Investigation report

C 3/2002 L

Translation of the Finnish original report

Violation of the radar separation minima in the vicinity of Helsinki Terminal Area on 17 January 2002

HA-LMD Fokker F28 Mk0070

FF-3 Fokker F27-400M

According to Annex 13 to 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 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 strandväg 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

Henkilöstö / Personal / Personnel:

Johtaja / Direktör / Director	Tuomo Karppinen
Hallintopäällikkö / Förvaltningsdirektör / Administrative director	Pirjo Valkama-Joutsen
Osastosihteeri / Avdelningssekreterare / Assistant	Sini Järvi
Toimistosihteeri / Byråsekreterare / Assistant	Leena Leskelä
Ilmailuonnettomuudet / Flygolyckor / Aviation accidents	
Johtava tutkija / Ledande utredare / Chief air accident investigator	Esko Lähteenmäki, vt
Erikoistutkija / Utredare / Aircraft accident investigator	Ville Hämäläinen, vt
Raideliikenneonnettomuudet / Spårtrafikolyckor / Rail accidents	
Johtava tutkija / Ledande utredare / Chief rail accident investigator	Esko Värttiö
Erikoistutkija / Utredare / Rail accident investigator	Reijo Mynttinen
Vesiliikenneonnettomuudet / Sjöfartsolyckor / Maritime accidents	
Johtava tutkija / Ledande utredare / Chief maritime accident investigator	Martti Heikkilä
Erikoistutkija / Utredare / Maritime accident investigator	Risto Repo

SUMMARY

An air traffic incident occurred within Helsinki Terminal Control Area (TMA) on Thursday 17 January 2002 at 14.18 UTC, when a Fokker F28 Mk 0070 aeroplane, call sign MAH742, which was operated by the Hungarian Malev Airlines on a scheduled passenger flight from Budapest to Helsinki, and a Fokker F27-400M aeroplane, call sign C21, operated by the Finnish Air Force on a flight from Jyväskylä to Helsinki, passed each other with a distance of about 1.85 nautical miles (NM) violating the radar separation minima required by the authority. The separation minima was violated because MAH742 did not initiate an anticipation turn before waypoint HK707 in accordance with the area navigation (RNAV) procedure, while flying the Porvoo 1C RNAV transition route for Helsinki-Vantaa airport as specified in its arrival clearance. MAH742 had 22 passengers and five crew members on board. C21 had 21 passengers and a crew of three. The Accident Investigation Board, Finland, initiated an official investigation of the incident on 29 January 2002. Vesa Palm was appointed as investigator-in-charge, and Ari Huhtala as a member of the investigation commission. Airline transport pilots Lauri Laine and Pauli Perttula were also invited as experts on flight operations. The Hungarian accident investigation authority did not appoint an accredited representative for the investigation.

MAH742 had been cleared for RNAV transition to runway 15 and to descend to 2000 feet. C21 was being radar vectored on heading 230° and reported maintaining the altitude of 4000 feet. The Traffic Alert and Collision Avoidance System (TCAS) of MAH742 indicated C21 flying on an intersecting track almost at the same altitude. When the air traffic controller noticed that MAH742 did not initiate a turn before waypoint HK707 as required by the Porvoo 1C transition procedure, he told MAH742 to turn left to heading 220° and C21 to turn right to heading 330°. The required radar separation minima of three nautical miles was lost in this situation.

The material available for investigation revealed no malfunctions in the systems of MAH742. On the other hand, the RNAV transition procedures for Helsinki-Vantaa were designed by the Finnish Civil Aviation Administration (FCAA) to be based on Precision Area Navigation (P-RNAV), but the methods used in their implementation and publication were not in accordance with EUROCONTROL rules effective at the time of the incident. MAH742 and several other aircraft were flying the P-RNAV procedures of Helsinki-Vantaa with equipment and approvals valid only for Basic Area Navigation (B-RNAV). The investigation revealed also minor deficiencies both in cockpit crew and air traffic controllers operations.

The reason for the infringement of radar separation minima was that MAH742 did not follow the Helsinki-Vantaa PVO 1C transition route as given in its arrival clearance. The aircraft did not initiate an anticipation turn before waypoint HK707. The exact cause of the incident could not be determined with certainty in the investigation. A technical malfunction or crew error could not be fully excluded. A contributing factor was that the pilot-in-command did not abort the lateral navigation conducted by the Flight Management System (FMS) and change into HEADING mode of the autopilot, or change into manual control and request radar vectoring, although he saw in the cockpit the transition route on the navigation display as rectangular, without anticipation turn routing. Moreover, the level of and device requirements for the RNAV procedure were not clearly indicated on Helsinki-Vantaa transition charts, which may also have affected the sequence of events. If the procedure had been easily identifiable, as required by EUROCONTROL instruc-

tions, the crew of MAH742 could have noticed that they were not appropriately certified to comply with the RNAV transition clearance given. In addition, the air traffic control did not monitor that the planned vertical separation was achieved between MAH742 and the Air Force C21 either. If the vertical separation had been achieved as planned, the incident would probably have been avoided.

