as per BSL D 2-1. No uniform procedure or system for this appears to exist. It seems rather to be the individual pilot's competence and experience that decides how the detailed planning prior to and during a flight is carried out. Nor has SHK found any documented methods in the Norwegian Air Force which establish a minimum safe flight level at atmospheric pressures below the standard.

On board the aircraft, an ENC and a chart of type DOD were found. These report the minimum safe altitude as 9.3 and 10.3 respectively. This includes a safety margin of at least 2,000 feet to the underlying terrain. On the aircraft's ”moving map”, the value 7.2 is given, which entails an applied safety margin of just 200 feet. Overall, this means that data were available both for planning the flight and for following up this plan along the route towards Kiruna, which could provide a basis for calculation of the applicable safe altitudes.

In summary, it is not possible to say exactly what kind of planning was actually carried out prior to the flight and how the planning was followed up during the flight. However, the available data for the minimum safe altitudes have likely not been used to actively check the obtained clearance to Flight Level 70. Had such a check been made, it would have been clear that the clearance was lower than the minimum safe altitude for the area.

In addition, the overall picture is that the pilots did not have detailed knowledge of the underlying terrain. Discussions recorded by the CVR concerned the position and height of Kebnekaise, but the crew does not identify the mountain as a risk when flying to Kiruna, despite it lying in the direction of flight in accordance with the planned route as per both the LFC chart and the actual flight path, according to the clearance, directly towards KRA. Nor was ”moving map” used, as far as the investigation has revealed, to check altitude or the geographical position of the mountain, in connection with the discussion. The latter can be explained by *HAZE 01* still being at Flight Level 130 at this point, in holding pattern on the Norwegian side with a magnetic track of 213 degrees, and it is not likely that Kebnekaise was in view on “moving map”. If the crew used ENC or DOD charts as a basis for planning and follow-up, neither Kebnekaise's position nor height are specified. The area is however marked as mountainous in both maps.

It is SHK's understanding that the crew must have been completely unaware of the actual height of the underlying terrain, or that they were entirely convinced that it did not constitute a risk to the flight. This may have been a contributory factor in the crew following the clearances without debate.

Weather

The interviews reveal that before departure the crew of HAZE 01 had considered flying VFR during the final stretch between Evenes and Kiruna. From the communication between HAZE 01 and air traffic control, it is clear that they wanted to conduct a visual approach. Though the flight was conducted under IFR for the entire sequence of events, the crew had wanted to fly VFR where conditions permitted. According to SHK, it is based on these conditions that the pilots' assessment of the prevailing weather should be viewed.

The portion of the flight in holding pattern and up until HAZE 01 descended into cloud when passing Flight Level 90 was primarily conducted above the clouds and in good visibility. These weather conditions meant that the terrain would have been intermittently visible and therefore give the impression that there was a rather thin cloud cover with good visibility below the clouds. The weather in Kiruna was CAVOK and the crew should have been able to see parts of the Swedish terrain closer to Kiruna from Flight Level 130 after having left the holding pattern. The part of the underlying terrain constituted by the Kebnekaise massif would likely have been hidden from the crew by the underlying cloud cover. This is also emphasised by the photography taken above the massif from a helicopter approx. 20 minutes prior to the incident. (see Section 1.8.1, fig. 12).

The above may, together with the inadequate knowledge of the underlying terrain and the crew’s reliance on the air traffic services (see below), have had an influence on the pilots' assessment that descending through the sporadically broken cloud cover below entailed no risk as the dangerous conditions – i.e., the mountains – were hidden by cloud.

Reliance on the air traffic services

Over the course of the investigation, in interviews and discussions with Norwegian pilots, there have been indications that there was a high confidence in the air traffic services' clearances. The reliability of the term *confidence* in this context must however be considered limited as no in-depth study has been carried out. There is however nothing remarkable about high confidence in clearances, but the pilots must have a readiness about them that comes from training and experience and which allows them to rely on the air traffic services whilst also verifying based on their own judgment and knowledge, as well as an awareness of the lowest usable flight level and minimum safe altitude during the various phases of the flight.

According to both Swedish and international regulations for the lowest usable flight level, when below this level, the vertical position must be expressed in altitude with the applicable QNH (ANS operations manual, Part 3, Section 2 – Chapter 4, 1.4 and Annex 2, 3.1.3 of the Chicago Convention). They also state that the lowest usable flight level is the flight level corresponding to or immediately above the established ”minimum flight altitude” (ICAO PANS-ATM, Doc. 4444, 4.10.3.2 Note 1). SHK returns to this matter in Section 2.2.5.

With knowledge of these regulations, the crew of *HAZE 01* may well have been of the understanding that the flight level to which they had been cleared by the air traffic controller was higher than the lowest usable flight level (i.e., that they were cleared to an obstacle-free altitude in accordance with the regulations) and consequently descended to the flight levels for which they had received clearance, without reflecting on the underlying terrain.

In this context, it can be established that the crew were informed neither by ACC Stockholm nor the tower in Kiruna that the clearance they received would take them out of controlled airspace and that the flight, below Flight Level 125, continued in uncontrolled airspace. Though the crew should be aware of the divisions of airspace and their own position, it probably did not occur to them that an air traffic controller would issue a clearance to leave controlled airspace without informing them of this. As no flight information was provided according to applicable phraseology, the crew were unaware that the aircraft had left controlled airspace and that they thus had to observe the special responsibility assigned to the Commander regarding separation from the underlying terrain for flight outside of controlled airspace. This, together with the aforementioned high confidence in the air traffic services and an expressed desire to conduct the latter part of the flight under visual conditions, may go some way to explaining why the air traffic controller's clearances were not questioned, instead being taken as confirmation that the situation was normal. This confirmation further hampered the pilots' chances of discerning and re-evaluating the situation. A false notion is often characterised by its resistance to correction and “confirmatory bias” (tendency to seek information which confirms an assumption), which may explain why the pilots failed to notice their circumstances[39].

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39 Hawkins, F. (2005). *Human Factors in Flight*. Hants: Ashgate.

The experience and composition of the crew

The composition of the crew was permeated by long professional experience. Other pilots in the squadron have described the flight as simple and routine both from a planning perspective and in terms of actually performing the flight. One factor that diverged from this picture was the high wind speed at the time, particularly at Evenes Airport. The above conditions, combined with a fairly routine and uneventful flight in the holding pattern for around one hour, means that the possibility cannot be eliminated that during the flight and in the final few minutes leading up to the landing the crew's attention to their respective operative tasks was diminished, unaware to them. It is known that such circumstances can lead to a deterioration in situational awareness among the members of a flight crew. [40]

In this context, it is also probably reasonable to assume that the co-pilot, with a rather limited number of hours on the model in question, had a great deal of confidence in the Commander, who was considered to be the squadron's most experienced pilot of C-130s. The co-pilot may therefore have felt he could rest assured that the experienced Commander was at hand and could support him where needed during the flight, correcting wrong decisions. Smith (2001) is of the opinion that this situation can be made worse if the configuration of the crew includes a pilot with very little experience and one with a great deal of experience, which was also the case with the crew in question concerning C-130 experience. However, SHK finds nothing in the recorded information to suggest that this was the case in the situation in question. Nevertheless, there is an implicit relationship of expectations on another's actions. The consequence of such a relationship is that the supervisory and monitoring function in a 2-pilot system can to a certain extent be eliminated.

The hierarchical difference between the two pilots from a professional perspective has also been taken into account; the Commander had a lower military rank than the co-pilot and the co-pilot was the Commander's immediate superior. SHK has however not found anything to suggest that this entailed any limitations in the cooperation between the pilots or that it in any other way affected the sequence of events.

Reliance on GCAS/TAWS

SHK has not been able to clarify or make a detailed assessment of the extent to which the crew of HAZE 01 relied on the Ground Collision Avoidance System, GCAS/TAWS. SHK cannot however eliminate the possibility that the pilots' reliance on the automation of the J model's ”glass cockpit” in any way instilled the pilots an unconscious faith in the system's capability to consistently provide the pilots with visual or audible feedback when e.g., flying above mountainous terrain, irrespective of their knowledge of the system. The information obtained from interviews with the crew that the J model entails better Situational Awareness (SA) may support such an assumption.

Performance

The accident occurred at a time when there is considered to be a natural dip in performance. This phenomenon can be latent in all individuals and has been demonstrated in a number of studies. This natural dip in performance may there-

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40 Smith, D.R. (2001). *Controlling Pilot Error*. New York: McGraw-Hill.

fore not be eliminated as a possible negative factor for the pilots which affected the operational procedures that preceded the accident. This may therefore have decreased the individuals' ability to perceive, detect and evaluate risks, events and decisions.

SHK is unable to assess the extent to which this may have affected the crew's performance.

2.1.4 *Other*

Regulations, etc.

SHK has reviewed great quantities of documentation and regulations concerning the Norwegian Air Force's operations. It is understandable that a military flight operator in a country that is a member of NATO, has international dealings and conducts some of its training in the USA must adapt its regulations to a number of other actors and operations. A military operator must also respond to various tactical conditions, which may also affect the planning and implementation of a flight. In the case of civil commercial aviation, it is easier to apply a ”S*tandard Operating Procedures”* which guides the crew through the various phases of the flight.

