Aircraft damage in hailstorm west of Helsinki on 21.7.2001

Micro-summary: **This McDonnell Douglas MD-81 experienced hail damage to its radome and empennage in cruise.**

Event Date: **2001-07-21 at 1407 UTC**

Investigative Body: **Finland Accident Investigation Board (AIB), Finland**

Investigative Body's Web Site: **http://www.onnettomuustutkinta.fi/**

Investigation report

B 5/2001 L

Translation of the Finnish original report

Aircraft damage in hailstorm west of Helsinki on 21.7.2001

LN-RMT

Douglas DC-9-81

According to Annex 13 of the Convention on International Civil Aviation, paragraph 3.1, the purpose of aircraft accident and incident investigation is the prevention of accidents. It is not the purpose of aircraft accident investigation or the investigation report to apportion blame or to assign responsibility. This basic rule is also contained in the Investigation of Accidents Act, 3 May 1985 (373/85) and European Union Directive 94/56/EC. Use of the report for reasons other than the improvement of safety should be avoided.

Onnettomuustutkintakeskus
Centralen för undersökning av olyckor
Accident Investigation Board Finland

Osoite / Address: Sörnäisten rantatie 33 C
FIN-00580 HELSINKI

Adress: Sörnäs strandvägen 33 C
00580 HELSINGFORS

Puhelin / Telefon: (09) 1606 7643
Telephone: +358 9 1606 7643

Fax: (09) 1606 7811
Fax: +358 9 1606 7811

Sähköposti: onnettomuustutkinta@om.fi tai etunimi.sukunimi@om.fi
E-post: onnettomuustutkinta@om.fi eller förnamn.släktnamn@om.fi
Email: onnettomuustutkinta@om.fi or forename.surname@om.fi

Internet: www.onnettomuustutkinta.fi

ISBN 951-836-093-6

ISSN 1239-5323

Multiprint Oy, Helsinki 2002

CONTENTS

LIST OF APPENDICES

Other reference material is stored at the Accident Investigation Board, Finland.

ABBREVIATIONS

ACC	Area control centre
AIS	Aeronautical information services
AMA	Area minimum altitude
AOM	Aircraft operating manual
AP	Autopilot
APP	Approach control
AT	Autothrottle
ATIS	Automatic terminal information service
BKN	Broken (5-7/8)
CA	Cabin attendant
CADC	Central air data computer
CB	Cumulonimbus
CSM	Cabin Safety Manual
CVR	Cockpit voice recorder
DFDR	Digital flight data recorder
DME	Distance measuring equipment
EFHK	Helsinki-Vantaa airport
EFTU	Turku airport
EMBD	Embedded
EPR	Engine pressure ratio
FEW	Few (1-2/8)
FGS	Flight guidance system
FIR	Flight Information Region
FL	Flight level
FMS	Flight management system
FOM	Flight operations manual
ft	Feet
GND	Ground control
GPWS	Ground proximity warning system
hPa	Hectopascal
IAS	Indicated air speed
ILS	Instrument landing system
JAR	Joint Aviation Requirements
kg	Kilograms
km	Kilometres
kt	Knot(s)
MEL	Minimum equipment list
METAR	Aviation routine weather report
MHz	Megahertz
MSL	Mean sea level
MSSR	Monopulse secondary surveillance radar
NM	Nautical miles

NOTAM	A notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.
OCNL	Occasionally
OPS	Operations
OVC	Overcast (8/8)
PF	Pilot flying
PNF	Pilot not flying
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
QAR	Quick Access Recorder
RAIS	Route documentation system, aeronautical information service (SAS)
RODOS	Route documentation system
SAS	Scandinavian Airlines System Ab
SAR	Search and rescue
SCT	Scattered (3-4/8)
SIGMET	Information concerning en-route weather phenomena which may affect the safety of aircraft operations
SMHI	Swedish Meteorological and Hydrological Institute
SWC	Significant weather chart
TAF	Aerodrome forecast
TAR	Terminal area surveillance radar
TCU	Towering cumulus
TWR	Tower
UTC	Co-ordinated universal time
VHF	Very high frequency (30-300 MHz)
Vnav	Vertical navigation
VOR	VHF omnidirectional radio range

SYNOPSIS

On Saturday 21 July 2001 at 14.07 co-ordinated universal time (UTC) there was an aircraft incident west of Helsinki, in which a Douglas DC-9-81 aeroplane (MD81) owned by Commercial Aviation Leasing Ltd and operated by Scandinavian Airlines System Ab (SAS), call sign SAS1700, registered LN-RMT, flew into a severe hailstorm in clouds while on a scheduled passenger flight from Stockholm-Arlanda to Helsinki-Vantaa airport. The aircraft radome was damaged and the windshields in front of the pilots were cracked. In addition, the engine inlet cowls and leading edges of wings and stabilisers were dented by hail. There were 63 passengers and six crew members on board.

The Accident Investigation Board, Finland, decided to set up a commission to investigate the incident on 23 July 2001 (decision No B 5/2001 L). Troubleshooting Coordinator Heikki Tenhovuori was appointed as investigator-in-charge, and the other members of the commission were airline captain Lasse Seppänen, Cabin Safety Officer Sami Sievä and meteorologist Ossi Korhonen. Moreover, the commission consulted air traffic controller Ari Huhtala as an expert of ATC operations, and he also assisted in writing the investigation report.

The accident investigation authority of Norway, which is the aircraft's state of registry, informed on 24 July 2001 that it will not appoint an accredited representative to the investigation.

Detailed examination of aircraft damage was carried out at Helsinki-Vantaa airport from 21 July to 1 August 2001.

The investigation was based on the Investigation of Accidents Act (373/1985) and Decree (79/1996), ICAO Annex 13 and European Union Council directive 1994/56/EC.

The draft investigation report was sent for comments to the Finnish Meteorological Institute on 17 May 2002, as required by Section 24, Sub-section 1 of the Investigation of Accidents Decree (79/1996). The comments received are annexed to this report and have been taken into account in the text as appropriate. However, the Investigation Commission does not share the view of the Finnish Meteorological Institute, which stated that the SIGMET was not prepared too late with regard to the development of the weather conditions. The comments received from Scandinavian Airlines System Ab (SAS) did not require any changes to the investigation report. The comments of the Norwegian accident investigation authorities have been taken into account in the report.

The comments received are annexed to this investigation report. The investigation was closed on 28.8.2002.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Cockpit crew actions

The pilots of SAS1700 reported for duty in the company briefing office in Stockholm-Arlanda. They planned the flights Stockholm-Helsinki, Helsinki-Copenhagen and Copenhagen-Paris, which were included in the same duty period. They printed the flight plan data from the route documentation system (RODOS). At the same time, the route documentation and aeronautical information service system (RAIS) also printed the aviation routine weather reports (METAR), aerodrome forecasts (TAF), NOTAM information and company circulars. For short-haul routes like this one, SAS pilots prepare the flights themselves. The pilots did not study the significant weather chart (SWC) for the route, nor did they take it with them. During the interview the pilot-in-command told that they had taken some extra fuel, since "there was some CB clouds and rain showers". After arriving at the aircraft, the pilot-in-command briefed the cabin crew for the flight, but did not mention anything about the weather conditions.

The pilot-in-command acted as pilot flying (PF) and the co-pilot as pilot not flying (PNF) during the flight. The scheduled departure time of SAS1700 from Stockholm-Arlanda was 13.10 UTC (all times used in this report are UTC, which on the date of the incident was Finnish local time -3 h). The departure was delayed for 20 minutes because of digital flight data recorder (DFDR) change. The pilots used the airborne weather radar during the climb, but it was switched off 10 minutes after take-off. The plane climbed to the cruising level, FL 290. The pilots told that the cruise part of the flight was flown above clouds in clear weather, and flight visibility forwards was unrestricted. During the flight the pilots listened to the Helsinki-Vantaa Automatic Terminal Information Service (ATIS) broadcast India. Tampere area control centre (ACC) cleared SAS1700 to descend to flight level 100, and thereafter handed the aircraft over to Helsinki approach radar (APP) from reporting point LAKUT.

SAS1700 contacted the APP controller at 14.05.18. The aircraft was issued an arrival clearance to fly heading 080º and maintain FL 100 after reaching it. Moreover, the pilots were informed of right-hand radar vectoring for runway 22 and that the distance to go was 60 nautical miles (NM). SAS1700 acknowledged the arrival clearance. The pilot-in-command switched on the FASTEN SEAT BELTS signs in the cabin. At the same time she gave a landing announcement, in which she told that they were commencing approach to Helsinki-Vantaa, reported the remaining flight time and requested the passengers to fasten their seat belts.

While descending in a cumulonimbus cloud (CB) through flight level 152, with the indicated airspeed (IAS) of 303 knots (kt) SAS1700 flew into a powerful cell which contained turbulence and large hailstones. There was also thunder in the CB cloud. The PNF tried to switch on the weather radar on the PF's request, but a radar image could not be obtained. The device only showed an error code. The windshield in front of the PF was cracked, and a moment later also the windshield on the PNF's side. During the hailstorm these parts of the windshield were cracked more, while the middle windshield and other flight deck windows remained undamaged. The aircraft's ground proximity warning system (GPWS) gave two TERRAIN warnings, and the autopilot (AP) disconnected almost simultaneously.

At 14.07.43 SAS1700 reported turning 180° to the right to avoid a CB cloud. Soon thereafter the autothrottle (AT) also disconnected. The APP controller accepted the turn and asked the crew to confirm the heading. At 14.08.48 the PNF reported the heading as 120°. The APP controller then asked SAS1700 to report when they would be ready to turn left to heading 080°. The PNF acknowledged the heading, and the turn was initiated.

At 14.10.14 the APP controller gave SAS1700 a heading of 060° and cleared it to continue descent to 5000 ft at a barometric setting of 1011 hPa (QNH). The PNF read back the clearance. At 14.10.58 SAS1700 sent a distress message, reporting that the windshields had cracked and requesting for radar vectors *(”Mayday, Mayday, Mayday, we’re having cracked windshields here and request vectors”)*. The APP controller instructed SAS1700 to turn right to heading 070° and cleared it to continue descent to 2000 ft, which the crew acknowledged.

At 14.12.37 the arrival radar controller (ARR) asked the aerodrome controller (TWR) in Helsinki to alert the rescue services of an aircraft accident. 20 seconds later the ARR controller changed the alert status into an aircraft emergency.

As the PF requested flaps 11º, the PNF noticed that the two airspeed indicators were showing different speeds. The PF’s IAS was 255 kt, while the IAS on the PNF’s side was 280 kt. The PNF then compared the reading of the standby airspeed indicator to his instrument, and concluded that these indications were almost identical. The aircraft was slightly slowed down before the flaps were extended. A moment later, after several attempts, the PF succeeded to keep the AP engaged.

At 14.15.57 SAS1700 cancelled the distress call. The aircraft was then about 9 NM from runway 22 threshold, within the instrument landing system (ILS) localizer beam.

At 14.16.23 the APP controller handed SAS1700 off to the TWR controller. At 14.16.57 the TWR controller cleared SAS1700 to land on runway 22. Due to the difference in airspeed indications, the pilots kept the approach speed slightly higher than usual. However, the difference was later reduced so that it was only about two knots during final approach. The plane landed at 14.19.