As a result of the investigation, the investigators recommends that the current organizations of the FCAA Air Navigation Services Department and Flight Safety Authority, as well as the quality assurance systems of both the FCAA public utility company and Flight Safety Authority, should develop the mechanisms for safeguarding their operations so that e.g. any deficiencies in the design and implementation of navigation procedures could be detected more certainly and corrected in time. Furthermore, the Air Navigation Services Department shall ensure that air traffic services units always have adequate flight plan data at their disposal. The Hungarian CAA shall require Malev Airlines to revise the Flight Operations Manual, Part A (FOM-A) to contain procedures for the handling of FDR and CVR recordings as specified in the JAA requirement JAR-OPS 1. In addition, Malev Airlines shall require their cockpit crews to report as precisely as possible any faults and malfunctions detected especially in aircraft FMS in RNAV operations, as well as to inform flight safety authority and manufacturers of equipment of their observations.

According to EUROCONTROL guidance material (ESARR 2 Guidance to ATM Safety Regulators, EAM 2/GUI 1, Severity Classification Scheme for Safety Occurrences in ATM, Edition 1.0, edition date 12-11-1999) this incident is classified as A3.

TABLE OF CONTENTS

ABBREVIATIONS

AFCAS	Automatic Flight Control and Augmentation System
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
AIS	Aeronautical Information Services
ANNEX	Annex to the convention on international civil aviation
AOC	Air Operator Certificate
AP	Autopilot
APP	Approach Control Office
ARR	Arrival Air Traffic Control
AT	Autothrottle
ATCO	Air Traffic Controller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Air Traffic Services
BKN	Broken (clouds 5-7/8)
B-RNAV	Basic Area Navigation
°C	Degrees Celsius (Centigrade)
CDU	Control and Display Unit
DA/H	Decision Altitude/Height
DCVR	Digital Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DIR	Direct to a Fix
DME	Distance Measuring Equipment
ECAC	European Civil Aviation Conference
EFHK	Europe Finland Helsinki Airport
EFES	Air Navigation Services Center for South Finland
EFIS	Electronic Flight Instrument System
EETT	Europe Estonia Tallinn Area Control Center
FIR	Flight Information Region
FCAA	Finnish Civil Aviation Administration
FD	Flight Director
FDR	Flight Data Recorder
FL	Flight Level
FEW	Few (clouds 1-2/8)
FMC	Flight Management Computer
FMP	Flight Mode Panel
FMS	Flight Management System
FOM	Flight Operations Manual, Malev
FPL	Filed Flight Plan
FSA	Flight Safety Authority
FT	Feet (dimensional unit)
FT/MIN	Feet per minute(s)

GEN	Aviation Regulations, Part General
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
H	Hour
HCAA	Hungarian Civil Aviation Authority
HPA	Hectopascal
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
INS	Inertial Navigation System
IRS	Inertial Reference System
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
KG	Kilogram
KM	Kilometer(s)
KT	Knot(s)
LLC	Limited Liability Company
LPOM	Working Orders or Directives of Chief of Helsinki ATC
M	Meter(s)
MDA/H	Minimum Descent Altitude/Height
MFDU	Multifunction Display Unit
MK	Mark
MHz	Megahertz
MIN	Minute(s)
MSG	Message
MSSR	Monopulse Secondary Surveillance Radar
NAV	Lateral Navigation
ND	Navigation Display
NDB	Navigation Data Base
NM	Nautical Mile
OPS	Flight Operations
OM-A	Operations Manual, Part A, General instructions
OM-B	Operations Manual, Part B, Aircraft Type Related instructions
OM-C	Operations Manual, Part C, Route Manual
PF	Pilot Flying
PFD	Primary Flight Display
PLC	Public Limited Company
PNF	Pilot Not Flying
P-RNAV	Precision Area Navigation
PROF	Vertical Navigation
PVO	Porvoo
QNH	Altimeter sub-scale setting to obtain elevation from the mean sea level
RA	Resolution Advisory
RAIM	GPS Receiver Autonomous Integrity Monitoring
RNAV	Area Navigation
RNP	Required Navigation Performance