The above means there is a greater demand for the military crew to be able to plan for various tactical scenarios prior to the flight and safely implement these during the flight, including for the portions of the flight not considered to require tactical application.

In connection with studying applicable rules, regulations and manuals for the flight operations, SHK has found a large number of references and cross references which suggest that it can be considered challenging, if not difficult, for each individual member of the crew to maintain a level of knowledge that satisfies the high requirements pertaining to safety and tactical performance during a flight. According to SHK, there may be cause to take steps to improve clarity in the aforementioned document.

Changes in the configuration of the crew and model change

In the previous version of the C-130 Hercules there was a dedicated navigator in the crew. According to interviews, this navigator played a key role in the planning work prior to each flight. In the more modern version of the C-130 Hercules, the navigator's role has been replaced by a new and different technology, as well as additional duties for both pilots. In addition, the loadmaster (LM1) has been added to the crew. The latter actively participates in the crew's collaboration (see SOP point 1.5, Section 1.11.4), and the recorded information reveals that LM1's duties include reading checklists and assisting in the rectification of malfunctions. SHK has not found any documentation which shows how the duties of the navigator in the previous crew configuration have been transferred to the new configuration.

The possibility cannot be eliminated that the changes to the configuration of the crew and the model shift have entailed changes for the pilots that have not been picked up on and handled by the Norwegian Air Force satisfactorily, which may have resulted in weaknesses being built into the system. The shift from analogue to ”glass” cockpit gives rise to new conditions and places different requirements on the pilots, but whilst SHK cannot eliminate the aforementioned consequences of the model change, there have been no clear indications during the course of the investigation that this has had a major influence on the event in question.

2.2 Air traffic services

2.2.1 ACC Stockholm

ACC Stockholm's clearance to Flight Level 100 was not in line with the applicable rules and regulations as it entailed the aircraft being allocated a cruising altitude less than 500 above the lower boundary of the control area, and as the pilot had not specifically requested this. Interviews with the air traffic controllers at ACC Stockholm have revealed that, at the time they were of the understanding that the YKL was Flight Level 95, rather than Flight Level 125, where the aircraft was located. Under such conditions, clearance to Flight Level 100 would not have been wrong. There is therefore nothing in the investigation to suggest that any of the air traffic controllers at ACC Stockholm were aware that the aircraft descended into uncontrolled airspace.

How was it then that the air traffic controllers at ACC Stockholm mistakenly believed that the YKL at the aircraft's location was Flight Level 95? According to ACC-E, the air traffic controller in question had the actual sector altitudes for Kiruna in mind in connection with the clearance and that they had therefore had not considered that the YKL was Flight Level 125. ACC-P has been unable to provide SHK with an explanation as to why it went unnoticed that the YKL was Flight Level 125.

In the opinion of SHK, it is unclear as to why ACC-E had the sector altitudes in mind in connection with the clearance to HAZE 01. The sector altitudes for Kiruna go out to approximately 25 NM from the airport and are therefore at a considerable distance from the position of 58 NM from Kiruna airport where *HAZE 01* was given the clearance to Flight Level 100. To consider the sector altitudes in this context when clearing the aircraft from Flight Level 130 to Flight Level 100 is puzzling. SHK returns to this matter in Section 2.2.3.

2.2.2 Kiruna TWR

When the air traffic controller at Kiruna TWR took over the aircraft from ACC Stockholm, it was descending to Flight Level 100, i.e., descending into uncontrolled airspace. However, the interviews revealed that the air traffic controller at Kiruna TWR was also unaware that the YKL in the area was Flight Level 125. It is therefore reasonable to assume that the air traffic controller in Kiruna TWR, in case the matter was closely considered, was of the understanding that at the time of the handover the aircraft was still within controlled airspace as the YKL in other areas of Sweden is Flight Level 95 and that an aircraft at Flight Level 100 is therefore always in controlled airspace there.

The clearance issued to Flight Level 70 means, from this perspective, that the aircraft left controlled airspace and entered uncontrolled airspace. However, this does not, as far as the investigation has revealed, appear to be something that the air traffic controller at Kiruna TWR reflected on. No traffic information concerning this was provided when the clearance was issued.

An aircraft flying in uncontrolled airspace cannot be cleared within uncontrolled airspace. A clearance to an aircraft in uncontrolled airspace can only be given in the form of permission to enter controlled airspace.

It is however quite possible to provide clearance for an aircraft in controlled airspace to enter uncontrolled airspace, if the aircraft has requested this by means of a flight plan or a direct request via radio. Under such conditions, which was not the case here, the pilot is however aware that they are leaving controlled airspace as this action is taken on the pilot’s own initiative and the clearance is only valid in controlled airspace.

Prior to 15 March 2012, it was also possible on air traffic control's initiative to provide a clearance which started in controlled airspace, with part of the flight in uncontrolled airspace, and then ended back in controlled airspace. There was however, a prerequisite for this: it either had to facilitate the expedition of traffic or serve to shorten a flight path. In addition, flight information was to be provided, including whether there was reported traffic outside of controlled airspace. By means of a procedure such as this, it is made clear to the Commander that the aircraft will leave controlled airspace. It also affords the latter the opportunity to consider the clearance in this respect and, where such a clearance is not considered appropriate, request an amended clearance. In this case, however, there has been nothing to suggest that the air traffic controller has made any such deliberations in these respects, and none of the findings of the investigation support the assumption that the issued clearance facilitated traffic expedition or entailed the shortening of a flight path. Furthermore, no flight information was provided. Nor can the distance to Kiruna and the relatively long flight path – around 40 NM – that the aircraft would have flown before passing into controlled airspace, can hardly be considered ”temporary” in the sense described in Dhb ANS, Section 2, Chapter 2, subsection 11.

To summarise, it is SHK's assessment that there was no cause under the circumstances in question to provide a clearance with the support of the old regulation.

In this context, it can be established that the implementation of this previously applicable exception was unfortunate from a flight safety perspective, as SHK deems the exception to have resulted in higher risks for the aircraft (cf. SHK investigation RL 2011:01). This because the exception also resulted in an expansion of the area in which the air traffic services can guide air traffic to beyond controlled airspace and into uncontrolled airspace, in a way which was unclear. The Swedish Transport Agency's removal of the exception may therefore be considered a solid measure to increase flight safety.

In the opinion of the SHK, the investigation shows that the air traffic controller at Kiruna TWR was focusing primarily on Kiruna's TMA, the control zone and the sector altitudes. The air traffic controller has therefore not reflected at length on the aircraft's precise position and altitude outside of these areas because, according to the latter, this is not part of Kiruna ATS's responsibility. During interviews, the air traffic controller has stated that the reason for issuing clearance to Flight Level 70 was that there were another aircraft at an altitude of 5,000 feet in the TMA. From such a perspective, the clearances were likely issued with the aim of providing separated altitudes for *HAZE 01* to enter the TMA; the intention was probably not to issue clearances that *HAZE 01* would follow in uncontrolled airspace. It can however be established that the clearance issued was such that it was not understood by *HAZE 01* in the manner which the air traffic controller had therefore intended.

According to the phraseology that should be used when issuing clearance via radio, the phrase “enter controlled airspace (or control zone) [via (s.p. or route)] at (level) [at (time)]” should be used when an aircraft is flying in uncontrolled airspace and is to be cleared to enter controlled airspace. Had this been used in this case, *HAZE 01* would have received a clear indication that the aircraft was flying in uncontrolled airspace. Instead, the clearance issued was “*HAZE 01, cleared towards overhead, descend flightlevel 70 initially*”, which was acknowledged by *HAZE 01*. Even if it is always the pilot’s decision as to when the descent shall begin, it is customary that ”descend” means that the pilot should begin the descent shortly thereafter (cf. Doc 4444, Section 12.3.1.2, where it is stated that DESCEND is an ”Instruction that a climb or descent to a level within the vertical range defined is to commence”). When an air traffic controller feels it is immaterial as to when the descent commences, the expression ”when ready” is generally used, which means that the altitude change commences according to the pilot’s judgment.

In light of this, the SHK is of the opinion that it was clear that *HAZE 01* intended to follow the clearance and continue the descent to Flight Level 70 once the clearance was acknowledged. It is the SHK's opinion that this is the only reasonable explanation for the meaning of the clearance, according to its wording. In this context, it can also be noted that foreign state aircraft must follow the regulations for civil aviation and fly in accordance with instructions from Swedish air traffic control when in Swedish territory, in accordance with Section 9 of the Ordinance concerning the Admission to Swedish Territory of Foreign State Vessels and State Aircraft (Admission Ordinance).

The above means that the clearance that was provided likely resulted in a misunderstanding between the air traffic controller and the crew of *HAZE 01*, due to the phraseology used and because the aircraft – in accordance with the perception the crew likely had at that time – was in controlled airspace.