When leaving the runway after landing, SAS1700 changed over to the ground control (GND) frequency and was given taxi instructions to stand 27. At 14.20.55 the GND controller asked SAS1700 to confirm if the operations were normal and the emergency could be cancelled. The crew confirmed the cancellation and reported that the operations were normal. The plane was parked at the stand at 14.22.

After parking the pilot-in-command announced to the passengers on the public address system that the aircraft had flown into a hail shower, and that it had been unpleasant but not dangerous. The pilot-in-command also told that she would be available at the flight deck door for any further information on the event.

When the mechanic came on board, he stopped the cockpit voice recorder (CVR) after having received the pilot-in-command's permission to do so.

Figure 1. SAS1700, MD81 after the incident

1.1.2 Cabin crew actions

The cabin crew had reported for duty in Stockholm-Arlanda as instructed, one hour before the scheduled departure time. This was the crew's first duty period for the day. The purser carried out the cabin crew briefing, which included safety instructions detailing each cabin attendant's (CA) duties and responsibilities in an emergency. The cabin crew performed the safety checks before the passengers embarked. Cabin emergency equipment was in compliance with relevant requirements. The safety briefing was given in English and Swedish, and by demonstrating the appropriate actions.

Cabin crew stations in the aircraft

CA 1 (Purser)	forward jump-seat, right-hand side
CA 2	aft jump-seat, left-hand side
CA 3	aft service door jump-seat
CA 4	forward jump-seat, left-hand side

MD81 cabin version 9806A has 18 business class seats and 112 economy class seats.

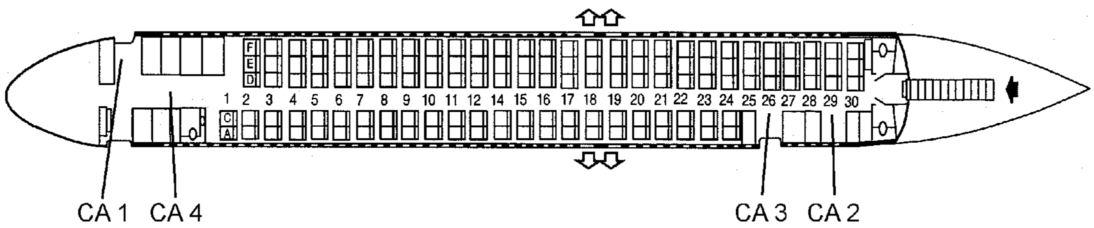


Figure 2. Cabin crew stations in the aircraft when the turbulence began

Sequence of events in the cabin

After take-off the cabin crew did not give an announcement recommending the use of safety belts during the flight. Cabin service was carried out as usual after take-off. When the pilot-in-command illuminated the FASTEN SEAT BELTS signs, all service equipment had been gathered away and the galleys had been secured for landing. At the same time, the pilot-in-command gave the landing announcement.

After the announcement the aircraft was shaken by severe turbulence. According to CA 1, *"the hailstones hit the plane so hard that the noise was incredible."* When the turbulence began, the cabin crew were near the galleys. In the forward cabin, CA 1 reached her seat rather quickly and helped CA 4 to get to her own seat. They managed to fasten their safety harnesses. In the aft cabin, CA 2 and CA 3 felt the turbulence very hard and fell down on the cabin floor. There was a passenger in both the forward and aft lavatory. After the turbulence had subsided, the passenger who was in the forward lavatory managed to get to a seat in the first business class seat row, crawling on his hands and knees assisted by CA 4. He also got his safety belt fastened. In the aft cabin, CA 2 and CA 3 reached their own seats. The passenger who was in the aft lavatory moved to the cabin crew seat next to CA 2. None of the passengers was injured, but some cabin attendants got bruises and mild muscle strains. The pilots gave no advance warning of the turbulence.

By the time the turbulence got stronger again, everyone in the cabin had their safety belts fastened. After the turbulence had subsided, the cabin crew paid attention to an abnormal, rattling sound of the engines. CA 1 opened the flight deck door, but the noise was so loud that conversation was impossible. The pilot-in-command pointed at the cracked windshields. CA 1 then gave an OK sign with her thumb, indicating that everything was in order in the cabin. The cabin attendants did not inform the cockpit crew of their observations about engine sound during the flight.

CA 1 looked to the aft cabin and saw that both CAs there were doing well. Since CA 1 was not sure if an emergency landing would be made, she gave no announcement to the passengers. She did not use the interphone either to call the CA in the aft cabin and check the situation there.

CA 1 then heard that the cockpit crew were making normal preparations for landing and the landing gear was extended. At that time she made an announcement to the passengers to fasten their safety belts and asked the attendants in the aft cabin to secure the galley for landing. However, the cabin crew did not check the cabin before landing by walking from one end to the other.

After landing CA 2 made the normal cabin announcement. The pilot-in-command then told the passengers what had happened. SAS airport staff came to meet the plane in Helsinki, prepared to write down the passengers' personal data. Two passengers contacted the airport staff.

The cabin was not damaged. All overhead stowage compartment doors remained closed and all hand baggage remained in its place. No emergency equipment was used.

1.1.3 Reporting

The pilot-in-command of SAS1700 filled in the company incident report form (Flight Safety Report) and made an entry about the incident in the aircraft technical log. The purser made a separate internal report for the cabin crew.

The shift supervisor in Helsinki ATC filed an internal occurrence report used by the Air Navigation Services Department of CAA Finland. The incident was also recorded in TWR and APP logs.

1.1.4 Crew debriefing after the flight

A debriefing session was arranged for all crew members in the SAS office at Helsinki-Vantaa airport. The crew was given an opportunity to discuss together their experiences on the flight, thus preventing any anxiety caused by the incident.

1.2 Injuries to persons

There were 63 passengers and six crew members on board.

Injuries	Crew	Passengers	Others
Fatal	None	None	None
Serious	None	None	None
Minor / no injuries	6	63	None

1.3 Damage to aircraft

The slat panels on wing leading edges were dented by hail, as were the leading edges of horizontal and vertical stabilisers and engine inlet cowls. A hole was torn in the radome, as a result of which the radar antenna surface was also dented. The outer surfaces of windshields in front of the captain and co-pilot were cracked. The aircraft structures or engines were not damaged.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Flight crew

Pilot-in-command: Female, 44 years
Licences: Airline transport pilot licence, valid until 2.2.2002
Medical certificate: Valid until 14.12.2001
Last check flight: 13.7.2001
Ratings: All required ratings were valid.

Pilot experience	Last 24 hours	Last 30 days	Last 90 days	Total, all types
MD81	52 min	51 h 25 min	125 h	6800 h

Co-pilot: Male, 29 years
Licences: Commercial pilot licence, valid until 23.8.2003
Medical certificate: Valid until 18.7.2002
Last check flight: 20.4.2001
Ratings: All required ratings were valid.

Pilot experience	Last 24 hours	Last 30 days	Last 90 days	Total, all types
MD81	4 h 15 min	56 h 53 min	150 h 50 min	4020 h

1.5.2 Cabin crew

Purser, CA1: Female, 53 years
Type rating: Issued prior to 1974
Emergency training: 21.12.2000

Cabin attendant, CA2:	Female, 28 years
Type rating:	Issued 1.4.1996
Emergency training:	10.1.2001

Cabin attendant, CA3:	Female, 23 years
Type rating:	Issued 2.7.2001
Emergency training:	11.7.2001

Cabin attendant, CA4:	Female, 44 years
Type rating:	Issued in January 1993
Emergency training:	2.12.2000

1.6 Aircraft information

Type and model:	Douglas DC-9-81 (MD81), twin-engine jet airliner with 130 passenger seats.
Nationality and registration:	Norway, LN-RMT
Manufacturer:	McDONNELL DOUGLAS CORPORATION
Serial number:	53001
Year of manufacture and reg.:	1991, 1992
Owner:	Commercial Aviation Leasing Ltd
Operator:	Scandinavian Airlines System Ab
Flight hours:	23673 h
Maximum take-off weight:	63503 kg
Landings:	20007
Certificate of airworthiness:	valid until 31.12.2001

Engines

Type and model:	JT8D-219 (derated JT8D-217C)
Manufacturer:	PWA Pratt & Whitney
Owner:	Commercial Aviation Leasing Ltd
Operator:	Scandinavian Airlines System Ab

Serial number, year of manufacture:

Right engine:	P 716740 DCN, 1985
Left engine:	P716723 D, 1985
Maximum thrust:	20850 lb

1.7 Meteorological information

1.7.1 General weather conditions

There was a warm and moist east-south-eastern airflow prevailing in the lower atmosphere in Southern Finland on 21 July 2001. Moreover, a warm front had progressed to the south-west of Finland, moving slowly north. On the other hand, there was an upper-air trough spreading from the west so that the air was cold higher in the atmosphere. This created a shift of wind direction with altitude (windshear) and an unstable state of equilibrium in the air, which in turn caused very powerful and long-lasting thunderstorm clouds to develop rapidly in the afternoon.

At 1200, thunderstorm clouds appeared in the north-eastern part of the Baltic Sea, in the south-western part of the Gulf of Finland, and along a line from Turku to Mikkeli, moving north-north-east. The buildups were very high, their tops reaching flight levels 350 - 400 (10 650 - 12 200 m) at their full stage of development. This created powerful upward currents and favourable conditions for the formation of hailstones.

1.7.2 Weather at the incident site

There was a thunderstorm cloud with horizontal dimensions of 15 km x 50 km at the incident site, extending from south to north. Weather radar images showed that it contained three powerful cells. The lightning location chart also indicated lightning strikes in the cloud. The top of the cloud was probably at about FL 400 (12 200 m), which can be concluded from weather radar and sounding information. According to a weather sounding made at the weather observation station of Jokioinen at 12 UTC, the tropopause was at flight level 380 (11 600 m). The tops of a CB cloud in the rising stage normally extend about 1000 - 2000 feet (300 - 600 m) above the tropopause. Moreover, the size of the hailstones also indicates that the buildup was exceptionally high. According to weather sounding information, there were stratiform clouds with tops at about flight level 230 (7000 m) along the flight route. A weather satellite image at 11.23 showed that the area of stratiform clouds associated with the weather front extended approximately from Stockholm to Lohja, Finland.

SAS1700 flew into the most powerful thunderstorm cell in the cloud, with horizontal dimensions of about 5 km x 10 km. There was severe turbulence at times. When the plane encountered the hail shower, the outside air temperature was from -7ºC to -10ºC and the hailstones were at or near their maximum size. The GPWS system in the aircraft activated for 20 seconds due to the hail, which indicates that the plane flew about 4 km in a heavy shower of hail.

1.7.3 Weather observations from the area

The local residents in Snappertuna, situated about 62 km south-west of VTI VOR/DME radio beacon, observed hailstones of approximately 1 cm in diameter at 13 - 14 UTC. These hailstones were not from the thunderstorm cloud at the incident site, but several observations about hail from that cloud were made west of VTI VOR/DME. In the municipality of Nummi-Pusula, hailstones of about 1 cm in diameter were seen at 13 - 14 UTC. Moreover, in the village of Hyönölä 17 km west of VTI VOR/DME, large hailstones were falling for about 10 minutes. The largest hailstones found on the ground were oval in shape, with the longer diameter about 4 cm and the shorter about 1 cm. These hailstones came exactly from the same cell in which SAS1700 was damaged. The oval shape was probably caused by melting of non-homogeneous hailstones when they were falling through a warmer layer of air, as the freezing level (0ºC isotherm) was approximately at 11 500 feet (3 500 m). The temperature at ground level was above +25ºC.