RPL	Repetitive Flight Plan
SID	Standard Instrument Departure
STAR	Standard Instrument Arrival
TA	Traffic Advisory
TAR	Terminal Area Surveillance Radar
TCAS	Traffic Alert and Collision Avoidance System
TGL	Temporary Guidance Leaflet (JAA)
TMA	Terminal Control Area
TWR	Aerodrome Control Tower
UTC	Coordinated Universal Time
VHF	Very High Frequency (30-300 MHz)
VOR	VHF Omni-directional Radio Range
WGS84	World Geodetic System (1984)

1 FACTUAL INFORMATION

1.1 History of the flight

The time used in this investigation report is Universal Time Coordinated (UTC) that on the date of the incident was Finnish local time minus 2h.

The crew of Malev MAH742 reported for duty on 17 January 2002 at 05.30. Their first flight was from Budapest to Frankfurt, leaving at 06.40 in the morning. Flight duration was 2 hours. They arrived back in Budapest according to schedule at 11.10.

Malev flight MAH742, operated with a Fokker 70 (Fokker F28 Mk0070) passenger jet airplane, departed at 12.10 from Budapest-Ferihegy for a scheduled flight to Helsinki-Vantaa, where it landed at 14.22. The routing was in accordance with a Repetitive Flight Plan (RPL) from Budapest via Krakow (Poland), Suwalki (Poland), Siauliai (Lithuania), and over Riga (Latvia) and Tallinn (Estonia) to Helsinki. The captain of the aircraft was acting as Pilot Flying (PF). The co-pilot was Pilot Not Flying (PNF) and was responsible for radio communications among other things.

MAH742 entered Tallinn Flight Information Region (FIR) at 13.38. Tallinn Area Control Center (EETT) cleared MAH742 directly to reporting point BALTI and to descend from flight level (FL) 350 to FL 130. The cockpit crew received information from EETT that runway 15 was in use for landings at Helsinki-Vantaa. Approximately 10 nautical miles (NM) before BALTI, EETT transferred the ATC control and radio contact of MAH742 to Helsinki-Vantaa Approach Control Office.

The Approach Radar Controller (APP ATCO) and Arrival Radar Controller (ARR ATCO) positions were manned at Helsinki-Vantaa Approach Control. The shift of the controllers had started according to the duty roster plan at 13.45. ARR ATCO's duties were carried out by the responsible radar controller and a radar trainee who was being trained for a radar rating. The trainee was working under the surveillance of the responsible controller who had been appointed as instructor. Air traffic controllers prepared for their shift according to the usual practice. The APP and ARR controllers worked in accordance with the valid cooperation agreement.

MAH742 contacted the APP ATCO right after passing BALTI at 14.08 and reported descending to FL 130 and having received information "Quebec" from Helsinki-Vantaa Automatic Terminal Information Service (ATIS). The cockpit crew used for navigation Jeppesen Sanderson Inc. Route Manual map "HELSINKI, FINLAND Vantaa, 22JUN01, Page 10-2E", which depicted the short transition route PVO 1C and long route PVO 1D for runway 15.

APP ATCO informed MAH742 of radar contact and cleared it to follow transition route PORVOO 1C direct to waypoint HK710 and to descend to 5000 feet on QNH 1009 hectopascal (hPa). APP ATCO straightened the flight route of MAH742 with approximately

11 NM and told it at 14.10 to maintain high speed. MAH742 acknowledged the clearances. At that time the distance to landing was approximately 51 NM.

A Finnish Air Force Fokker 27 (Fokker F27-400M) turboprop aircraft, call sign C21, departed from Jyväskylä to Helsinki-Vantaa for a transport flight at 13.45. C21 contacted Helsinki APP at 14.10, when passing through FL 109 when descending down to the clearance altitude of FL 100. The APP ATCO reported radar contact, gave C21 an approach clearance to fly heading 220° and cleared it down to FL 80. Besides this the cockpit crew was informed about radar vectoring for left circuit to Helsinki-Vantaa runway 15 and that the distance-to-go was 41 NM. A little later, at 14.11, the APP ATCO told C21 to continue descent down to 5000 feet on QNH 1009 hPa. C21 read back the clearances. Even though C21 had 9 NM less to go than MAH742 at that time, the APP ATCO decided to take MAH742 first for approach to runway 15 due to its higher speed and the developing traffic situation. APP ATCO transferred the control and radio contact of MAH742 to ARR ATCO at 14.14. APP ATCO cleared C21 down to 4000 feet and transferred the radio contact and responsibility to ARR ATCO at 14.15. ARR ATCO was aware of the priority order of the aircraft and acknowledged that. APP ATCO transferred the responsibility to ARR ATCO in good time.