From the interviews with the air traffic controller at Kiruna TWR it is revealed that he/she was of the understanding that *HAZE 01* was visually orientated and flying VFR – taking into account the request for a ”visual approach when approaching” and the fact that it was CAVOK at Kiruna Airport – despite the fact that they had not cancelled the IFR flight plan. However, the findings here do not give cause to assume that the air traffic controller's perception in this regard directly influenced the clearance to Flight Level 70; as mentioned above, the controller's intention with this was to provide separation from another aircraft in the TMA. On the other hand, it is clear that the air traffic controller's perception of the circumstances under which HAZE 01 flew, together with the lack of radar coverage, affected and diminished his/her situational awareness. Based on the information that was available at the time and the interpretation of it, there was no concrete indication to the air traffic controller that there was any danger of collision with the terrain.

2.2.3 *Influencing factors*

Neither the air traffic controller at ACC Stockholm nor the air traffic controller at Kiruna were aware that the YKL was Flight Level 125 in the area in question, which resulted in *HAZE 01* being unintentionally cleared into uncontrolled airspace without the aircraft being informed of this. The extent of YKL is included in training during the eligibility phase for the air traffic controllers at ACC, who have also answered correctly to test questions on this. Traffic from the west at the actual level that was to land at Kiruna was however unusual, nor is it something that is specifically practised in the training or during the eligibility phase. The air traffic controllers therefore lacked practical experience working with aircraft at a level where it was necessary to descend an aircraft to the lower limit of YKL in this area and then descend further for landing at Kiruna Airport. In this context, it is apt to note that both of the air traffic controllers at ACC Stockholm and the air traffic controller at Kiruna were relatively inexperienced and had only worked for a short time in their current positions. Together, these circumstances may likely go some way to explaining the noted deviations. SHK returns to this matter in Section 2.2.4.

The observance of sector altitudes of the air traffic controller at ACC Stockholm, in connection with the issued clearances, provide indications that there may be shortcomings in terms of knowledge of the extent of the airspace and the relevant conditions for clearance within CTA before handover.

Nor is the air traffic controller in Kiruna ATS seen to have been mindful of the boundary between CTA and uncontrolled airspace when providing the clearance to Flight Level 70. This is a further indication of an inadequate grasp of the extent of the airspace and the various conditions in controlled and uncontrolled airspace respectively. Where the air traffic controller in Kiruna is concerned, it has also been established that incorrect phraseology has been used in communication with *HAZE 01*. Nevertheless, it has been revealed that these different elements are also included in the training carried out, but the training appears to have failed to convey such knowledge which would have led to the practical work being carried out in a safe manner in accordance with the applicable rules and regulations.

On a general level, all air traffic controllers interviewed by SHK have very clearly pointed out that it is the Commander's responsibility to maintain separation from the terrain in a situation such as this one. This is of course correct. As far as SHK is concerned, however, it is also important to emphasise the fact that air traffic control must provide advice and information useful for the safe and efficient conduct of flight, in accordance with Annex 11 of the Chicago Convention. According to SHK, a prerequisite for this is that an air traffic controller has a good overview not only of their own area of responsibility in terms of the formation of and terrain within the TMA and the control zone, but also of areas adjacent to this, so that they are able to provide, where necessary, advice and information conducive to a safe and efficient flight, even if the aircraft is outside of the air traffic controller's direct area of responsibility. In this context it is worth noting that, in addition to information concerning the aircraft's distance from and direction in relation to the airport, maps and a direction finder were available in the tower. During an interview with the manager at the Kiruna tower, it was discovered that LFV had withdrawn the ”TMA flights” as an economy measure. Such excursions are now reportedly undertaken (at least in Kiruna) by car.

According to SHK, TMA flights are a means of increasing the individual air traffic controller's situational awareness and knowledge of the terrain. This benefits the operative work and can hardly be replaced by a car journey.

On the radar screens used by the air traffic controllers at ACC Stockholm, the *mountainous area* with a YKL of Flight Level 125 was shown. As *HAZE 01* was flying at a level where there was no radar coverage, the aircraft was not visible on the radar screen, which may explain why that aid did not draw the air traffic controllers' attention to the applicable YKL at *HAZE 01*'s location. Had *HAZE 01*'s position been visible on the radar screen within the demarcated area for YKL 125, there would have been a greater likelihood that the air traffic controllers had noticed this.

In summary, the combination of the air traffic controllers' knowledge and experience and the aids available to them at the time was such that, with the prevailing conditions, they were unable to safely handle air traffic from the west.

<u>*Performance*</u>

The corresponding conditions for performance described in Section 2.1.3 for the flight crew also apply to the air traffic controllers in question. As with the crew, SHK is unable in this respect to assess the extent to which this may have affected the air traffic controllers' ability to carry out their duties.

2.2.4 Safety culture

<u>*Introduction*</u>

The term ”safety culture” can be said to embrace norms and values that dictate human behaviour and which therefore, in the long-term, reflect individuals’ attitudes to and prioritisation of matters of risk and safety, within an organisation. Safety culture covers a broad range of issues, from the approach to the individual's responsibility for safety to how to learn from mistakes and incidents, but the term also comprises how safety is established, implemented and maintained in complex systems and in which patterns of behaviour this is expressed.

A system within an organisation may encompass structured activities, but it may also include people and technology. A system as a whole may for example consist of an aircraft and its crew or an air traffic controller and surrounding functions. The system can be said to be complex when rules and regulations, and the processes for and activities around collaboration between people and technology, are of a sufficient scope[41].

Research has shown that organisational changes can have a negative impact on safety in an organisation; such changes can also affect safety by means of encumbering the work. In operations which are primarily governed by instructions, procedures and regulations, it is more difficult to create a climate of change that benefits the organisation. It may also be said that an organisation which comprises an operation with high demands on safety can compensate for the failings of the individual by being properly designed and having the right management methodol-

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[41] Ternov, S. (1998). *Människor och misstag i sjukvården [People and mistakes in healthcare].* Lund: Student literature.

ogy[42]. It should be emphasised that a good safety culture starts on the management level. The management's commitment is a prerequisite for maintaining a good safety culture.

According to LFV's flight safety policy, flight safety is the highest priority in the organisation. The authority runs an active flight safety work which is also continuously followed up.

It is the SHK's opinion that it is important to always work to identify circumstances that can adversely affect the safety culture and actively work to reduce these. Over the course of the investigation, SHK has identified a number of circumstances which indicate that there may be weaknesses in the safety culture. In addition, SHK has in three other investigations (RL 2012:01, 2012:16 and 2013:07) shown indications of weaknesses in LFV's safety culture.

In the present investigation, indications of this nature are given in the points below.

Duty and experience

The fact that the air traffic controllers were relatively newly qualified and inexperienced in their respective roles cannot, as mentioned above under section 2.2.3, be eliminated as a potential influential factor in the chain of events. Being newly qualified can mean that a person is bright, alert and attentive, and that the knowledge is fresh in their mind. But it can also entail limited experience and a lack of familiarity with handling certain situations. In addition, the air traffic controller at Kiruna was alone in the tower, which places even higher demands on knowledge, competence and experience to handle situations as there is no-one onsite to provide advice or other forms of assistance.

Though all air traffic controllers were qualified and were approved to exercise air traffic control in the areas in question, experience is an important factor when carrying out duties. At certain times, for example in periods where large volumes of traffic or changed traffic patterns are expected, there may be a need to ensure duties are carried out by – or at least with support from – someone with solid experience. However, considerations of this nature do not appear to have been made.

SHK considers the act of allowing air traffic controllers with limited experience to carry out their duties under the circumstances prevalent at the time, i.e., increased traffic volumes and different traffic patterns as a result of the ongoing exercise, to be an indication of a latent weakness affecting the safety culture.

LFV's investigation of the incident

The aim of producing an incident report is that the incidents are processed and, where necessary, investigated, so that the experience and recommendations can be fed back into the organisation and thus enable practical application of the lessons learned. In order to ensure the dissemination of accurate and necessary information via LFV's internal investigations, it is extremely important to check the quality of the content of the investigations before sending them to employees.

[42] Haddon-Cave, C. (2009). *The Nimrod Review*. London: Ministry of Defence.

According to SHK, the internal investigation gives indications of a lack of knowledge in LFV's investigation function in the manner described below.

According to LFV's investigation of the incident, 5.5.1 – phraseology, the expression "*descend*" means that the pilot may commence descent immediately, but that he/she may also remain at their current altitude until further notice. The report also says that "*in other words, the phrase can be used when, from air traffic control's perspective, it is immaterial whether or not descent is commenced immediately*". As mentioned above under Section 2.2.2, this is an interpretation of the expression "*descend*" which SHK does not agree on.

In the opinion of SHK, it seems unlikely that the prevalent interpretation among air traffic controllers is that the pilot will remain at their current altitude until further notice if the air traffic controller issues a clearance with the expression "*descend*" and the pilot reads this back. Nor is it the opinion of SHK that the pilots would have this perception of a clearance.