1.7.4 Estimated hail size at the height of the incident

The extent of the hailstorm was about 5 km x 10 km. The hailstones had reached their full dimensions higher, at around flight level 200 - 250 (6100 - 7600 m), and were at their maximum size when they hit the plane. Judging from the observations made at ground level in Hyönölä and the dents in the aircraft, the largest dimension of the hailstones was more than 5 cm.

SAS1700 flew into a cell in the CB cloud at 14.07. Figure 3 depicts the aircraft at flight level 290 before commencing the descent. The future flight path is marked with a dotted line. In figure 4, the plane is approaching runway 22. The actual flight path is marked with a solid line. The cloud moved north-northeast between the times of figure 3 and 4.

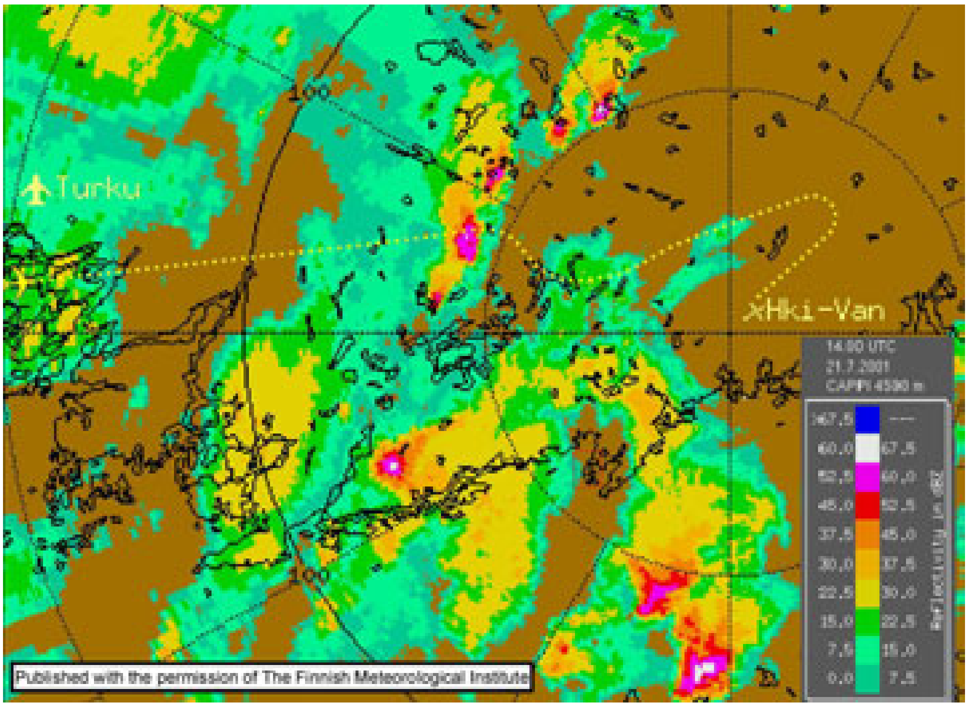


Figure 3. Weather radar image at 14.00 from the altitude of 4500 m

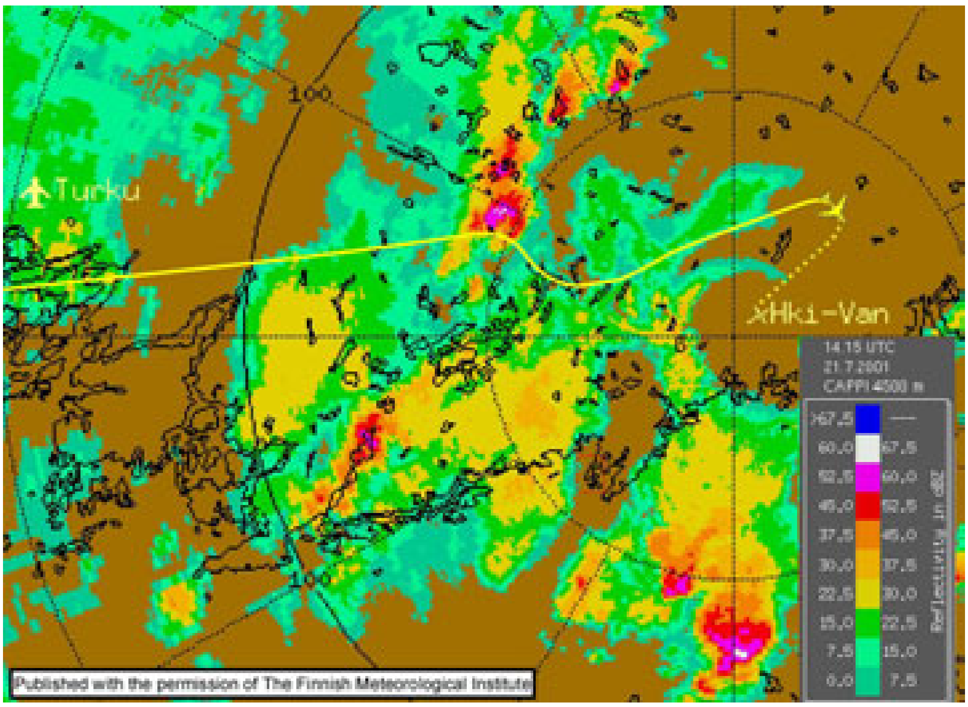


Figure 4. Weather radar image at 14.15 from the altitude of 4500 m

1.7.5 Aerodrome forecasts (TAF)

Helsinki-Vantaa (EFHK) TAF for 09-18: Wind 120º 7 kt, visibility more than 10 km, clouds few (FEW, 1–2/8) at 3500 ft, temporarily between 10-18 light showers with 30% probability, scattered (SCT, 3–4/8) CB clouds at 3500 ft.

Turku (EFTU) TAF for 09-18: Wind 050º 3 kt, visibility more than 10 km, clouds broken (BKN, 5–7/8) 2000 ft, BKN 5000 ft, temporarily between 09-18, visibility 4000 m, showers, BKN 1000 ft and SCT CB clouds at 3000 ft, with 30% probability between 09-11, BKN 200 ft.

EFHK TAF for 12-21: Wind 120º 6 kt, visibility more than 10 km, clouds FEW at 3500 ft, temporarily between 15-21 light showers with 30% probability, FEW CB clouds 3500 ft.

EFTU TAF for 12-21: Wind 350º 3 kt, visibility more than 10 km, BKN 2000 ft, temporarily between 12-21 visibility 4000 m, showers, BKN 1000 ft, SCT CB clouds at 3000 ft, temporarily between 12-21 light thundershowers with 40% probability.

The crew had EFHK and EFTU aerodrome forecasts for the period 09-18 in their RAIS printout. However, they did not have the TAFs for the period 12-21, although they had been distributed from Helsinki-Vantaa airport communications centre at 11.40 according to the time of delivery marking.

1.7.6 Aviation routine weather reports (METAR)

EFHK METAR at 1120: Wind 140º 7 kt, variation 110º-190º, visibility more than 10 km, clouds FEW 4000 ft, BKN 20000 ft, temperature 26ºC, dewpoint 16ºC, QNH 1012, no significant change expected in two hours (NOSIG).

EFTU METAR at 1150: Wind 030º 3 kt, visibility more than 10 km, clouds SCT 1200 ft, SCT CB clouds 3000 ft, BKN 9000 ft, temperature 20ºC, dewpoint 17ºC, QNH 1013.

The crew had the EFTU METAR at 1150 in their RAIS printout, but the EFHK METAR was from 1120. EFHK METAR at 1150 contained the marking NIL.

EFHK METAR at 1350 (ATIS, information India): Wind 120º 6 kt, variation 070º-140º, visibility 50 km, FEW towering cumulus (TCU) 4000 ft, SCT 10000 ft, BKN 20000 ft, temperature 26ºC, dewpoint 16ºC, QNH 1011, transition level FL 55, NOSIG, runway 22 in use.

1.7.7 Significant weather chart (SWC)

The Nordic SW chart published by the Swedish Meteorological and Hydrological Institute (SMHI) contains information about significant weather phenomena along the route. The chart for 12 UTC indicates occasionally high CB clouds embedded in other clouds at FL 350 and thunder in south-western Finland along the intended route. This chart would have been available for the crew, but they did not use it or another European SW chart published by the World Area Forecast Centre in London.

1.7.8 Warning messages on significant weather (SIGMET)

The SIGMETs for Tampere flight information region (FIR) are prepared by the Aeronautical Weather Services, Southern Finland. These messages have priority over other weather services, since they contain warnings about weather phenomena which may affect the safety of aircraft operations. On the day of the accident, the SIGMET was distributed at 14.15, eight minutes after SAS1700 had flown into the CB cloud cell.

1.7.9 Airport radars

Due to strong filtering of signals, the primary radar (TAR) used in Helsinki approach control (APP) at the time of the accident did not show the CB clouds on ATC radar display. The secondary surveillance radar (MSSR) is not technically able to detect CB clouds at all. Moreover, the APP has a weather radar image updated every 15 minutes in test use, but in cannot be used in actual operations. The briefing room also has a weather radar image, updated every 30 minutes.

1.8 Aids to navigation

Aids to navigation had no effect on the incident.

1.9 Communications

The radio communications between SAS1700 and Helsinki air traffic control were conducted in English. Judging from the recordings, radio reception was good and there was no interference on the frequency. The phraseology used was mainly in accordance with the instructions.

1.10 Location of the incident

The incident occurred about 7 NM west of VTI VOR/DME radio beacon, at an altitude of approximately 15 000 ft (4550 m).

1.11 Flight recorders

The aircraft was equipped with a digital flight data recorder (DFDR) manufactured by Allied Signal, product number P/N 980-4100 DXUN, serial number S/N 2693. SAS removed the DFDR and stored it for retrieval of information.

The aircraft also had a recording device used for maintenance and condition monitoring, Quick Access Recorder (QAR), manufactured by Penny & Giles, P/N D51434-1, S/N 1016/02/93. SAS read out the QAR recording and made the data available to the Investigation Commission. Since the QAR records at least the same information as DFDR, there was no need to retrieve the DFDR data. The time of the QAR recording was, on an average, 26 seconds ahead of the ATC communications recording. In this report, the times of the QAR recording have been corrected to match the communications recording.

Moreover, the aircraft was equipped with a cockpit voice recorder (CVR), manufactured by Allied Signal, P/N 980-6020-001 DXUN, S/N 2240. SAS removed the CVR and delivered the tape recording to the Investigation Commission. However, the tape only contained the recording for the last 5 minutes of the flight, since the recording relevant to the incident had been recorded over. The CVR, used in the aicart, is capable of recording for 30 minutes.

1.12 Examination of aircraft damage

A hole of about 50 cm in diameter was torn in the radome, as a result of which the radar antenna surface was also dented by hail.