At 14.14 MAH742 reported to ARR ATCO passing through 7500 feet and descending down to the clearance altitude of 5000 feet. ARR ATCO reported radar contact and cleared MAH742 to continue the descent to 3000 feet, and about one minute later, down to 2000 feet. MAH742 flared out the descent below 5000 feet to reduce airspeed for final approach. At 14.15, C21 informed ARR ATCO that it was maintaining 4000 feet and flying heading 230°. ATCO informed C21 of radar contact. The ARR ATCO and the trainee realized the developing conflict between MAH742 and C21.

At 14.16.09 ARR ATCO cleared MAH742 for ILS approach to runway 15 and told the crew to report when established on ILS localizer. At 14.17.07 MAH742 reported ARR ATCO *"Malev 742, we have traffic information 5 miles ahead, below 100 feet"*. They received this information from the aircraft's Traffic Alert and Collision Avoidance System (TCAS). The system did not give any Traffic Advisory (TA) or Resolution Advisory (RA) about the other aircraft. The crew had the traffic in sight and was able to recognize it to be a Fokker 27. At that moment MAH742 was approximately 3 NM southwest of waypoint HK707 when flying the PVO 1C transition. ARR ATCO acknowledged the TCAS information of MAH742, emphasized that it should follow the PVO 1C transition and cleared it for the second time for an ILS-approach by saying: *"Malev 742, follow Porvoo 1C transition, turn left and you are cleared for ILS approach."* MAH742 read back ARR ATCO's clearance by informing: *"Turning left and cleared for ILS approach, 742."*

At 14.17.32, after noticing that MAH742 did not initiate a left turn in accordance with the PVO 1C transition before waypoint HK707, ARR ATCO told MAH742 immediately to initiate a left turn to heading 220°. MAH742 acknowledged this order. According to the cockpit crew, the Flight Management System (FMS) of the aircraft initiated the turn for base leg simultaneously. The crew saw the Fokker 27 (C21) above them when starting the turn until they dived into clouds. At 14.17.47 ARR ATCO told Finnish Air Force C21 to turn right to heading 330°. At that point, C21 was maintaining 4100 feet. The top of

11 NM and told it at 14.10 to maintain high speed. MAH742 acknowledged the clearances. At that time the distance to landing was approximately 51 NM.

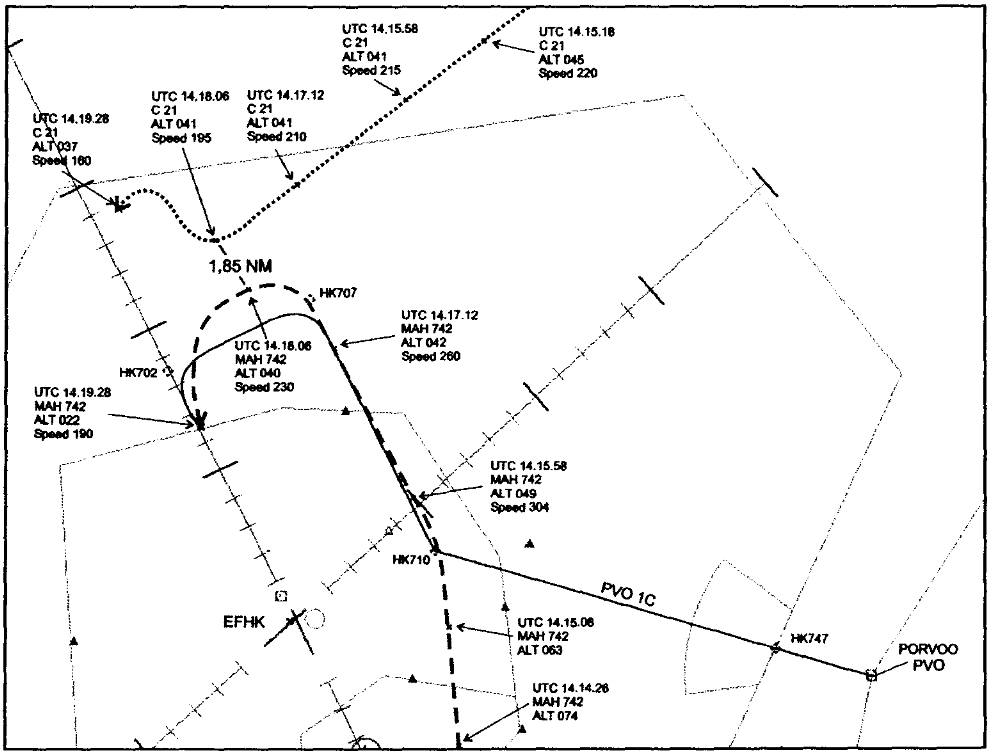
A Finnish Air Force Fokker 27 (Fokker F27-400M) turboprop aircraft, call sign C21, departed from Jyväskylä to Helsinki-Vantaa for a transport flight at 13.45. C21 contacted Helsinki APP at 14.10, when passing through FL 109 when descending down to the clearance altitude of FL 100. The APP ATCO reported radar contact, gave C21 an approach clearance to fly heading 220° and cleared it down to FL 80. Besides this the cockpit crew was informed about radar vectoring for left circuit to Helsinki-Vantaa runway 15 and that the distance-to-go was 41 NM. A little later, at 14.11, the APP ATCO told C21 to continue descent down to 5000 feet on QNH 1009 hPa. C21 read back the clearances. Even though C21 had 9 NM less to go than MAH742 at that time, the APP ATCO decided to take MAH742 first for approach to runway 15 due to its higher speed and the developing traffic situation. APP ATCO transferred the control and radio contact of MAH742 to ARR ATCO at 14.14. APP ATCO cleared C21 down to 4000 feet and transferred the radio contact and responsibility to ARR ATCO at 14.15. ARR ATCO was aware of the priority order of the aircraft and acknowledged that. APP ATCO transferred the responsibility to ARR ATCO in good time.