According to SHK, in the situation it cannot be seen as if *HAZE 01* requested to descend into uncontrolled airspace on its route towards Kiruna, as is indicated in point 8.4 of LFV's investigation of the incident. "*The controller in Sector K also received coordination from Bodö that HAZE 01 wished to fly direct Kiruna for landing. From that perspective, a clearance under Flight Level 130 is not incorrect since it is interpreted as if the pilot is requesting descent*." This is also noted in the conclusions of the aforementioned investigation, in which it is stated that "*According to AIP Sweden, a flight can be cleared from Suecia CTA if the pilot requests it, which HAZE 01 was understood to have done"*. According to SHK, there is nothing in the rules and regulations to indicate that a "*direct*" flight also entails a request for permission to descend. Such an interpretation would mean that all "*direct*" flight, which is the vast majority today, also entail a request to descend.

In SHK's perception, the interpretation of the term made by LFV in its internal investigation increases uncertainty as to the meaning of established phraseology, which in turn can lead to misunderstanding between air traffic controllers and pilots. The fact that these (as SHK sees it) false interpretations of terms are not identified and discussed in more detail before they are disseminated further within the organisation is an indication that there may be weaknesses in the safety culture.

Issuance of a supplement due to amendments to rules and regulations

On 09 March 2012, information was available on LFV's intranet concerning the amendments that would apply from 15 March 2012. It described the larger amendments of regulations and included information about the removal of the Swedish exception. It also stated that a supplement to LFV's operational manual (Dhb ANS) was on the way. The supplement was published on LFV's intranet on 13 March 2012, but the physical publication did not arrive at Kiruna Tower until 16 March 2012. The supplement was however available digitally for the air traffic controllers at Stockholm ATCC on 15 March.

According to SHK, it is inappropriate that the publication of an amendment of this significance and scope is not given a better time margin. The idea that the air traffic controllers should be able to review and understand the significance of the amendment so that it could be applied in practice the same day it was read does not seem reasonable. Furthermore, parts of the supplement were unclear, causing LFV to issue, on 14 March 2012, an explanatory e-mail to operations managers the day after publication on LFV's intranet. Then, on 23 March 2012, a clarifying supplement was published. There have therefore been shortcomings both in terms of ensuring the amendments to the rules and regulations were communicated to operative personnel within a reasonable time before application and with regard to the analysis and the consequences of the Swedish exception that was removed. This is something that may indicate weaknesses within the safety culture.

Return to duty following the accident

According to Chapter 2, Section 9 of TSFS 2012:6, when an incident has occurred where aviation safety has been adversely affected, the official in charge shall expeditiously make an assessment of whether a lack of expertise has contributed to the incident. A lack of expertise in air traffic controllers or AFIS personnel is to be notified to the Swedish Transport Agency.

According to Chapter 4, Section 4 of TSFS 2012:6, the person who has been involved in a crash or a serious incident during his operational service shall be withdrawn from duties as soon as possible. Duties may be resumed when it is the assessment both of the appointed official in charge of safety at the Air Traffic Services unit and of the person concerned that this can take place without an adverse effect on aviation safety.

How a person reacts to an incident is highly individual and therefore the need for support must also be assessed in the individual case. Following a traumatic incident, the brain may continue to process information on an unconscious level. It is entirely natural for a person involved in an incident such as a crash to both consciously and unconsciously reflect on the incident afterwards; what they did, what they didn't do and so on. Such reasoning can result in limitations in cognitive ability. Human memory is sensitive to negative emotional events. Irrespective of the degree of stress that follows such an event, a potential consequence is that the person in question temporarily forgets instructions and undertakings. Furthermore, a negative event of this nature may also cause others to reflect on and become concerned with the correctness of their own working methods[43].

In the present case, the air traffic controllers returned to work relatively soon. The air traffic controllers at ACC Stockholm returned to work on the same day, whilst the air traffic controller in Kiruna was back three days later. There is no reason to doubt that the air traffic controllers themselves felt they did not need to take a longer period of leave, nor is there any indication that there have been any shortcomings in their manner of carrying out their duties after returning to work. According to SHK, however, it is important to point out that the individual air traffic controller's assessment of their fitness for work should not be relied upon too heavily (cf. RL 2012:16).

It is in SHK's opinion that the amount of time that passed before the air traffic controllers returned to work seemed somewhat short, considering that an employ-

[43] Christianson, S-Å. (2002). *Traumatiska minnen [Traumatic memories]*. Stockholm: Nature and culture.

ee who holds a position that entails responsibility for safety should be afforded the opportunity to make a full analysis of the circumstances in order to adopt an informed standpoint on the aspects required in accordance with TSFS 2012:6, especially in light of the established shortcomings in the matter of the clearances issued (see Sections 2.2.1 and 2.2.2). There is no requirement for consideration and analysis of this nature to be documented, except for where a lack of expertise is established, as in such cases this is reported to the Swedish Transport Agency. SHK has therefore been unable to investigate this matter further.

Organisational conditions

In recent years, LFV has faced big changes in its operations, in the form of reorganisation and a shift in duties. It is natural for changes to take place over time, and it is something that an authority must always respond and adapt to. Changes are often brought about by political decisions that the authority itself is unable to influence to any great extent. At the same time, it is essential in connection with such changes within the authority to have a clear focus on safety so that, for example, commercial considerations and savings do not in any way prevent safety from being the primary factor that controls and limits the running of operations. From an international perspective, organisational changes have on a number of occasions been seen as an underlying cause of an accident (see e.g., Columbia Accident Investigation Board Report, 2003 and the Nimrod Review, 2009, and references therein).

LFV has come to have a relatively complicated organisational structure, with part-owned subsidiaries that run parts of the operation. Over the course of SHK's investigation, it was revealed that, in connection with certain changes, personnel did not know whether they were employed by NUAC or LFV.

In interviews with the manager of Kiruna Tower, it was discovered that in the past year there had been a staffing shortage due to sick leave and parental leave. This will have meant that the manager of Kiruna Tower periodically had to carry out her administrative obligations during operative duty or during time off. This can entail a flight safety risk; an air traffic controller on operative duty not being given full opportunity by the employer to prioritise flight safety during this part of their duty.

Summary

It is the SHK's opinion that, as mentioned above, there are indications of weaknesses attributable to the safety culture within LFV. With regard to the organisational changes in LFV in recent years, SHK has not found any obvious circumstances that can be linked to the incident in question, but from a general flight safety perspective it is of course important, considering the potential impact of such changes on the safety culture, that an independent analysis of these problems is carried out.

2.2.5 *Lack of clarity in the rules and regulations*

There are certain discrepancies between the Swedish and international provisions regarding the use of the expression *"Lowest usable flight level"* (LUF) and its application in areas with area-type controlled airspace. In the airspace for which the introduction of this provision in ICAO was intended (ca. 1966), area-type of controlled airspace was very uncommon, which is why there is also a lack of specific instructions for its application.

It was really only in North America that a *lowest usable flight level* was applied which also coincided with the boundary for area-type controlled airspace. In other words, it was strictly regulated that QNH (i.e., altitude) was always used when flying below the lowest usable flight level.

In Sweden, area-type controlled airspace applies from Flight Level 95 and Flight Level 125 and up. Transition altitude applies solely within TMA, and the published *lowest usable flight level* is at Flight Level 100 and Flight Level 130 respectively. At the same time, other provisions stipulate that IFR flights in uncontrolled airspace must be at flight level when above the *lowest usable flight level* and "height above sea level when below the lowest usable flight level".

With this setup, an aircraft requesting to descend below the area-type controlled airspace is given a clearance in feet with reference to QNH, in accordance with the rules on *"lowest usable flight level"*. This is therefore within the same airspace in which, according to the other provision, the pilot must fly at flight level. This means that unclear circumstances arise; see fig. 43.

In this context, it can also be added that the application of area-type controlled airspace with a lower limit of the controlled airspace expressed in flight level is not compatible with the current provisions pertaining to the lowest usable flight level.

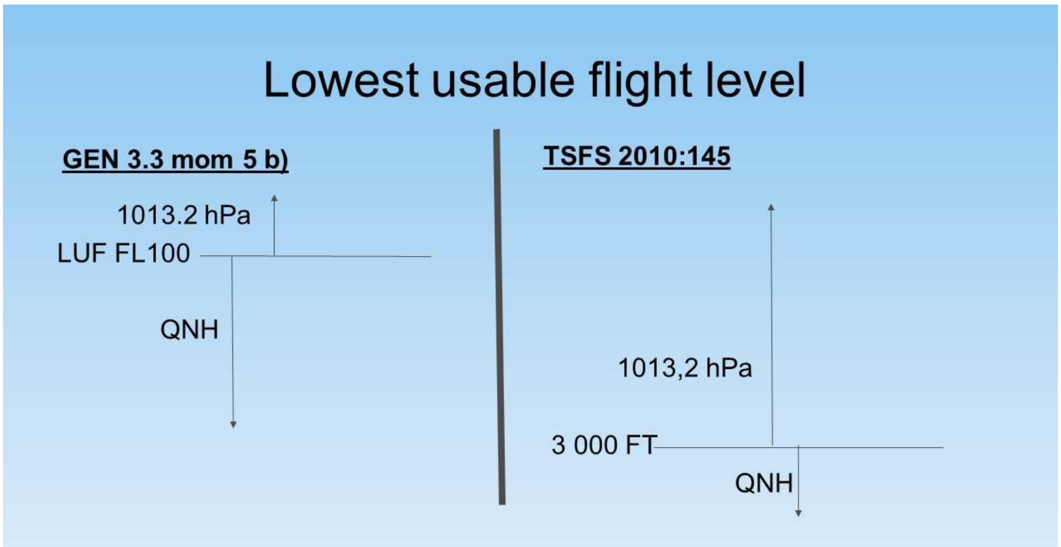


Fig. 43. The image shows the two variants of "lowest usable flight level" published in Sweden today, which are not compatible with one another when following the ICAO working method for "lowest usable flight level".