Figure 5. The damaged radome

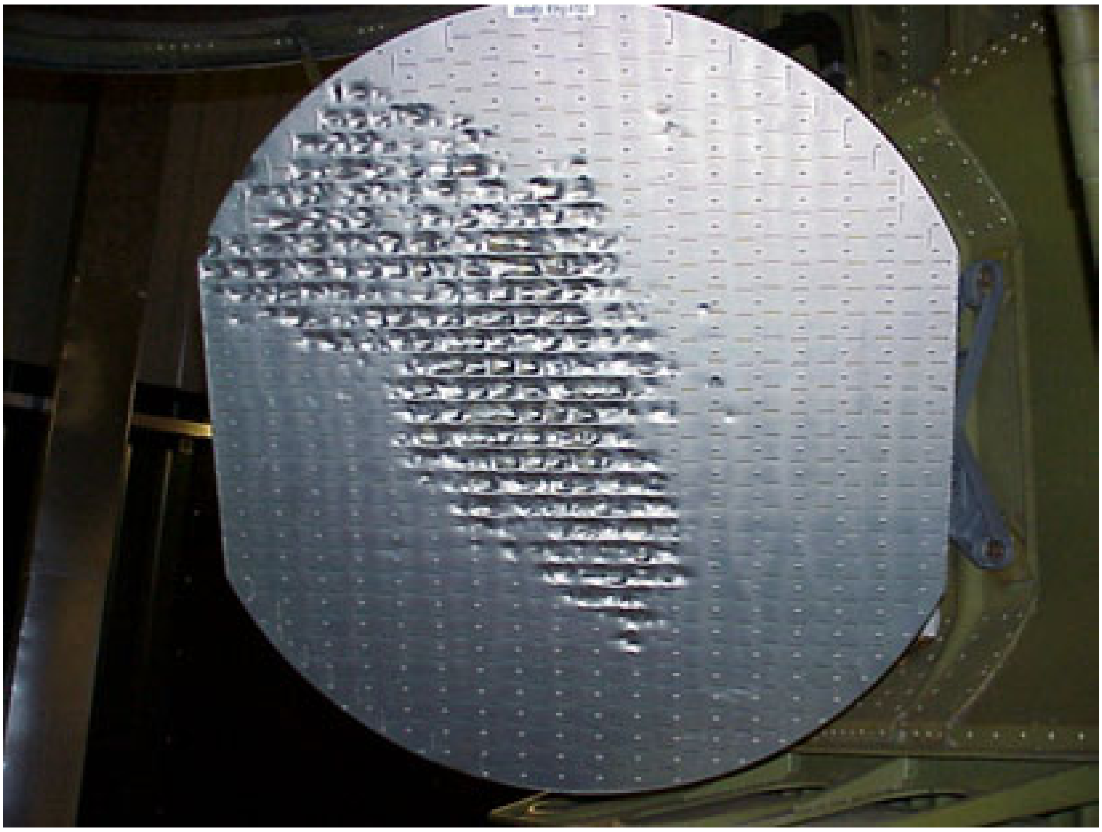


Figure 6. Dented radar antenna surface

The outer surfaces of windshields in front of the captain and co-pilot were cracked. However, cracks in outer surface do not affect structural integrity of the windshield.

Figure 7. Left and right cockpit windshields as seen from the inside

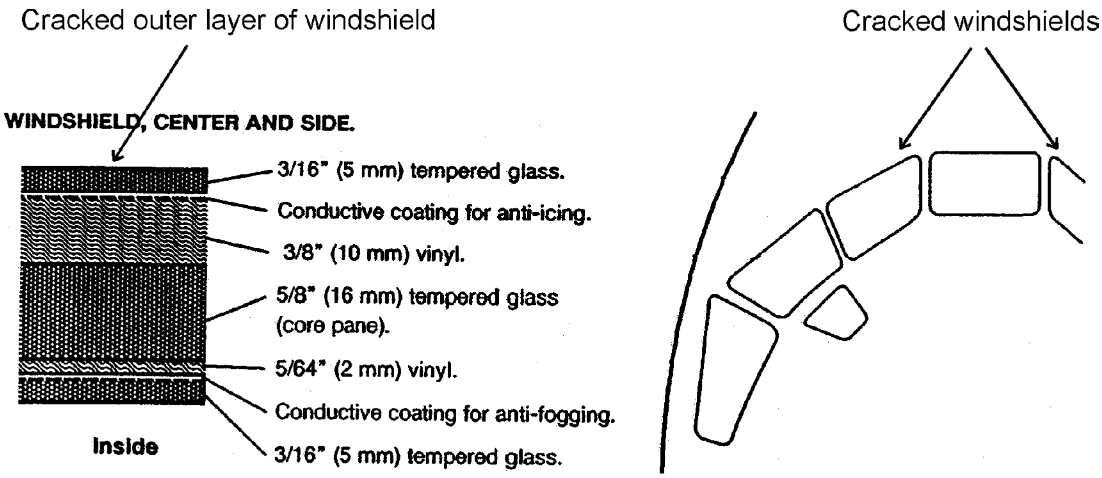


Figure 8. Windshield structure and location of the cracked windshields

The slat panels on wing leading edges were dented by hail, as were the leading edges of horizontal and vertical stabilisers. The worst dents in both wings were found on slat panel no. 1 (the second panel from wing root). Both panels had about 120 dents in total. The largest dents were 70 x 50 mm2 in diameter and 5 mm deep.

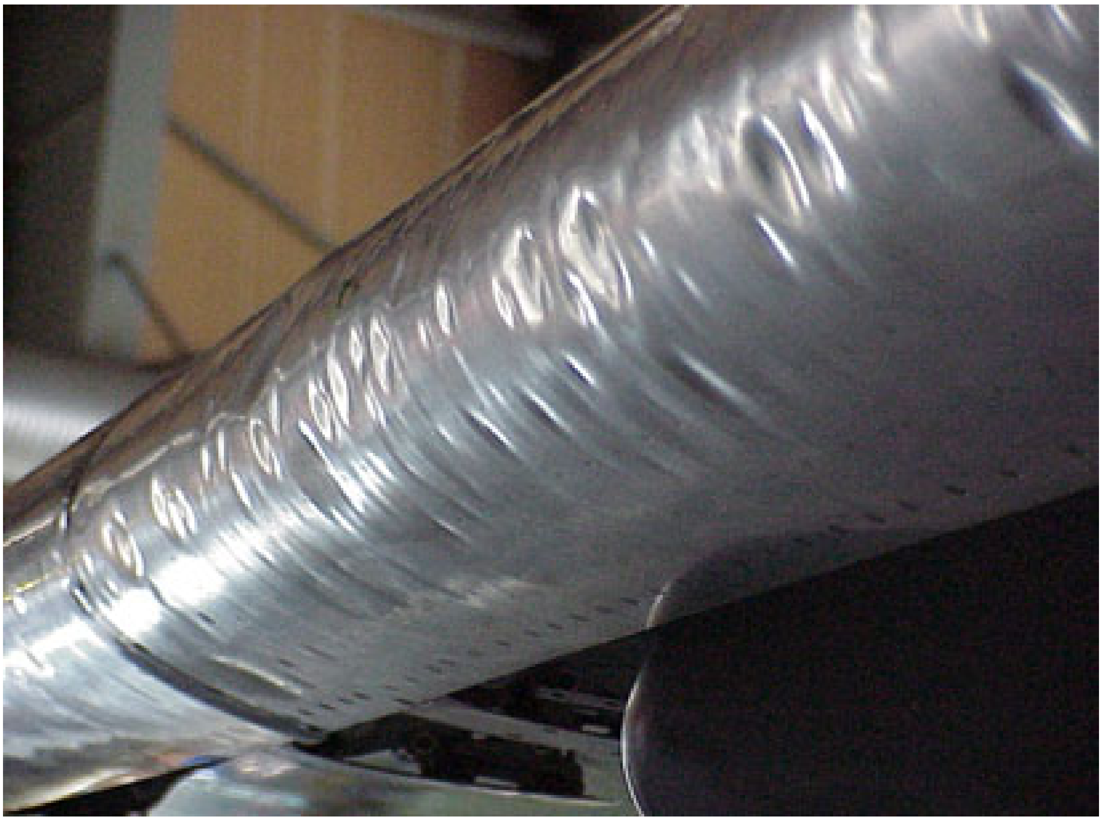


Figure 9. Right wing leading edge slat panel no. 1

There were altogether 14 oval-shaped dents on the leading edges of horizontal stabilisers. The dents were 1,5-3,8 mm deep and their largest diameter was 74 mm. In addition, the leading edges had several smaller dents. The vertical stabiliser had three dents, the largest of which was 4,4 mm deep.

Moreover, the engine inlet cowls and the bullet in the centre of the compressor were dented in a similar way as the wings and stabilisers. The engines sustained no other visible damage.

Figure 10. Left engine inlet cowl

1.13 Medical information

The police made alcometer (breath analyser) tests to the pilots after the plane arrived at the stand. The result was 0.0 per mille for both pilots.

1.14 Fire

There was no fire.

1.15 Rescue operations

1.15.1 Airport rescue category and readiness

The rescue category of Helsinki-Vantaa airport is CAT 8, and the rescue services were in compliance with the requirements for this category. Emergency response was initiated by a command unit and three foaming units. The number of rescue staff was six.

1.15.2 Alerting services

SAS1700 sent a distress message (MAYDAY, MAYDAY, MAYDAY) on the APP frequency at 14.10.58. At the APP controller's request, the TWR controller gave an aircraft accident alarm at 14.12.52 by pressing the red alarm button at the aerodrome control tower. The alarm was received by Helsinki-Vantaa airport rescue services and Helsinki Emergency Control Centre.

1.15.3 Initiation of rescue operations

The fire officer on duty at the airport rescue services reported on the TWR vehicle frequency at 14.13.33. The rescue units were on the move by that time. The fire officer was in the command vehicle, using the call sign Lento 3 (LP3). He was followed by two major foam units Lento 11 (L11) and Lento 12 (L12), and by foam unit Lento 21 (L21). The units moved to their predetermined positions in the airport manoeuvring area. The rescue units were in position about one minute after L3 first reported on the airport vehicle frequency.

At 14.14.14 the officer on duty at Helsinki Emergency Control Centre gave an alarm and issued an emergency preparedness report for Helsinki-Vantaa airport to the rescue units already on the move, in accordance with the dispatch list. The emergency response of Vantaa municipal fire brigade consisted of the fire officer on duty, Vantaa P3 (VP3), water tank units Vantaa 13 (V13), Vantaa 23 (V23) and Vantaa 33 (V33), hydraulic platform vehicle Vantaa 16 (V16), firefighting unit Vantaa 21 (V21) and rescue equipment container unit Vantaa 271 (V271). From Helsinki came water tank unit Helsinki 53 (H53), heavy rescue unit Helsinki 15 (H15) and firefighting unit Helsinki 41 (H41). The officer on duty repeated the alarm.

At 14.16.55, Helsinki Emergency Control Centre read out again the alerted rescue units as requested by VP3. Moreover, it reported that ambulance units 191 and 291 as well as emergency medical helicopter MediHeli had also been alerted.

About two minutes after the aircraft accident alarm, at 14.15, the TWR changed the alert status into an aircraft emergency by pressing the yellow alarm button as requested by the APP.

At 14.15.57 SAS1700 cancelled the distress message, while about 9 NM from runway 22 threshold within the instrument landing system (ILS) localizer.