At 14.14 MAH742 reported to ARR ATCO passing through 7500 feet and descending down to the clearance altitude of 5000 feet. ARR ATCO reported radar contact and cleared MAH742 to continue the descent to 3000 feet, and about one minute later, down to 2000 feet. MAH742 flared out the descent below 5000 feet to reduce airspeed for final approach. At 14.15, C21 informed ARR ATCO that it was maintaining 4000 feet and flying heading 230°. ATCO informed C21 of radar contact. The ARR ATCO and the trainee realized the developing conflict between MAH742 and C21.

At 14.16.09 ARR ATCO cleared MAH742 for ILS approach to runway 15 and told the crew to report when established on ILS localizer. At 14.17.07 MAH742 reported ARR ATCO *"Malev 742, we have traffic information 5 miles ahead, below 100 feet"*. They received this information from the aircraft's Traffic Alert and Collision Avoidance System (TCAS). The system did not give any Traffic Advisory (TA) or Resolution Advisory (RA) about the other aircraft. The crew had the traffic in sight and was able to recognize it to be a Fokker 27. At that moment MAH742 was approximately 3 NM southwest of waypoint HK707 when flying the PVO 1C transition. ARR ATCO acknowledged the TCAS information of MAH742, emphasized that it should follow the PVO 1C transition and cleared it for the second time for an ILS-approach by saying: *"Malev 742, follow Porvoo 1C transition, turn left and you are cleared for ILS approach."* MAH742 read back ARR ATCO's clearance by informing: *"Turning left and cleared for ILS approach, 742."*

At 14.17.32, after noticing that MAH742 did not initiate a left turn in accordance with the PVO 1C transition before waypoint HK707, ARR ATCO told MAH742 immediately to initiate a left turn to heading 220°. MAH742 acknowledged this order. According to the cockpit crew, the Flight Management System (FMS) of the aircraft initiated the turn for base leg simultaneously. The crew saw the Fokker 27 (C21) above them when starting the turn until they dived into clouds. At 14.17.47 ARR ATCO told Finnish Air Force C21 to turn right to heading 330°. At that point, C21 was maintaining 4100 feet. The top of the clouds was at about 3800 feet, and so both aircraft were above clouds in visual flight conditions. The aircraft were at the closest 1,85 nautical miles from each other.

At 14.18.13, ARR ATCO told MAH742 to fly heading 180° and cleared the aircraft for a third time for ILS approach for runway 15. Distance to touchdown was 10 NM at that moment. At 14.18.27, ARR ATCO told C21 to fly heading 180° and cleared it also for ILS approach for runway 15 when the distance to touchdown was 12 NM. ARR ATCO transferred ATC control for MAH742 to Helsinki Tower Control (TWR) at 14.19.53, when the aircraft was 5 NM from touchdown.