In summary, a lowest usable flight level has been established in the Swedish AIP; Flight Level 100 and Flight Level 130. In light of the provisions of Annex 2, Chapter 3, 3.1.3 b) of the Chicago Convention, the aircraft's altitude shall therefore be expressed in altitude when below the lowest usable flight level. From the provisions of TSFS 2010:145 follows, however, that even for flights below the established usable flight level shall in specified cases still be performed at flight level and not altitude.

In order to create uniformity in the rules and regulations, the lowest usable flight level (lägsta användbara flygnivå, LAF) in CTA (Flight Level 100 and 130) as published in AIP can be removed and to follow the provisions of ICAO, which entails the application of flight level at or above the lowest usable flight level (LAF) and altitude below the lowest usable flight level. If there is a wish to retain the LAF expressed in CTA and follow the provisions of ICAO, however, the CTA lower limit should be specified as 9,500 feet and 12,500 feet respectively and LAF should be determined with consideration to the applicable QNH. Altitudes below LAF should then always be given in "... feet QNH". In line with this, TA should be amended in TMA in order to harmonise with LAF. Another alternative is to only follow TSFS 2010:145, which means that flight level applies when in level flight at levels above 3,000 ft above the ground or water, and altitudes in all other cases.

As mentioned above in Section 2.1.3, the clearance issued to *HAZE 01* gave no indication that it entailed flight in uncontrolled airspace. The possibility can therefore not be eliminated that this contributed to the crew not paying attention to or considering the lowest usable flight level. A clearance from ATC to a flight level gives a signal to the pilot that this is to obstacle-free level, if no other information is given in connection with the clearance. As a pilot, one can expect to continue flight in controlled airspace if no other information to the contrary is received, and that the flight level to which clearance has been provided is either the lowest usable flight level or higher. This does not however, relieve the pilot-in-command of his responsibility to ensure that adequate terrain clearance will exist at all times, except when an IFR flight is vectored by radar In accordance with *Annex 11 – Air Traffic Services, paragraph 2.2* of the Chicago Convention, ATS' duties do not include responsibility for obstacle clearance. It should however be pointed out that, in accordance with paragraph 2.2 d), *the objectives of the air traffic services shall be to [...] provide advice and information useful for the safe and efficient conduct of flights".*

According to the LFV operations manual, flight level is applied when flying at or above the lowest usable flight level (LAF), and altitude is applied when below LAF. If this provision is to be followed strictly, air traffic control would therefore provide the QNH when clearing for a descent below LAF, as well as the altitude; not flight level. When area-type controlled airspace is applied - as in Sweden, for example - this contradicts *Annex 2 – Rules of the Air, 5.3.1* of the Chicago Convention, which states that flight level applies, in accordance with *"the table of cruising levels in Appendix 3"* when flying above 3,000 feet (900 m).

2.3 Technical investigation

2.3.1 Technical functioning of the aircraft

At the time of the collision, the aircraft was in level flight. No warnings were active, and SHK has not found any technical malfunction that caused the incident or contributed to its occurrence.

2.3.2 GCAS/TAWS

One question in the investigation has been whether the Ground Collision Avoidance System/Terrain Avoidance Warning System (GCAS/GCAS) was able to provide a timely warning which would have facilitated avoidance of the collision.

Studies of the terrain profile under the flight path, see Fig. 44, shows that the downward-looking function of GCAS had not been able to give any warning before the moment of collision as it was only in direct connection with the collision that the distance to the ground went below the set warning level of 200 ft. This is also confirmed by the reference flight, where no alert occurred even with the reference altitude set to 1,000 ft before the site of the accident and the ridge between the South and North Peaks was passed.

Furthermore, the analysed information from the CVR contained no warning for collision with underlying terrain.

Studies of the terrain profile and the specifications of the GCAS/TAWS system suggest that the reference altitude would have had to be set to at least 1,500 feet in order to trigger a warning along the flight path in question that would facilitate evasive manoeuvres to avoid collision with the terrain.

The crew likely set the reference height to 200 feet as this corresponds to the landing minimum for the planned ILS landing at Kiruna Airport in connection with running through the *Combat Entry Checklist*, which was done in the holding pattern around one hour prior to the collision with the mountainside.

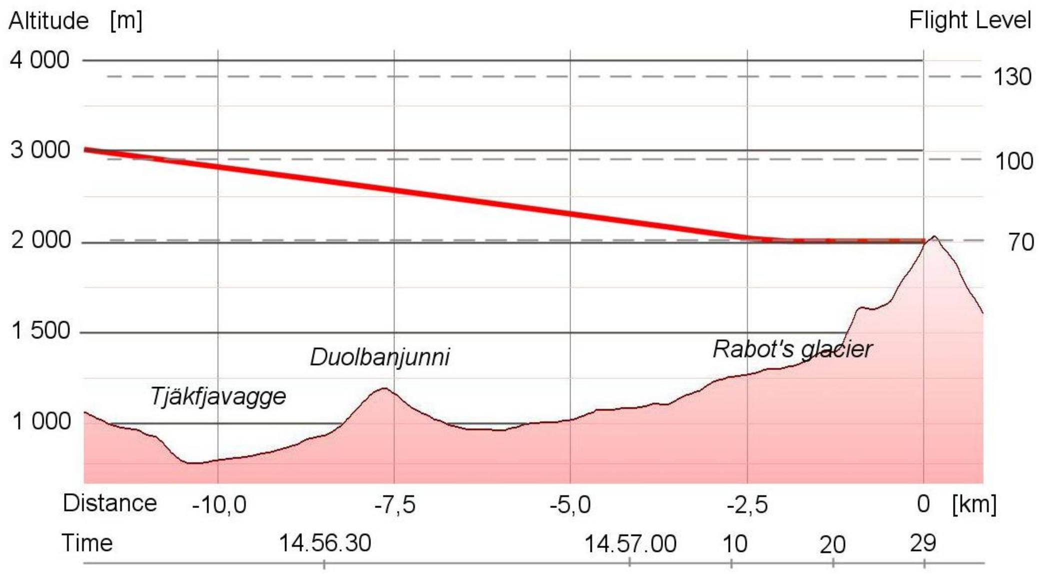


Fig. 44. The terrain curve under the flight path, indicated with a red line. (Terrain profile retrieved from Google Earth.)

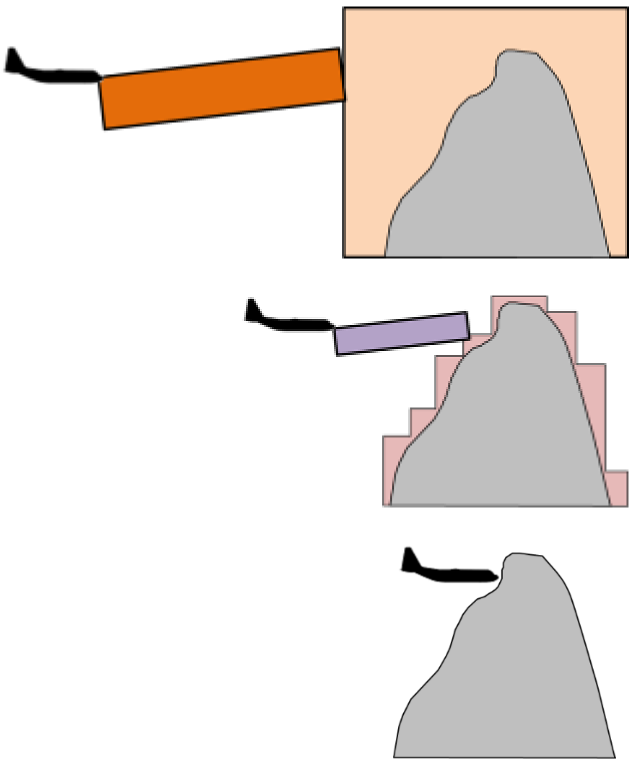
Through the switching of the GCAS/TAWS to *Tactical* the function of TAWS in the area in question has drastically been degraded, to the extent that it only includes warnings for obstacles such as masts and towers. No such warnings have, however, been obtained from the warning system's “forward-looking” function.

Due to the nature of the terrain profile, the lack of terrain data in the TAWS database in *Tactical Mode*, the Tactical function selected in TAWS and the reference height of 200 feet, the aircraft's systems for ground collision avoidance and terrain avoidance have not issued any alert that might have prevented the collision.

SHK finds that in terms of the system's warning capability, it has functioned in accordance with the description that emerges overall in studies of system description, emergency checklist and supplement to the flight manual.