At 14.17.25 Helsinki Emergency Control Centre informed VP3 of a passenger aeroplane that would land on runway 22 after six minutes. The control centre reported that the number of passengers and fuel quantity were not known.

At 14.17.55, when VP3 called LP3 on the airport vehicle frequency, the air traffic controller reported that there was 6600 kg of fuel and 69 persons on board. VP3 acknowledged the report and asked about the estimated time of landing. The controller estimated that the plane would land after one minute. VP3 then told the units approaching the airport to gather at the search and rescue (SAR) meeting point by the road Ilmailutie.

When SAS1700 landed on runway 22, the emergency medical helicopter MediHeli 01 reported at 14.19.13 to the TWR controller, announcing that it was taxiing on the ground at its own station.

L21 inspected runway 04/22 after SAS1700 had landed. The TWR controller also specifically asked L21 if there were any parts separated from the plane on the runway.

1.15.4 Withdrawal of rescue operations

The TWR controller cancelled the alerts at the airport at 14.21.55. At 14.22.05 LP3 reported to VP3 that the emergency was over. The ATC shift supervisor called Helsinki Emergency Control Centre at about 14.23.30 to cancel the alerts given by the controllers.

1.16 Detailed investigations

The investigation material consisted of incident reports made by the pilot-in-command and air traffic control; interviews of the persons involved; recordings of radar data, radio communications and telephone conversations; recorded weather information as well as various documents and instructions.

SAS made a boroscope inspection and test run to the engines. The inspections or test run did not reveal any internal damage or changes in performance.

1.16.1 Flight recorders

The data recorded by the QAR was available to the investigators, whereas the CVR information on the incident had been recorded over. The CVR recording would have been useful for finding out about cockpit work and incident. Otherwise the material was sufficient for the investigators to form a detailed view of the course of events.

1.16.2 Airborne weather radar

The aircraft weather radar was tested on the ground before the antenna was removed. The radar seemed to be working properly despite the dents in the antenna. SAS removed the antenna for closer examination.

The weather radar receiver/transmitter unit was removed from the aircraft and sent to Finnair Avionics Department for testing and read-out of fault memory. The unit was found to be serviceable. The fault list recorded showed that the malfunction in flight had been caused by antenna stoppage. The stoppage was simulated during the test.

1.17 Organisations and management

1.17.1 SAS

SAS has an Air Operator Certificate number SCA-001 issued by the Danish, Norwegian and Swedish civil aviation authorities. The company operations are based on JAR-OPS 1, as well as a Flight Operations Manual (FOM), Aeroplane Operating Manual (AOM) and Cabin Safety Manual (CSM) in compliance with national requirements of the above-mentioned states.

1.17.2 Weather service

Aeronautical weather service is a part of air navigation services. In Finland, weather service for aviation is organised by the Civil Aviation Administration (CAA). The CAA has a commercial agreement on the purchase of aviation weather forecast and warning services from the Finnish Meteorological Institute. Weather service is provided in Tampere and Rovaniemi flight information regions (FIR). Information about aeronautical weather observations and reports as well as aerodrome forecasts is published in the Aeronautical Information Publication (AIP), sections GEN and AD 2.

Regional weather services of the Finnish Meteorological Institute have been divided into four separate units. These regional service units also act as aeronautical weather service centres, providing weather services for aviators within their own areas of responsibility. Besides regional general aviation forecasts and aerodrome forecasts, the Aeronautical Weather Services, Southern Finland regional unit prepares SW charts, upper wind charts and temperature charts for flights to Scandinavia and Finland as well special weather forecasts for Helsinki-Vantaa airport.

Distribution of weather documents to international flights in Finland is the responsibility of the Briefing Centre at Helsinki-Vantaa airport. The documents are delivered via a satellite distribution system (SADIS). At Helsinki-Vantaa airport, weather advice is provided by the Finnish Meteorological Institute. The RAIS used by SAS updates its information from SADIS at one-minute intervals.

Weather watch is provided in Tampere and Rovaniemi FIRs. The Meteorological Watch Offices are the Aeronautical Weather Services, Southern Finland regional unit at Helsinki-Vantaa airport and the regional service for Northern Finland, located at Rovaniemi airport. SIGMET warnings in accordance with international regulations are also prepared in Finland, for a maximum validity period of four hours.

2 ANALYSIS

2.1 Flight preparation

The pilots' reporting time for the flight as required by the company was at 12.25, which is 45 minutes before the scheduled departure time. However, the pilots had actually reported for duty earlier, since they had printed the flight information from RAIS at 12.17 already.

The pilots had printed the aerodrome forecasts (TAF) for the period 09-18 for EFHK and EFTU, which was the destination alternate airport. EFHK TAF reported temporarily light showers and SCT CB clouds at 3500 ft for the period 10-18 with a probability of 30%. Flight route of SAS1700 passed about 10 NM south of Turku airport. EFTU TAF indicated a visibility of 4000 m, showers and SCT CB clouds at 3000 ft temporarily for the period 09-18. The pilots also had the 1120 METAR for EFHK and 1150 METAR for EFTU. EFTU METAR reported SCT CB clouds at 3000 ft. When interviewed about flight preparation, the pilot-in-command told that they had taken some extra fuel for the flight, since *"there was some CB clouds and rain showers"*. This indicates that the pilots knew about the possibility of CB clouds along the route during flight preparation.

The pilots should also have had the EFHK and EFTU TAFs for the period 12-21 when preparing for the flight. However, the RAIS had not printed these TAFs, although their time of delivery from Helsinki-Vantaa airport Communications Centre had been marked as 11.40. This may be due to the fact that the Aeronautical Weather Services, Southern Finland had not reported the time of preparation in the TAF. Reporting the time of preparation had been a common practice, although it was only a recommendation in ICAO Annex 3 at the time of the incident. The reporting later became mandatory. Nevertheless, the TAFs are delivered to the communications centre at Copenhagen airport even if the time of preparation has not been reported. The pilots could also have obtained the TAFs for the period 12-21 by other means than the RAIS.

When the pilot-in-command was interviewed, she told having watched the weather reports in television and noticed that there was a warm front between Sweden and Finland. The pilots had forgotten to check the Nordic SW chart prepared for the route by SMHI at 12 UTC and take it with them. This chart showed occasional embedded CB clouds with tops at FL 350 and thunder for the final part of the route in south-western Finland. A CB cloud entails a risk of moderate or severe turbulence, icing and hail. Moreover, the pilots did not study the SW chart prepared for the European area by World Area Forecast Centre.

For the third flight of the day from Copenhagen to Paris, a change of aeroplane had been planned for the flight crew. The RAIS printout indicated four uncorrected minimum equipment list (MEL) remarks for the other aeroplane. The pilots wanted to check the significance of these defects to airworthiness from the aeroplane operating manual (AOM) in Stockholm already. The investigators got an impression that the pilots were probably in a hurry when preparing for the flight.

2.2 Flight performance

The pilots told that at cruising level, FL 290, SAS 1700 was flying above the clouds in clear skies and the visibility forwards was unrestricted. Weather radar and sounding data showed that there was a CB cloud probably reaching around FL 400 along the route. According to the pilot-in-command, however, the boundary line between the clouds and clear sky was somewhat obscure, which was due to moisture in upper atmosphere caused by the warm front. It is likely that the obscurity prevented the pilots from seeing the CB cloud ahead. The pilots did not use the airborne weather radar.

During flight preparation, the pilots had become aware of the possibility of CB clouds along the route, since they had taken some extra fuel for this reason. The pilots monitored the development of weather conditions by listening to the automatic terminal information service (ATIS) broadcast for Helsinki-Vantaa terminal control area. The broadcast indicated that there were a FEW towering cumulus clouds (TCU) with bases at 4000 ft at the airport. Despite this information, the pilots did not switch on the weather radar.

After leaving the cruising level, the plane flew into an even layer of clouds approximately at FL 260 according to the pilots. The airborne weather radar was not used during the descent before entering the CB cloud cell. When interviewed, the pilot-in-command told that she did not suspect anything strange and had no triggering factor for using the weather radar. The co-pilot, on the other hand, said that he had thought about using the weather radar, but came to think of it too late. In the investigators' opinion, there would have been sufficient reason for using the weather radar. The company FOM, paragraph 3.2.13.4.1 states:

"Weather avoidance"

"Whenever flying where thunderstorm activity is forecast or expected, the radar shall be used to provide a timely warning of CB activity and guidance for appropriate avoidance action. The weather radar is for avoidance of severe weather, not for penetration. Ask ATC for a detour around the build up area."

The plane descended with the AP and AT engaged and engines at idle. The flight guidance system (FGS) heading select mode was maintaining heading 080º. The vertical navigation (Vnav) function of the flight management system (FMS) was adjusting the descent profile. At that time, the aircraft rate of descent was about 2600 ft / min and the indicated airspeed (IAS) 300 kt. Engine ignition systems were in the position GRD START & CONTIN (ground start & continuous), and engine anti-ice systems had been switched on as instructed.

The pilot-in-command illuminated the FASTEN SEAT BELTS signs in the cabin slightly earlier than usual, since the ATIS broadcast contained information about TCU clouds. At the same time, she gave a landing announcement by the public address system. Immediately after the announcement the plane flew into turbulence and hail on flight level 152 and with a speed of 303 kt IAS. The turbulence was light at first, increased then to moderate or severe, and decreased again for about 20 seconds. Thereafter the turbulence grew again to moderate or severe and decreased once more. Right when the hail shower began, the pilot-in-command asked the co-pilot to switch the weather radar on. The pilot-in-command told that she had to repeat the request for a couple of times, since the noise on the flight deck was very loud due to the hail. When the co-pilot was interviewed, he told having tried to switch the radar on, but it took a few seconds because of the turbulence. However, the weather radar could not produce an image, since the hail had damaged the radome so that the radar antenna was not able to move. The radar image is lost when the antenna stops. The windshields in front of the pilots were also cracked by hail.

The GPWS gave two TERRAIN warnings, the first of which came about 13 seconds after the turbulence began and continued for 14 seconds. The other warning was given two seconds later and continued for four seconds. The warnings were caused by the radio altimeter starting to measure distance from the hailstones, which were abundant in the cloud. At that time, the plane was flying about 12 600 ft above the area minimum altitude (AMA). In the area of the incident, AMA is 2300 ft from mean sea level (MSL).

The PF did not disengage the AT after the plane had flown into moderate turbulence, although it is recommended in the AOM. On the other hand, the PNF did not remind the PF to disengage the AT or to reduce speed towards the recommended rough air speed, which is 285 kt IAS. The loud noise caused by hail made cockpit crew co-operation more difficult. Furthermore, the PF's failure to reduce speed may also have been influenced by the fact that her airspeed indicator was possibly showing a lower airspeed than the PNF's indicator. The difference in airspeed indications will be dealt with later in this report.

The AP disconnected about 28 seconds after the turbulence began. At that time, the FMS Vnav mode changed into the FGS vertical speed mode. The AP was disconnected because the vertical acceleration of the aircraft exceeded the limiting values set for AP disconnect. The AT then switched to the speed select mode, seeking to maintain the airspeed by adjusting engine power. Almost simultaneously, the PF turned the aircraft manually to the right to get out of the hailstorm.