Picture 1. Flight paths of MAH742 and C21

MAH742 landed at Helsinki-Vantaa airport at 14.20 and C21 about one minute later at 14.21. On the request of Ground Control (GND), the captains of both aircraft contacted the Approach Control Office. The ARR ATCO in duty at the time of the incident, who was also acting as an instructor, explained them the chain of events leading to the incident and also informed them that he would report the incident to the Finnish Flight Safety Authority and the Air Navigation Services Department of Civil Aviation Administration as required by the authority. The ARR ATCO asked the captain of MAH742 to make a similar report to his own authority. However, the captain said that he would not report the incident as he had not received any RA from the TCAS of the aircraft. The captain reported the incident to the Chief Pilot and his assistant in the Fokker Type Division of Malev. Later on, after having been requested by the investigators, the captain filed a written report about the incident.

C21 was not equipped with a TCAS system. The crew of the aircraft was therefore not informed of the violation of radar separation minima while in-flight and they did not file a report on the incident.

1.2 Personnel information

1.2.1 Air Traffic Control Staff

Approach Radar Controller (APP ATCO)

Gender and age:	Male, 32 years
License:	Air Traffic Controller, valid until 12 July 2003
ATCO's medical certificate:	Valid until 12 July 2003
Ratings:	Approach Control (APP), EFHK Terminal Area Radar (TAR), EFHK Aerodrome Control Tower (TWR), EFHK.

Arrival Radar Controller (ARR ATCO)

Gender and age:	Male, 34 years
License:	Air Traffic Controller, valid until 29 January 2004
ATCO's medical certificate:	Valid until 29 January 2004
Ratings:	Approach Control (APP), EFHK Terminal Area Radar (TAR), EFHK Aerodrome Control Tower (TWR), EFHK.

Radar Trainee

Gender and age:	Male, 27 years
License:	Air Traffic Controller, valid until 20 April 2003
ATCO's medical certificate:	Valid until 20 April 2003
Ratings:	Aerodrome Control Tower (TWR), EFHK.

1.2.2 Cockpit crew

Captain of MAH742

Gender and age:	Male, 40 years
Duty on board:	Pilot Flying (PF)
Licenses:	Airline Transport Pilot License (ATPL) valid until 31 March 2002
Medical certificate:	JAR Class 1, valid until 30 April 2002
Ratings:	Line check valid until 1 May 2002 Operator proficiency check valid until 31 March 2002

	Fokker F28 Mk 0070 captain CAT III/B
Type Ratings:	Tupolev TU-134, May 1987 Fokker F28 Mk0070, May 1997
Training:	Route Instructor Ground and refresher training valid until 6 December 2002 Differences and Familiarisation training Fokker 70 May 1997
Flying experience:	

Flying Experience	During last 24 h	During last 30 days	During last 90 days	Total hours and landings
All aircraft Types	10 h 09 min 5 landings	57 h 29 landings	149 h 81 landings	7939 h 4892 landings

Co-pilot of MAH742

Gender and age:	Male, 51 years
Duty on board:	Pilot Not Flying (PNF)
Licenses:	Airline Transport Pilot License (ATPL) valid until 3 March 2002
Medical certificate:	JAR Class 1,valid until 31 May 2002
Ratings:	Line check valid until 1 April 2002 Operator proficiency check valid until 31 March 2002 Fokker F28 Mk 0070 Co-pilot from February 1998
Type Ratings:	Tupolev TU-154, 1996 Fokker F28 Mk 0070, February 1998
Training:	Ground and refresher training valid until 31 May 2002 Differences and Familiarisation training Fokker 70, February 1997
Flying experience:	

Flying Experience	During last 24 h	During last 30 days	During last 90 days	Total hours and landings
All aircraft Types	5 h 40 min 3 landings	31 h 21 landings	133 h 79 landings	8515 h 4266 landings

Cockpit crew of C21

The whole crew of the aircraft had valid licenses and ratings required for their duties. License information of the crew was not handled in detail, as their actions had no significance in the chain of events.