However, SHK's assessment is that awareness of the TAWS system's function and limitations north of 60° N to some extent was low among the pilots of the squadron. This assessment is based on statements of squadron members concerning their own lack of understanding of the system prior to the accident, as well as the wording of ”Red Marker”[44] from 4 June 2012 *(“It has become clearly evident that the system has an inadequate or limited database north of 60 degrees N when in 'Tactical mode'”).* SHK also notes the fact that even after the incident, when studying flight manuals and in aircraft and simulators, it has been difficult to ascertain both the meaning and incidence of the message *TAWS TACTICAL VOID*.

Theoretical analysis of GCAS/TAWS functions with various settings



TAWS function in *Normal*.
Standard resolution terrain database.
Good margin to terrain.

TAWS function in *Tactical*.
High resolution terrain database and shorter *Look Ahead Distance*.
Reduced margin to terrain.

TAWS function in *Tactical* >60° N.
No terrain database.
No warning.

Fig. 45. Schematic of the aircraft's terrain warning function: Terrain database and distance for warning. (Caution: “TERRAIN AHEAD”).

In relation to the schematic pictures in Figure 45, a comparison can be made between two different theoretical cases and the outcome of the flight in question.

GCAS/TAWS in Normal:

A flight along the flight path of *HAZE 01* with GCAS/TAWS in *Normal* would result in an early *Caution* warning, “*TERRAIN AHEAD”,* from TAWS. The warning would with great certainty be issued even before the aircraft had time to come down to Flight Level 70, both because of the aircraft's descent angle and because of the great margin to the terrain ahead through a *Look Ahead Distance*

[44] See 1.19.1 in Chapter ”Measures taken following the incident” by the Norwegian Air Force.

corresponding to up to 60 seconds of flight. This is shown both by studies of the flight path and terrain profile and by completed reference flights. The warnings would provide adequate opportunities for the crew to increase altitude and avoid the terrain.

GCAS, which measures the closure rate between terrain and aircraft, would initially not issue any warning because the flight path runs along a valley. Only tenths of a seconds before the point of collision is the terrain elevation so great that it could theoretically initiate a GCAS warning. This is confirmed by completed reference flights.

GCAS/TAWS in Tactical with complete terrain database:

During flight in *Tactical* with full TAWS functionality, i.e. with a terrain database that covered the area in question, the Look Ahead Distance would, in principle, be halved compared with flight in *Normal*. An analysis of TAWS specifications shows that the Look Ahead Distance at the speed in question should exceed 4.3 kilometres (2.3 NM). This would mean about 30 seconds of advance warning through the *Caution* warning “TERRAIN AHEAD”.

However, it is difficult to calculate a correct value of this advance warning. An uncertainty in the calculation arises through the low set value on the TAWS *Minimum Operating Altitude* (MOA), which generally results in a later alert. An additional uncertainty in the calculation arises through the system “looking ahead” with a certain width. Because the approach takes place at an oblique angle to the mountain wall, this would have the effect of an earlier warning. Another factor of uncertainty is details of the design of the terrain database, i.e., how a mountain is defined in the database.

It can be established, however, that a TAWS system with a complete terrain database would most likely be able to issue a warning in time to prevent the accident. This is probable not least because it would have required a pull-up in the order of only 50 m (about 150 ft) to avoid the terrain.

GCAS/TAWS in Tactical without terrain database:

No terrain warning is triggered, as the lack of a terrain database means in essence that the system perceives the ground as completely flat and free of terrain obstacles. Furthermore, as there is no mast located at high altitude in the Kebnekaise area, no obstacle warning is produced. This corresponds to the outcome of the flight in question. The equivalent outcome is achieved if the system setting ”TERRAIN INHIBIT is selected in *Tactical*. Furthermore, the consequences of this choice are unaffected by the geographical position. This means that if ”TERRAIN INHIBIT” is selected in accordance with what is said to have been taught for approaches with C-130J, no terrain warning would be triggered at any location in the world. SHK has found nothing to suggest that ”TERRAIN INHIBIT” was selected during the flight in question.

Possible explanations for the choice of Tactical

It is in SHK's assessment that there are a number of partial explanations for the switch to *Tactical*:

- Basic training on the system has taken place in the USA and in areas with no current limitation in terrain data. During training, the participants were taught to set GCAS/TAWS to *Tactical* in connection with Combat Entry. The decision to use the system in *Tactical* could thus be explained as an ingrained procedure that was carried out without further consideration of the actual consequences on the system's functionality. Thereby the crew may have learnt routines which then without sufficient analysis has been transferred to general use.
- The operator has enabled general use of *Tactical* by delegating to the commander the decision to select *Tactical*, in the *Combat Entry Checklist*, without further limitations or requirements in terms of other circumstances such as visual meteorological conditions.
- Lack of understanding of the system's function.

SHK deems the following conditions to have contributed to the crew from the squadron in question having a lack of understanding of the system's function:

- The warning message to tell the crew that no database is available, *TAWS TACTICAL VOID*, is classified as “advisory”. No action is recommended – *Crew action: None.*
  The low classification and the fact that no action is required entails a risk that the significance of the message is not analysed deeply enough to allow for, e.g., the discovery of deficiencies in training.
- Facts must be obtained from different parts of the system documentation (system description, emergency checklist and supplements to the flight manual) in order to get an overview of the system's limitations.
- The various parts of the description do not cover completely the system's functions, and provide to some extent a false impression of the system's limitations:
    - The way to express the warning concerning the limitation in the *TAWS* database in the issued supplement - “*TAWS may not give proper terrain warning” –* does not allow for the interpretation that there is a total lack of terrain warning outside the coverage area. Instead, the conveyed impression is that a terrain warning is sometimes given and sometimes not. SHK believes that this impression is inaccurate.
    - The description in the flight manual's emergency checklist of *TAWS TACTICAL VOID* states as a reason for the message: “*No TAWS database data is available due to operations at latitudes greater than 60 degrees North or 56 degrees South”.* This is true only as a criterion for warning. The text may however be perceived as misleading, as it is only the terrain database that is inaccessible as per the system's fundamental design. The system's other database (containing obstacle data) is available.

The fact that terrain data are missing whilst obstacle data are available is the foundation of a system behaviour that may be perceived as difficult to interpret during flight. As the aircraft flies in and out of areas with obstacles when north of 60° N, the *VOID* message is switched off and on. The possibility cannot be eliminated that this was the case also in the flight in question, which could explain the cause of one or more of the *advisory* signals registered on the CVR. Studies during subsequent flights reveal that a boundary between areas with and areas without registered obstacles is geographically located roughly half-way between GILEN and Kebnekaise, and that the VOID message is therefore active when passing the mountain.

Conversations with pilots from the squadron in question reveal that the explanation for the VOID message being switched on an off when flying north of 60° N was not fully known prior to this investigation. The behaviour has instead contributed to the message being seen as unreliable and difficult to interpret by several crews.

SHK is of the opinion that the formulation of the criteria for the *VOID* message is inadequate. The fact that the *VOID* message is switched off north of 60° N in areas where the *TAWS* database contains obstacles means in practice that a crew can fly in an area with risk of ground collision without *ACAWS* indicating the absence of *TAWS*' terrain warning function. At the same time, the ground in these areas is marked in black or blue on the *TAWS* display, which according to the flight manual indicates a terrain separation of more than 2,000 feet. The characteristics of the *TAWS* system are therefore such that there is a high risk that a crew is given a false sense of safety when flying north of 60° N.

This fact is not part of the information found in the flight manual or in any other documents made available to SHK, but has emerged through the analysis that followed the accident. SHK considers this to be an unsafe condition.

In light of the measures which the aircraft manufacturer has reported to SHK, these are considered to satisfactorily rectify the deficiencies noted in the aircraft’s documentation and systems.

Overall, SHK finds that inadequate procedures adopted by the operator and lack of clarity in the system documentation and training have entailed potential shortcomings in the crew's knowledge of the system for ground collision avoidance. This coupled with the inadequacies in the system design may explain the crew's use of *TAWS Tactical* despite the limitations north of 60° N.

2.4 The rescue operation

The rescue operation was characterised by very good access to resources from both Sweden and abroad. There were considerable resources in the area of Kiruna and in the north of Sweden from the very moment the accident occurred. The following efforts lasted for a relatively long period of time and were carried out under extreme weather conditions in treacherous alpine terrain. The investigation of the rescue operation reveals the importance to further develop management, collaboration and training in several areas. The need for effective rescue operations in mountainous environments is also warranted by the ever increasing international air traffic in northern Scandinavia of recent years.

The difficult weather conditions meant that, despite an extensive rescue operation, it took a relatively long period of time to locate the site of the accident and establish that there were no survivors. In other weather conditions, without low clouds, snowfall and strong winds, it would most likely have been possible to locate the site of the accident much quicker, given the available resources.

A full analysis of the rescue operation is given in Appendix 1 (available only in Swedish).

2.5 Other

2.5.1 Loss of ELT function

In order for the ELT (Emergency Locator Transmitter) to function as intended, the transmitter component must be operational and the transmitter antenna must be intact and connected.

The ELT's transmitter component has sustained such damage that in all likelihood a signal could not be generated for any significant period of time after the collision. In addition, the damage to the unit's antenna connections is heavy, and the coaxial cables have been separated from the transmitter unit. The conclusion is that due to the damage, the ELT was unable to emit any signal that could have been received by satellites or other receivers.