Between the times when the turbulence began and the AP disconnected, the aircraft rate of descent was reduced to about 900 ft / min because of an ascending air current within the cloud. In manual control, the rate of descent was further reduced. After the IAS also decreased, the AT increased engine power with a large and rapid movement of throttle levers to maintain airspeed. This increase of engine power occurred while the turbulence was moderate or severe. However, FOM paragraph 3.3.3.4.4, *Engine handling*, recommends that large and rapid throttle lever movements should be avoided in such conditions.

The AT disengaged about 66 seconds after the turbulence began, at an airspeed of 312 kt. The engine power setting was left at about 1.7 EPR (engine pressure ratio). This power setting was so high that the airspeed was not reduced. About 20 seconds after AT disconnect, engine power was manually retarded to idle. Almost at the same time the aircraft flew out of the turbulence with an IAS of 309 kt. After reaching heading 145º, a left turn was initiated to heading 080º. The AT disconnect was probably caused by conflicting information provided from pitot tubes to central air data computers (CADC1 / 2).

By the time of AT disconnect, the plane had descended to 14474 ft QNH. After a short period of level flight, it started slowly climbing in manual control. The plane reached an altitude of 16128 ft QNH. The turn from heading 080º to 145º actually increased the time the aircraft was flying in the hail shower within an oval-shaped cell. The total time of flying in the turbulence was about 1,5 minutes. The IAS varied from 287 to 327 knots, mainly remaining between 305 and 310 knots. Vertical acceleration varied from –0,23 to +2,34.

The pilots heard a vibrating noise from the engines and, for this reason, sent a distress message about 2,5 minutes after the turbulence had ceased. At that time, SAS1700 flew through flight level 141 with the throttle levers set at idle. However, the engine monitoring instruments had no unusual indications, and no vibration could be felt in the aircraft. In the distress message, the pilots told that the windshields were cracked, but did not mention about the noise of the engines, which was actually stated as the original reason for sending the message. No reason for the vibrating noise could be determined from engine parameters recorded by the QAR, and it did not affect engine performance. The engines were not equipped with a vibration monitoring system. As a result, no reliable explanation could be found for this noise.

After the windshields had been cracked, the PF turned windshield heating switch off. This action is not included in the malfunction check list *"Flight deck window cracks in flight"*. On the other hand, the actions contained in the check list were not taken. When the pilots were interviewed, they told having considered that the preparations for an expeditious landing were higher in priority than going through the check list.

Despite several attempts by the PF, the AP did not remain permanently engaged. However, the investigation revealed nothing to indicate an AP malfunction. Some AP disconnections were caused by exceedance of limiting values, and one possibly by manual control. The reasons for all disconnections could not be determined from the fault memory of AP computer or from QAR recordings. Later the PF succeeded to keep the AP engaged.

The pilots noticed a difference in their airspeed indications when the PF asked flaps 11º. At that time, the PF's airspeed indicator showed 255 kt IAS, while that at the PNF's side showed 280 IAS. The standby indicator had almost the same reading as the PNF's indicator. However, when height and airspeed were reduced, the difference between airspeed indications decreased to about two knots during final approach. The difference in indications probably resulted from disturbed airflow to pitot tubes, caused by the damaged radome.

SAS1700 cancelled the distress message when about 9 NM from runway 22 threshold, since the aircraft seemed to be working quite normally and nothing unusual was perceived in engine operation. The landing was uneventful. Before the aircraft arrived at the stand after landing, the GND controller asked the pilots to confirm if the operations were normal.

When the mechanic entered the flight deck, he stopped the CVR after discussing the matter with the pilot-in-command and receiving a permission to do so. The time elapsed from the beginning of the turbulence to the time when the aircraft was parked at the stand was approximately 15 minutes. Nevertheless, the CVR was stopped so late that the recording from the time of turbulence and hailstorm had already been recorded over. The CVR was capable of recording for 30 minutes.

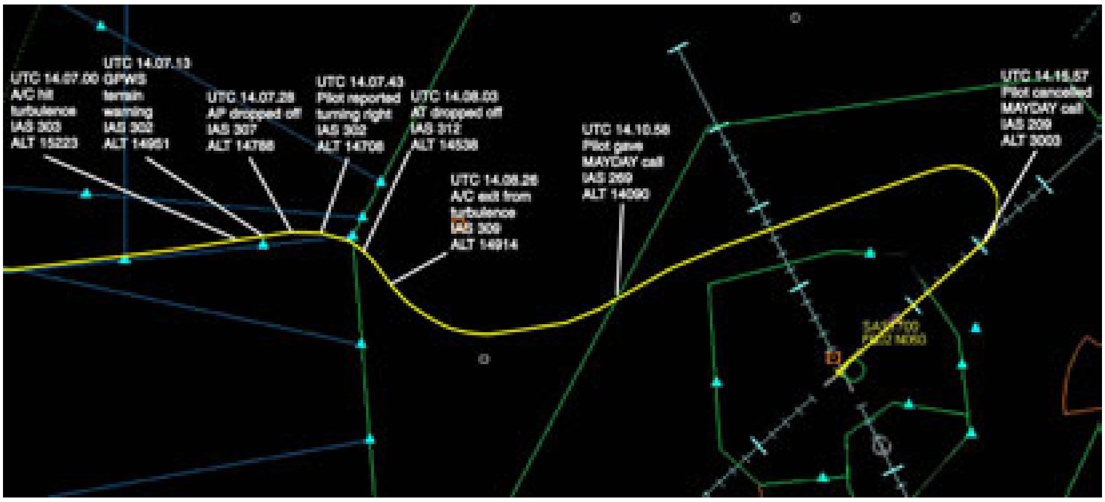


Figure 11. Flight track of SAS1700 on ATC radar screen

2.3 Cabin crew actions

After the plane departed Stockholm, the cabin crew did not make an announcement about the use of safety belts during flight according to JAR-OPS 1.285(c), since this instruction has not been published in SAS cabin safety manual (CSM).

Furthermore, the cabin crew did not check the cabin by walking from one end to the other before landing in Helsinki. This may have been justified, because the cabin crew maybe did not know about the flight conditions to be expected before landing.

2.4 Preparation of SIGMET

The meteorologist on duty at the Aeronautical Weather Services, Southern Finland, started her shift at 11.00. She received a weather briefing from the meteorologist in the previous shift, which included a review of an SW chart for 12 UTC prepared by this meteorologist. The chart showed a warm front, including in the west-east direction an area of BKN/OVC clouds from Mariehamn to Helsinki, and up to the level of Kajaani in the north. This cloud area had been marked to contain showers and thunder, as well as OCNL CB clouds with tops between flight levels 250 - 340. Since the CBs had been forecast within an area of BKN/OVC clouds, the investigators see that the marking should have been OCNL EMBD CB, as in the SW chart prepared by the SMHI. The weather satellite image at 11.23 was available to the meteorologist before SAS1700 flew into the hailstorm. This satellite image shows the BKN/OVC cloud area extending approximately from Stockholm to Lohja, Finland. Due to the orbits of the satellites, the next weather satellite image at 14.23 became available only after the incident.

Weather soundings from Jokioinen, Tallinn and Visby 00 UTC indicate that the air mass was favourable for the formation of high CB clouds and thunder. Similar air mass properties can also be seen in the weather soundings from the same stations 12 UTC. Weather radar images 12 UTC show several CB clouds. According to the lightning location chart, a total of 53 lightning strikes were recorded between 1200 and 1300. The majority of these strikes were on the northern coast of Estonia and the rest in Southern Finland.

The operations manual of the Finnish Meteorological Institute states that a SIGMET will be prepared at discretion to warn aviators of extensive or otherwise significant hazardous weather phenomena, such as extensive thunderstorms, powerful, usually frontal squall lines, heavy hail showers etc. However, ICAO Annex 3 uses an imperative form (shall) about the preparation of a SIGMET, which does not correspond with the wording *"at discretion"* used in the operations manual.

The meteorologist on duty had been preparing a SIGMET around the same time when SAS1700 flew into the hailstorm. According to the meteorologist, the SIGMET was prepared on the basis of weather radar depictions of frequent thunderstorms (FRQ TS) and lightning records. The investigators see that the SIGMET was published too late with regard to the development of weather conditions, since the weather observations available would have been sufficient to forecast the development of powerful CB clouds and the risk of embedded thunderstorms (EMBD TS). As a result, Stockholm and Tampere ACC or Helsinki APP were not able to transmit the SIGMET to SAS1700 during the flight. At the time of the incident, the meteorologist's duties also included the preparation of an SW chart and aerodrome forecasts.

Moreover, the TAR controller could not inform SAS1700 of the CB clouds or give instructions to avoid them, because at the time of the incident, the filtering of clutter caused by clouds in the primary radar (TAR) prevented the CB clouds from being seen on radar display. With a secondary radar (MSSR), it is not technically possible to detect CB clouds at all.

2.5 Rescue operations

SAS1700 had 6600 kg of fuel when departing Stockholm. After landing in Helsinki, the remaining fuel quantity was about 4000 kg. However, the apron management service relayed to the GND controller an information received from the SAS office in Helsinki, according to which the plane would have 6600 kg of fuel on landing. The GND controller also reported this quantity to the rescue units. It is essential for the planning of rescue operations that the rescue units have an exact knowledge, to the extent possible, about fuel quantity, any dangerous goods transported and other factors affecting rescue operations.

3 CONCLUSIONS

3.1 Findings

1. The pilots' licences and ratings were valid.
2. The aircraft had a valid certificate of airworthiness.
3. There were 63 passengers and six crew members on board.
4. The pilot-in-command acted as the pilot flying (PF) and the co-pilot as pilot not flying (PNF).
5. The pilots' reporting time for the flight was at 12.25, 45 minutes before the scheduled time of departure. They reported for duty well before the required time.
6. The pilots planned the flight and printed the flight information themselves in the company briefing office at 12.17.
7. The pilot-in-command took some extra fuel for the flight, since *"there was some CB clouds and rain showers".*
8. For the third flight of the day from Copenhagen to Paris, a change of aircraft had been planned for the cockpit crew. They wanted to check the AOM for the significance of uncorrected MEL remarks to aircraft airworthiness in Stockholm already.
9. The pilots did not study or take with them the Nordic SW chart for 12 UTC, prepared by SMHI. This chart showed occasional embedded CB clouds with tops at FL 350 and thunder for the final part of the route in south-western Finland. Moreover, they did not study the SW chart prepared for the European area by World Area Forecast Centre.
10. According to the pilots, the cruise part of the flight was flown above clouds in clear weather, and flight visibility forwards was unlimited. However, the boundary line between the clouds and clear sky was somewhat obscure.
11. Weather radar and sounding data showed a CB cloud along the route, with the top probably at FL 400 (12 200 m).
12. The Aeronautical Weather Services, Southern Finland was preparing a SIGMET, but it was published too late with regard to the development of weather conditions.
13. The airborne weather radar was off during cruise and descent, before the aircraft flew into the hail shower.
14. The pilots did not pay enough attention to the TCU cloud announced in EFHK ATIS, so that they would have switched the weather radar on.
15. Engine anti-ice and ignition systems were used as instructed.
16. The galleys in the cabin had been secured for landing.
17. Just before the plane flew into the turbulence and hail, the pilot-in-command illuminated the FASTEN SEAT BELTS signs and gave a landing announcement.
18. When the turbulence began, the cabin crew was near the galleys.