1.3 Aircraft information

MAH742

Type and model:	Fokker F28 Mk 0070, commercial aircraft with two jet engines
Registration and nationality:	HA-LMD, Hungary
Manufacturer:	Fokker Factory
Owner:	Aachen Aviation Llc.
Operator:	Malev Plc.
Maximum take-off weight:	38100 kg
Serial number:	11563
In operation since:	1995
Air Operator's Certificate:	AOC No H-001, approved on 14 August 2001
RNAV approval:	B-RNAV operation, valid until 30 April 2002
RNP performance:	RNP5

C21

Type and Model:	Fokker F27-400M Troopship, military transport aircraft with two turboprop engines
Registration and nationality:	FF-3, Finland
Manufacturer:	Fokker Factory
Owner:	Finnish Ministry of Defence
Operator:	Finnish Air Force
Maximum take-off weight:	20412 kg
Serial number:	10662
In operation since:	1984
Military aircraft registration:	N:o 457/Db/FF-3/2.2.-84
RNAV approval:	None
RNP performance:	None

1.4 Meteorological information

According to the weather report at 14.20, weather conditions at Helsinki-Vantaa airport (EFHK) were as follows: wind direction 240° and speed 8 knots, variable between 220-290°, visibility 20 km, clouds few (FEW) at 700 FT, scattered (SCT) at 1000 FT, broken (BKN) at 2000 FT, temperature +1,6 °C and dew point +0,6 °C, humidity 93%, QNH 1009,3 hPa and QFE 1003,1 hPa, temporarily (TEMPO) BKN at 900 FT.

Wind conditions are updated at Helsinki-Vantaa airport by the meteorologist on duty always when needed or at least every 3 hours. The current wind conditions for the time of the incident had been updated at 13.40 as follows:

Altitude:	**Direction:**	**Speed:**
FL 100	280	15 KT
FL 50	290	20 KT
2000 FT	280	15 KT
1000 FT	280	15 KT.

According to a report from the Aeronautical Weather Services unit for Southern Finland of the Finnish Meteorological Institute, the wind conditions at the time of the incident were very common at Helsinki-Vantaa airport. Wind speed at FL 100 can be described as weaker than usual. It is notable that between 1000 FT and FL 100 there were only slight changes in wind direction and speed.

According to the cockpit crew of MAH742, they had a strong tail wind, which may have caused a high ground speed for the aircraft.

It is the understanding of the investigators that wind conditions did not have any significance for the chain of events.

1.5 Aids to navigation

VOR/DME stations (VHF Omni-directional Radio Range, VOR and Distance Measuring Equipment, DME) ANTON (ANT), HELSINKI (HEL), VIHTI (VTI), ORIMAA (ORM) and PORVOO (PVO) are located in Helsinki Terminal Control Area (TMA).

According to AIP Finland, when performing DME/DME operations, the navigation aids ANT, HEL, ORM and PVO must be functioning in RNAV transitions for runway 15. The system planning cannot guarantee more than 2 DME inputs at all times within the operating area. The transitions may not be performed with Category A Global Navigation Satellite System (GNSS) equipment.

Helsinki Terminal Area is well covered by Terminal Area Surveillance Radar (TAR) and Monopulse Secondary Surveillance Radar (MSSR) for radar control of the Air Navigation Service Unit. The recordings of the MSSR system were available to the investigators.

No malfunctions or system failures were found either in the navigation aids or radar systems at the time of the incident.

1.6 Communications

The recordings of Helsinki-Vantaa APP and ARR frequencies were checked regarding the incident. The radiotelephone communication between the aircraft and the ATC Unit was mainly in compliance with the instructions given in ICAO ANNEX 10. In the transition clearance, the APP ATCO did not inform MAH742 of the runway in use, as required by the RNAV Transition Phraseology in the chart EFHK AD 2.12-5 of AIP Finland.

Neither the APP ATCO, nor the ARR ATC Trainee and his instructor were using telephone in their mutual communications, as their working positions were next to each other in the APP Control Office. The recordings of radiotelephone communications of the APP Control Office were checked after the incident regarding the conversations between ATC and the captain of the aircraft.

The radiotelephone and telephone communications were conducted normally at the time of the incident.

1.7 Place of the incident

The incident occurred 12 NM north-east of Helsinki-Vantaa airport. MAH742 was flying the transition route PVO 1C for runway 15 according to the given clearance.

According to radar recordings, the distance between MAH742 and C21 was 4.2 NM (7.5 km), when both aircraft were at the same altitude of 4100 FT (1250 m). At closest, the distance between them was 1.85 NM (3.4 km), at which time the vertical separation between the two aircraft was 300 FT (90 m). At that moment C21 was in level flight at the altitude of 4100 feet and MAH742 was descending and passing through the altitude of 3800 feet.

1.8 Flight recorders

HA-LMD had both a Digital Cockpit Voice Recorder (DCVR) and a Digital Flight Data Recorder (DFDR). The recordings of neither equipment were available to the investigators, as the recordings had not been preserved for investigation.

1.9 Medical information

No medical investigations were performed.