The ELT unit's crash resistance is great, in terms of the specifications. Despite this, its function has failed through the unit being torn apart when the surrounding structure was destroyed. The investigation has been unable to establish whether the mountings in the aircraft correspond to the recommendations given in the standard DO-182, which are to guarantee the functioning of the ELT at forces up to +/-100 G in the direction of flight. However, SHK's calculations reveal that the G forces at the point where the ELT unit is mounted at the rear of the aircraft were far below this value.

In order to maximise the likelihood of function following an accident, the transmitter and antenna units should, in accordance with the aforementioned standard, be located as close to one another as possible. SHK finds that the transmitter and antenna on the aircraft in question were located close to one another, but that the connections broke despite this.

In order for signals from an ELT to be detected, an antenna must be positioned so that the aircraft's outer shell does not block the signal. Where an accident entails such damage as would cause the separation of the ELT from the aircraft, the problem arises that the transmitter then also separates from the antenna. SHK finds that this risk can be minimised with other design solutions; e.g., if the outer antenna is complemented with a built-in antenna. In another accident scenario in which survival had been possible, the intended function of the emergency transmitter would have been essential in order to locate and rescue the crew in time. There is therefore cause to question the requirements imposed on the construction, robustness and mounting of the emergency transmitter and the antenna, as well as the design of the equipment. In order to ensure the greatest possibility of survival in the event of an air accident, SHK feels there is cause for an in-depth investigation and analysis of the crash resistance of both the transmitter unit and the antenna installation for the emergency transmitter.

2.5.2 *Flaws in the CVR and DFDR data*

Data from the CVR have been very important in the investigation. One limitation that was discovered when analysing the recorded sound data was the high level of noise from the *Area Microphone*, which records general sound in the cockpit. Poor quality of the sound recording from this microphone has considerably hampered interpretation of the conversations that took place before the pilots put their headsets on. The sound recording from the microphone after the point at which the aircraft takes off could not be used in the analysis due to a further increase in the level of noise.

Identified limitations in the DFDR data have had a considerable impact on the investigation. This applies not least to the low resolution for the aircraft's position, which partly hindered and delayed the work to establish a detailed picture of the aircraft's flight path.

As the so called “End of File” (EoF) was missing, additional work was required when trying to extract the DFDR data. The missing EoF may be explained by a sudden loss of power to the DFDR in connection with the collision. The registration thereby stopped in an uncontrolled manner.

The fact that neither *Caution* nor *Advisory* messages from ACAWS are stored on the DFDR has entailed a certain residual uncertainty in the investigation as to the status of the on board system. Among other things, the existence of the *VOID*-message has not been possible to determine in detail.

The lack of parameters to determine the status of the recording unit itself *(Flight Data Acquisition Unit Status Word)* entails a certain factor of uncertainty. However, readings of interest to the investigation were assessed as true by means of probability analysis and comparisons with values from other sources.

2.5.3 *Results of the medical examination*

According to information, the commander was exempt from undergoing a flight physical examination up until June 2012. It has not been possible to evidence the reason for the exemption, which SHK finds noteworthy. The document supporting this was drawn up after the accident. The document pertaining to the exemption decision is not signed by the *director of the Norwegian Association of Aviation Medicine* as per the rules. This means that SHK is unable to say with certainty whether the commander was formally fit for duty at the time of the accident.

It has been discovered that, over the days leading up to the accident, the commander had mild sinus troubles, but there is nothing else to suggest that he had a reduced general condition at the time of the accident. There is nothing to suggest that the troubles in question or the granting of an exemption contributed to the occurrence of the accident.

2.5.4 *Investigation of the site of the accident*

The work to find the CVR and DFDR in the snow masses at the site of the accident were hampered considerable by the lack of some form of locator function in any of the units. The methods and approaches, including the use of a piste machine, ground radar and metal detectors, proved efficient and effective in searching through and writing off search areas. In this way, the work could progress to new areas with a high degree of confidence that the areas searched did not contain the CVR or DFDR.

At the same time as the CVR and DFDR were found by the search parties, an analysis was underway of the red-filtered panoramic image that had been constructed of a large number of very high resolution images. During the analysis, it was possible to identify the recorder units and their chassis. This method can therefore be considered effective and a good complement to keen-sighted search parties at the site of the accident.

The fact that the work was carried out without injury and incident in the very demanding environment is attributable to the highly skilled guides and personnel from the Swedish Armed Forces who were assigned to manage the safety work at the site of the accident. Their work was also a big factor in the success of locating the CVR and DFDR.

2.6 Final conclusions

Accidents in complex systems are rarely caused by a single circumstance, but there are often several circumstances that must coincide for an accident to occur. The present case is no exception. The investigation's section of analysis shows that there were circumstances in both the area of flight operations and in Air Traffic Services which together have led to the occurrence of the accident.

According to SHK, a central circumstance is the fact that the pilots and the air traffic controllers have not in all respects understood each other's intentions and been able to place these in the perspective of the surrounding terrain and airspace. It is therefore important to point out that both pilots and controllers together have an overall responsibility for the implementation of safe aviation, irrespective of where the formal responsibility for individual parts lies. Both pilots and controllers should therefore have a preparedness and understanding with respect to the fact that mistakes are made and have the capability to deal with these.

In order to prevent undesirable incidents as far as possible, various types of barriers are also needed to bring the sequence to a halt. Such barriers may, for example, be constituted by rules and methods (organisational barrier), warning symbols and signals (symbolic barrier), physical obstacles such as fences (physical barrier) and such things as passwords (functional barrier). In general, barriers are divided into two main groups; administrative and technical barriers, where administrative barriers represent organisational protection against erroneous action and a technical barrier represents a physical barrier. Barriers require regular human maintenance, and with respect to the barriers that are rarely put to the test, it can be difficult and unrealistic to verify their functionality before the barrier has been tested in a live situation[45].

Thus in the present case, the various barriers that are intended to prevent the occurrence of an accident have not worked. The barriers of primary relevance are described below.

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45 Hollnagel, E. (2004). *Barriers and accident prevention*. Hampshire: Ashgate.

The planning of the flight is fundamental to being able to perform a safe flight and thus represents a significant barrier for preventing dangerous circumstances from arising. The planning documentation to which SHK has had access is that supplied by *Mission Support* and actually corresponds to the documentation that would have been relevant if the mission had been carried out as a tactical low-altitude mission performed visually. To be able to perform a safe flight in the mission that came be executed, it has thus been necessary to implement a more detailed planning of the flight. There is a lack of sufficient information regarding the crew's preparations and planning of the flight to be able to establish how this planning was actually implemented.

In the planning of all IFR flight, regardless of whether it is a military or civil operation, the establishing of the minimum safe flight level for each section of the route is an important part of this planning. In the case of an event which entails that the crew must execute a rapid descent from its cruising altitude to a considerably lower flight level, for example if there is a loss of cabin pressure or smoke develops on board, it is necessary that such planning has been implemented so that the minimum safe flight level is clearly evident. This safe flight level shall then at least correspond to a clearance to underlying terrain or obstacles of no less than 1,000 feet or 2,000 feet, depending on the terrain elevation. Consideration must then also be given to the relevant corrections that must be made with respect to pressure, temperature and wind speed.

The calculated minimum safe flight level, as above, is thus a barrier that is intended to prevent the crew from flying the aircraft at unsafe altitudes. According to SHK, there can be two reasons for the barrier failing; either that the visual conditions were such during the last part of the flight that the crew were imbued with a clear perception that the underlying terrain posed no danger to the flight, or that confidence in Air Traffic Services was such that they found no reason to question the clearance. This has then resulted in the crew not having consulted the planning or reviewing other available information. Of course, a combination of these two reasons may also be a possible explanatory model. The above is supported by the fact that the crew in no way discussed the implications of the obtained clearances.

With regard to Air Traffic Services, it is primarily administrative barriers in the form of regulations and methods that are intended to guarantee that accidents do not occur, but there are also technical aids, such as radar screens with warning systems etc., to facilitate and guarantee that the work is carried out in a correct manner. Naturally, it is necessary for the air traffic controllers to have sufficient training and practical experience in the use of these rules and methods, as well as access to technical aids. Moreover, in order to identify deviations, there should be systems for following up how these are used and how the work is conducted. So far as it appears, this has not worked in practice in this systematic manner. As shown in the analysis section 2.2, there were deviations with regard to the applicable regulations and the phraseology used. Nor was there access to technical aids, in the form of radar or an equivalent technical solution, for monitoring and guiding air traffic at the level at which *HAZE 01* was situated. The above means that there is significant potential for development in the strengthening of these barriers.

GCAS/TAWS constitutes the last barrier in the sequence of events. Normally, this barrier will not be used; rather a warning from GCAS/TAWS means that earlier barriers have already failed. GCAS/TAWS is then to give such advance warning that collision with terrain or obstacles can be avoided. The investigation has shown that with the terrain profile in question and the settings in question, the criteria for a warning are not fulfilled. It is SHK's understanding that this barrier can be developed in order to achieve safer operations.