19. The PF did not disengage the AT when the aircraft flew into turbulence, as recommended by the AOM.
20. The pilot-in-command asked the co-pilot to switch the weather radar on. She had to repeat this request, since the noise on the flight deck was very loud due to the hail.
21. The co-pilot tried to switch the weather radar on, but no radar image was shown.
22. The GPWS gave two TERRAIN warnings.
23. The AP and AT disconnected.
24. The pilot-in-command made a right-hand turn to avoid the CB cloud.
25. According to the QAR recording, the airspeed varied in the turbulence from 287 to 327 knots, mainly remaining between 305 and 310 kt IAS. Vertical acceleration varied from -0.23 to +2.34.
26. The total time of flying in the turbulence was about 1.5 minutes.
27. The aircraft radome was broken and the windshields in front of the pilots were cracked by hail. The slat panels on wing leading edges were dented, as were the leading edges of horizontal and vertical stabilisers. Moreover, the engine inlet cowls and the bullet in the centre of the compressor were also dented. The largest diameter of the hailstones was more than 5 cm.
28. After the windshields had been cracked, the PF turned windshield heating switch off. This action is not included in the malfunction check list *Flight deck window cracks in flight*. The flight crew did not take the actions mentioned in the checklist.
29. The pilots heard a vibrating noise from the engines and, for this reason, sent a distress message. However, the engine monitoring instruments had no unusual indications, and no vibration could be felt in the aircraft.
30. The cabin crew paid attention to the abnormal, rattling sound of the engines. However, they did not inform the cockpit crew of their observation during the flight.
31. In the distress message, the pilots told that the windshields had been cracked, but did not mention anything about the vibrating noise of the engines, which was stated as the original reason for sending the message.
32. The air traffic control gave an aircraft accident alarm, but later changed the status of the situation into an aircraft emergency.
33. There was a difference of about 25 kt between the PF's and PNF's airspeed indications, but it was reduced to about 2 knots during final approach.
34. The pilots cancelled the distress message while at 9 NM final to runway 22.
35. The aircraft landed uneventfully.
36. At the stand, the pilot-in-command informed the passengers about the incident on the public address system and told that she would be available at the flight deck door for any further information on the event.

37. When the aircraft had been parked, a mechanic switched the CVR off. However, the CVR was stopped so late that any information on the actual incident had already been recorded over.
38. The cabin was not damaged. All overhead stowage compartment doors remained closed and all hand baggage remained in its place. No emergency equipment was used.
39. The weather radar receiver/transmitter unit was found to be serviceable when tested. The fault list recorded showed that the malfunction in flight had been caused by antenna stoppage.

3.2 Probable cause

SAS1700 flight preparation was partly inadequate in respect of en-route weather, and the pilots did not form a correct picture of the weather conditions in flight so that the airborne weather radar would have been used to avoid the CB cloud.

A contributing factor was that the warning message on significant weather (SIGMET) was prepared too late considering the development of weather conditions.

4 RECOMMENDATIONS

SAS should take appropriate actions to ensure that the pilots pay sufficient attention to weather conditions during flight preparation and in flight, and make efficient use of airborne weather radar.

The Finnish Meteorological Institute should consider creating a system to facilitate the monitoring of rapidly developing weather phenomena and preparation of SIGMETs.

Helsinki, August 28, 2002

Heikki Tenhovuori　　Lasse Seppänen

Ossi Korhonen　　Sami Sievä

REFERENCE MATERIAL

The following material is stored at the Accident Investigation Board, Finland:

1. Decision on commencing the investigation
2. Incident report filed by the pilot-in-command
3. SAS Cabin operation report system (CORS) made by purser
4. Police report no. 6840/S/32735/01 (in Finnish only)
5. Internal occurrence report made by Helsinki-Vantaa ATC on 21.7. 2001 (in Finnish only)
6. Copy of aircraft technical log
7. SAS1700 flight information
8. Copies of QAR printout
9. Recording of radio communications at Helsinki-Vantaa ATC on 21.7.2001
10. Records on flight crew and meteorologist interviews
11. Information on flight crew training and licences
12. Radar recording of Helsinki-Vantaa MSSR
13. Radar recordings from Finnish Meteorological Institute
14. Recording of radio communications on Helsinki-Vantaa airport vehicle frequency (in Finnish only)
15. Relevant weather information and report on weather conditions in flight on 21.7.2001
16. Airworthiness and maintenance documents of the aircraft LN-RMT
17. Printouts of DFGC, EFIS and radar fault recordings from the aircraft LN-RMT
18. Photographs

FINNISH METEOROLOGICAL INSTITUTE

SAAPUNUT

66 1 5. 07. 2002 5 L

Translation from Original Finnish version IL drnro 37/410/02

STATEMENT
19.6.2002

ACCIDENT INVESTIGATION BOARD, FINLAND

Reference: Request for statement 17.5.2002

Subject: Investigation report draft: Hail damage west of Helsinki 21.7.2001

The statement of Finnish Meteorological Institute (FMI) deals with the parts that relate to aviation weather service in the investigation report draft B 5/2001 L.

The instructions in force for drawing up a SIGMET message.

ICAO Annex 3[1] item 7.1.1 instructs the drawing up a SIGMET message as follows:

"SIGMET information shall be issued by a meteorological watch office .... the occurrence and/or expected occurrence of specified en-route weather phenomena, ***which may affect the safety of aircraft operations...***

- *Thunderstorm*
  - *Obscured*
  - *Obscured with hail*
  - *....."*

The definition is not very detailed e.g. with respect to the geographical wideness of the weather phenomenon. FMI has interpreted this instruction so that single thunderclouds do not cause danger to aircraft operations, because they can easily be flown around and therefore their existence does not require a SIGMET message to be made. It is only in the case of a widespread thunderstorm observed or forecasted that a SIGMET message is required to be made.

The instruction of FMI for drawing up a SIGMET message is as follows:

"SIGMET-message is made at discretion to warn air traffic about a widespread or otherwise significant dangerous weather phenomenon, in Finnish circumstances mainly:

- *Widespread thunderstorm, mostly of frontal type*
- *Heavy hail*
- *....."*

[1] ICAO: Annex 3, Meteorological Services for International Air Navigation, 14. Ed., July 2001

BASIC WEATHER SERVICES
PO Box 503 (VUORIKATU 24) FIN-00101 HELSINKI TELEPHONE +358 9 19291 TELEFAX +358 9 1929 3303 www.fmi.fi LEONIA BANK PCL 800011-22350

The notebook "Ilmailun sääpalvelu" ("Aviation Weather Service") (Edition 4/01) published by The Department of Area Control being part of the Civil Aviation Association (CAA) is in line with the SIGMET instructions of FMI:
" In SIGMET-messages warnings are issued about the following weather phenomena

- *thunder (not local)*
- *heavy shower of hail*
- *....."*

Weather conditions before the accident

As it is stated in the investigation report the state of atmosphere over Southern Finland was unstable, which made it possible for thunderclouds to develop, like the meteorologist on duty had forecasted. (SW-chart, GAFOR, TAF for EFTU).

In the investigation report one has made a very far-reaching conclusion that the state of the atmosphere might have enabled development of strong and long-lasting (3-12 hours) supercell storms on the day in question. According to the available literature it has not been confirmed that supercell storms ever have been observed in Finland. It is also unclear whether at these latitudes and the geographical location concerned initiation of a supercell storm even theoretically is possible. In the light of the soundings from the night before this kind of forecast cannot be made.

In the radar images in appendix 1 two separate thunderclouds are seen to develop in southern part of the Gulf of Finland at about 13 UTC. At 14 UTC the thunderclouds have moved over the coast of Tammisaari and two more thunderclouds with small extent have appeared over Karjalohja area. Even at this stage the clouds were separate and easy to fly around. The meteorologist has however foreseen intensification of the thunderclouds and predicted their amount to increase in the nearest future and made a SIGMET warning message.

When interpreting the radar images attached at least the following points must be taken into account:

- the image of a certain point of time will be in use by the meteorologist not until the time for gathering, processing and transferring of the data has elapsed. The image type shown in the appendix is in use not until about 10 minutes after the time marked on the image. E.g. the image of 14.00 UTC is ready to be seen at about 14.10 UTC.
- The colour scale of the images is such that the possibility for thunder begins at red colour and at violet colour the possibility for a hail shower is already high.

In appendix 2 there are charts of lightning observations, where the observation period is 15 minutes. Until 13.45 UTC there were only two flashes observed in the area of Karjalohja-Vihti. Until 14.00 in the area mentioned about 10 flashes were observed associated with two isolated thunderclouds. In a widespread and strong thunder cell there are typically several hundreds of flash strokes during a 15-minute period.

The cloud that caused the hail damage was a rapidly developed thunder- and hail shower cloud, whose strong core, where the hail grains were born, was only some kilometres in diameter.

The expression of opinion by FMI

The opinion of FMI is that the meteorologist on duty when making the SIGMET message acted completely along the instructions in force and that the SIGMET message was issued early enough with respect to weather conditions.

Thus in the report draft in point 3.1 (12. "The Centre for Aeronautical Weather Services in Southern Finland was preparing the SIGMET, but it was late with respect to the development of weather conditions") and in point 3.2 ("A contributing factor has been that the drawing up of significant warning message (SIGMET) was late with respect to the development of weather conditions") the comments concerning the delay of the SIGMET message must be deleted because they have no justification.

FMI is ready, in co-operation with the aviation weather authority (CAA), to consider a possible more accurate interpretation of the national instructions for making SIGMET messages.

To improve detection and prediction of rapidly developing thunderclouds and to issue related warnings, a radar-based warning system is under development at FMI. The warnings should, however, also be communicated straight to the flight control or even to the aircraft, so that the warning about rapidly (even within 15 min) developing and strong thunderclouds and hail showers would reach the user early enough. The time lag caused by drawing up and communicating a SIGMET message is about 15 minutes.

Director
Basic Weather Services

Martti Heikinheimo

Appendices

1. Series of radar images in 21 July 2002 from 12:00 to 14:30 UTC at half hourly intervals
2. Location of flash strokes (+ and -) in 21 July (points marked with o are major towns)
   - from 13:30 to 13:45 UTC : 43 strokes (37 flashes)
   - from 13:45 to 14:00 UTC: 93 strokes (55 flashes)
   - from 14:00 to 14:15 UTC: 71 strokes (39 flashes)

Appendix 2

Aircraft Accident Investigation Board, Norway HSL

Heikki Tenhovuori
Accident Investigation Board
Sörnästen rantatie 33 C
00580 Helsinki
Finland

Handled by
Arne Østby Wik 64 84 57 71
Our date
04.06.2002
Our reference
HSLB/2002/172-2 AW
Your date
17.5.2002
Your reference

DRAFT OF FINISH AIB INVESTIGATION REPORT B 5/2001 L, LN-RMT

AAIB/N is grateful for the opportunity to comment on the above mention report.

1. Since it is commented under Analyses, 2.2 Flight performance, page 24 that the IAS varied from 287 to 327 kt, we suggest that the entrance speed into the CB also should be entered on page 1: last section "descending through FL 152".
2. Is reason for the delay of a SIGMET for Tampere FIR clarified? Since the CB cloud cells had developed to such a magnitude, one should think they could have been observed at an earlier stage.
3. Did the Commander have an explanation of why the WX radar was not turned on at the start of the descent? (Referring to FOM 3.2.13.4.1.)