In summary, the investigation indicates that latent weaknesses have existed both at the Norwegian Air Force and at LFV. It is these weaknesses and not the mistakes of individual persons that are assessed to be the root cause of the accident.

3 CONCLUSIONS

3.1 Findings

a) The crew members were qualified to perform the flight.
b) The aircraft was airworthy and maintained in accordance with the approved maintenance programme and other approved applicable maintenance data.
c) No technical malfunction on the aircraft has caused or contributed to the occurrence of the accident.
d) Everyone on board was killed immediately upon the collision with the mountain.
e) The Swedish Air Traffic Services lacked radar coverage in that part of the Swedish airspace where the flight was being performed.
f) The crew members have not checked the Air Traffic Services' clearances against the minimum safe flight level or the highest terrain in the area.
g) All air traffic controllers were relatively newly qualified and inexperienced in their respective roles.
h) The crew members have in no way become aware of the imminent danger of underlying terrain.
i) SHK has not found any uniform procedure at the Norwegian Air Force that entails the planning of flights in accordance with existing regulations.
j) The clearance from ACC Stockholm entailed that the aircraft was unintentionally cleared out of controlled airspace, and relevant flight information was thereby not provided.
k) The clearance from Kiruna entailed that the aircraft was assigned an altitude that did not provide a clearance to underlying terrain on its route towards Kiruna Airport.
l) The planning documentation that was supplied to the crew exhibited deficiencies in the chart material and was moreover for another type of mission.
m) When giving the clearances, neither the air traffic controllers at ACC Stockholm nor in Kiruna have been able to geographically place the aircraft where it was situated in reality.
n) SHK's investigation points to several circumstances that indicate weaknesses in LFV's safety culture.
o) GCAS/TAWS has not warned of collision with the terrain.
p) The combination of the terrain profile in question and the settings in question does not fulfil the criteria for a warning by GCAS/TAWS.
q) GCAS/TAWS has functioned in accordance with the description that emerges overall in studies of system description, emergency checklist and supplement to the flight manual.
r) Inadequate routines at the Norwegian Air Force and ambiguity in the system documentation and training may have occasioned deficiencies in the crew's knowledge and management of the system for GCAS/TAWS.
s) The decision to grant the commander an exemption from undergoing a flight physical examination was not made by an authorised person.
t) No alerting was carried out from Stockholm ACC with reference to the information about non-response to radio calls to HAZE 01.
u) An alert about the missing aircraft was executed by Kiruna TWR 20 minutes later than is prescribed in current regulations.
v) The Norrbotten County Police issued the order for an operation to four mountain rescuers approximately 3.5 hours after the incident became known at that authority.

w) Management of the air rescue services at JRCC was performed without application of a clear and effective management model that took charge of system management and operation management, including how the management on site in the expected crash area would be implemented and coordinated.
x) JRCC lacked a training plan, which was approved by the Swedish Transport Agency, for the initial and recurrent training of Air Rescue Coordinators.
y) JRCC lacked specific liaison procedures for the search for missing aircraft in mountainous terrain.
z) The Swedish Maritime Administration had no programme, or the equivalent, for training and exercise at the individual level with respect to the helicopter crew's ability to operate in a mountainous environment.
aa) The Swedish SAR helicopter needed about two and a half hours from the alert, with two intermediate landings for refuelling, before it arrived in the search area.
bb) The Norwegian Armed Forces and the Swedish Armed Forces made units with expertise in operating in alpine terrain available for the search on the ground.
cc) ELT exhibited such damage that it had not been able to transmit any emergency signal.

3.2 Causes

The accident was caused by the crew on *HAZE 01* not noticing to the shortcomings in the clearances issued by the air traffic controllers and to the risks of following these clearances, which resulted in the aircraft coming to leave controlled airspace and be flown at an altitude that was lower than the surrounding terrain.

The accident was rendered possible by the following organisational shortcomings in safety:

- The Norwegian Air Force has not ensured that the crews have had sufficiently safe working methods for preventing the aircraft from being flown below the minimum safe flight level on the route.
- LFV has not had sufficiently safe working methods for ensuring, partly, that clearances are only issued within controlled airspace during flight under IFR unless the pilot specifically requests otherwise and, partly, that relevant flight information is provided.

4. RECOMMENDATIONS

The Royal Norwegian Air Force is recommended to:

- Ensure that procedures are used that prevent aircraft from being flown below the minimum safe altitude or flight level en route in IFR flight.. (RM 2013: 02 R1).

- Ensure that flight crew knowledge and routines means that the system for ground collision avoidance is used in a safe manner. (RM 2013: 02 R2).

- Further examine whether, and where necessary take measures to ensure that, the current crew configuration on the C130J attends to all aspects of the safe implementation of planning and flight. (RM 2013: 02 R3).

- Develop clear rules, manuals and procedures, which make it easier for flight crews to conduct safe air operations. (RM 2013: 02 R4).

The Swedish Transport Agency is recommended to:

- Ensure that an investigation of the safety culture within LFV is carried out with the aim of creating the conditions for maintaining and developing operations from an acceptable aviation safety perspective. (RM 2013: 02 R5).

- Further examine whether, and where necessary take measures to guarantee that, the controlled airspace is so designed that it encompasses an area large enough to contain the published routes for outgoing and incoming aircraft under IFR for which air traffic control is to be exercised, so that aircraft can execute all manoeuvres in controlled air, taking into account the aircraft's performance and the aids to navigation that are normally used in the area. (RM 2013: 02 R6).

- Ensure that air traffic controllers possess sufficient expertise and aids to manage situations that do not frequently occur. (RM 2013:02 R7).

- Ensure that the discrepancies between the provisions regarding the use of QNH below the lowest usable flight level and the provisions regarding the use of flight levels above 3,000 feet (900 metres) MSL in airspace class G are eliminated. (RM 2013: 02 R8).

- Take measures to remove the ambiguity of having different applications of LAF. (RM 2013: 02 R9).

- Ensure that the English translation of *“lägsta användbara flygnivå”* in AIP Sweden is changed to *“lowest usable flight level”* so as to be in accordance with international regulations. (RM 2013: 02 R10).

- Act so that ICAO reviews its regulations with respect to *“lowest usable flight level”* in order to ensure that they also satisfy the circumstances in an area-type controlled airspace, or clarifies in guidance material how the regulations are to be applied in such airspace. (RM 2013: 02 R11).

- Ensure that regulations and general advice for airborne rescue units are issued that cover helicopter crew training and exercises in a mountainous environment, with requirements for special training and exercise programmes and that completed training and exercises be documented. (2013: 02 R12).

- Ensure that a management model is developed by the Swedish Maritime Administration for the air rescue services at JRCC that encompasses system management and operation management, including local management within the likely area of a crash involving an aircraft, and that the personnel are trained and drilled in accordance with the established management model. (RM 2013: 02 R13).

- Ensure that the Swedish Maritime Administration develops, trains and drills the personnel at JRCC in a staff model adapted for air rescue services and the established management model at the air rescue centre. (RM 2013: 02 R14).

- Ensure that the Swedish Maritime Administration develops documented liaison procedures for air rescue services in a mountainous environment. (RM 2013: 02 R15).

- Ensure that the Swedish Maritime Administration develops planning in collaboration with concerned authorities and organisations for appropriate resources regarding search from the ground in a mountainous environment and how these are to be alerted. (RM 2013: 02 R16).

- Ensure that the Swedish Maritime Administration develops and uses an objective for helicopter SAR operations that is possible to evaluate with respect to each individual operation. (RM 2013: 02 R17).

- Ensure that the Swedish Maritime Administration trains and drills JRCC personnel in collaboration with air rescue services and mountain rescue services and develops procedures for this. (RM 2013: 02 R18).

The Swedish National Police Board is recommended to:

- Ensure that police authorities with responsibility for mountain rescue services plan and organise activities in such a way that rescue operations are commenced within an acceptable time of receiving an alert and implemented with adequate resources. (RM 2013: 02 R19).

The Swedish Civil Contingencies Agency is recommended to:

- In consultation with the Swedish Maritime Administration, the Swedish Transport Agency, the Swedish National Police Board, the Swedish National Board of Health and Welfare and SOS Alarm, ensure that the alerting of rescue and healthcare resources is carried out within an acceptable time, even in the case of events where there is only an imminent danger of an aircraft accident. (RM 2013: 02 R20).

- Examine measures necessary for guaranteeing that rescue operations are commenced within an acceptable time without delay and are executed in an effective manner, even in the event of parallel (simultaneous) operations with the participation of national rescue services, and thereafter inform central and local government authorities responsible for rescue services. (RM 2013: 02 R21).

- Within the Nordic cooperation for rescue services, act so that knowledge of the different countries' rescue service organisations becomes sufficiently familiar to the parties that may be subject to participation in rescue operations. (RM 2013: 02 R22).

Clarification

It has been noted that the SMHI's Significant Weather Chart (SWC), figure 13 in the final report, is dated 15 March 2011, i.e. one year before the event.

On request, SMHI confirms that the weather data on the map refers to 15 March 2012, but that SMHI mistyped wrong year.

The Swedish Accident Investigation Authority takes no other action than this clarification appended to the report.

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