AAIB/N consider the draft report to very thorough. It gives an excellent description of the incident. AAIB/N fully agree to the given recommendations.

Yours sincerely

Finn Heimdal

Arne Østby Wik

Postal address	Visiting address	Telephone - switchboard	Telefax
PO Box 213 N-2001 LILLESTRØM Norway	Sophie Radics vei 17 2003 LILLESTRØM	+ 47 64 84 57 60	+ 47 64 84 57 70

C.I.T.

CIT COMMENTS

CIT has participated in the investigation together with the Finnish AIB. We agree with the **Factual Information** as well as the **Analysis** and **Conclusions** with one minor exception.

- The report page 25 states:

2.3 Cabin crew actions

After the plane departed Stockholm, the cabin crew did not make an announcement about the use of safety belts during flight according to JAR-OPS 1.285(c), since this instruction has not been published in SAS cabin safety manual (CSM).

The SAS procedure for the cabin crew is to give the reminder to the passengers already when demonstrating the safety belts before take off.

After take off the responsibility for announcement of safety belts lies with the Commander.
This is reflected in SAS' Flight Operations Manual, FOM 3.3.3 4.1.
The reminder is normally not given after each take off in SAS, but only when the CDR expects turbulence.

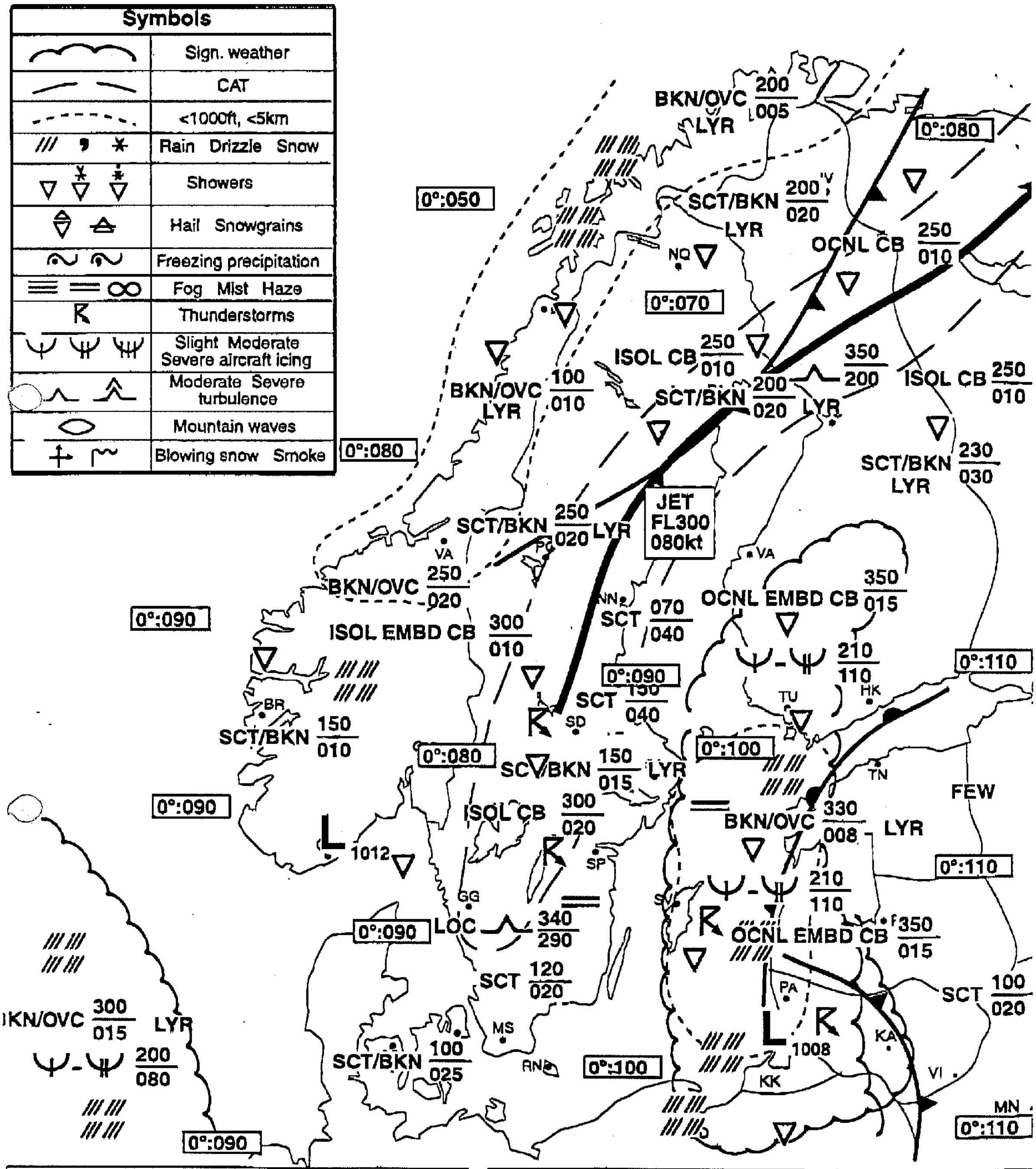
JAR-OPS 1.285 states – *An operator shall ensure that:*
(c) After take-off
Passengers are reminded of the following if applicable:
(i) Smoking regulations; and
(ii) Use of safety belts and/or safety harnesses.

The interpretation of *"if applicable"* can differ. However CIT find the procedure used by SAS acceptable.

For SAS Company Investigation Team

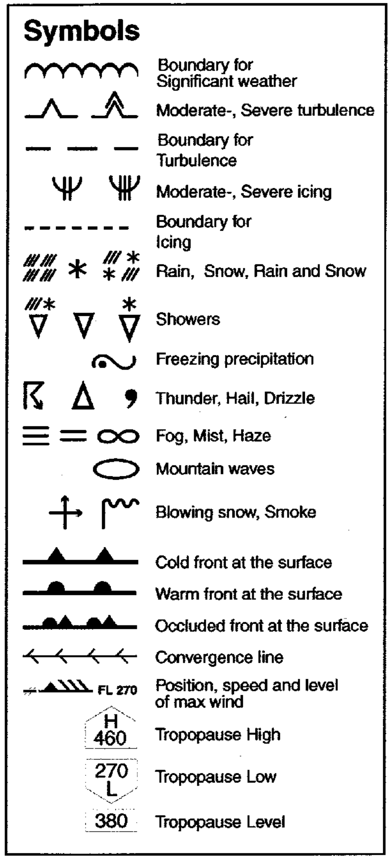
Frank Kristensen
Chief Investigator

SMHI SIGWX CHART VALID 12 UTC 2001- 07- 21
SFC-FL400 ISSUED BY MET OFFICE ESSA



Notes
1. Heights in FL. BLW FL50 in feet/100.
2. K and CB imply icing and turbulence.
3. All speeds in knots.
4. IMC not detailed in MON areas.

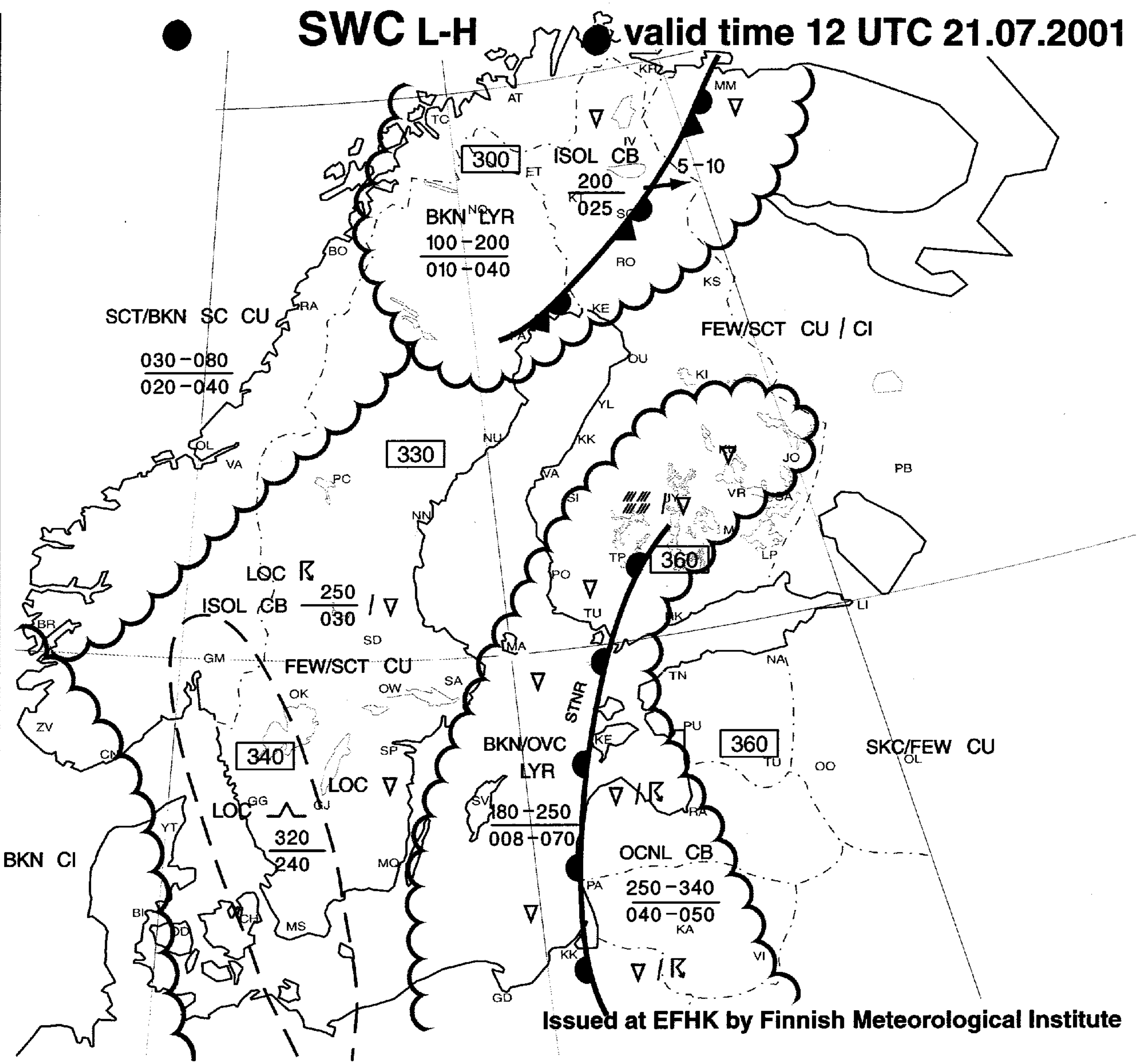
An unstable air mass covers the south part of Scandinavia with CB-activity and showers during the day. Rain and thunderstorms move north in connection with the front along the coast of the Baltic States. /ÅM



Fixed time prognostic chart.

Symbols and "CB" imply moderate or severe turbulence, icing and hail. Light icing ( ) is not considered on this SWC.

Units used: knots; in flight levels at FL50 and above; altitude in hectofeet above the ground or mean sea level below FL50.



Appendix 5

The composite image of the Southern Finland weather radars