1.10 Tests and research

1.10.1 Area Navigation (RNAV)

General

Area Navigation (RNAV) is a navigation procedure that enables the operation of aircraft along any desired flight path. Position information of the aircraft can be based either on the information from ground aids or the own positioning sensors of the aircraft or on the combination of these two systems. RNAV equipment defines automatically the position of the aircraft based on the information from one or more of the previously mentioned sensors. Based on the defined position information, RNAV equipment will fly the aircraft along the defined routing. Additional information related to air navigation such as distance and bearing to a pre-selected waypoint, can be calculated based on the position of the aircraft and the waypoint depending on the RNAV equipment of the aircraft.

Position information is displayed to the crew in many different ways. Mostly the display is showing the position of the aircraft in relation to the routing pre-calculated by the computer. Generally RNAV equipment can define any lateral deviation of the aircraft from the routing and based on that, provide the autopilot with deviation information. The system directs the aircraft back to the original routing. In those aircraft equipped with unsophisticated RNAV equipment, this function is done manually by the cockpit crew.

The goal for the implementation and development of RNAV procedures in international aviation has been to improve flight safety. Additional goals have been to improve the efficiency of aircraft operations and Air Navigation Services and to reduce environmental nuisances.

The European Organization for the Safety of Air Navigation (EUROCONTROL) has prepared a plan for developing the air navigation systems of the Member States of the European Civil Aviation Conference (ECAC) and has presented it in a document called "Navigation Strategy for ECAC" (Edition 2.1, Edition Date 15.03.1999). The document deals with area navigation in the European Airspace as a whole. The document gives guidelines for the Member States of ECAC for planning and implementation of the systems. Both Finland and Hungary are members of the organization established by 38 European States.

The previously mentioned document also includes a plan for the renewal of basic construction of ground aids in air navigation systems. The plan defines a 2 Dimension (2D) RNAV procedure for lateral area navigation, where the position of the aircraft can be determined by heading and distance. The 3 Dimension (3D) RNAV procedure uses altitude as an additional parameter. The 4 Dimension (4D) RNAV procedure also includes time.

The EUROCONTROL document "Standard Document for Area Navigation Equipment, Operational Requirements and Functional Requirements (Edition 2.2/Doc003-93, Dec 1998) defines the operational functional criteria for aircraft equipment, which apply to the Required Navigation Performance (RNP) of the RNAV procedure. The accuracy requirement of the RNAV procedure is determined either as Basic Area Navigation (B-

RNAV) or Precision Area Navigation (P-RNAV) according to the defined RNP performance.

Accuracy requirements for B- and P-RNAV procedures are presented in the table below. According to the document "Navigation Strategy for ECAC", B-RNAV will be later replaced by RNP5 RNAV, and P-RNAV by RNP1 RNAV procedure. An RNP(x) RNAV procedure, which is considerably more precise than the previously mentioned procedures, will be used in the future within Terminal Areas for take-offs, approaches and landings in accordance with decisions made at a later date.

Procedure	Track-keeping accuracy	RNP performance
B-RNAV	±5 nautical miles 95 % of flight time	RNP5
P-RNAV	±1 nautical miles 95 % of flight time	RNP1
RNP(x)-RNAV	< ±1 nautical mile 95 % of flight time	RNP(x) (X<1)

Table 1. RNAV procedures, track-keeping accuracy and RNP performance

Basic Area Navigation, B-RNAV

The B-RNAV-procedure is the foundation for European RNAV operations. Navigation accuracy of the procedure (±5 NM) corresponds to the accuracy of the ATS routes used in conventional air navigation based on VOR/DME, when the VOR ground aids are located less than 100 miles from each other.

Achieving the required level of navigation accuracy is not only dependent on the accuracy and functionality of aircraft equipment, but also on the coverage of ground aids used for navigation in the area and on the accuracy of the coordinates. In Europe the primary aids providing navigation information are VOR/DME, DME/DME and GPS. EUROCONTROL has assessed the coverage and continuity of VOR and DME almost for the whole area of Europe, and it can be considered to fulfill the requirements for navigation accuracy for the route phase. A single Member State of ECAC, like Finland, has to take care of the infrastructure enabling the use of RNAV procedures.

The design criteria for Terminal Area B-RNAV instrument flight procedures are given in the EUROCONTROL instructions "Instrument Flight Procedure Design Criteria for B-RNAV Operations in Terminal Airspace" and will be dealt with later.

Airworthiness approval and operational requirements for aircraft regarding B-RNAV operations in European Airspace are defined in the Joint Aviation Authorities (JAA) Temporary Guidance Leaflet No 2 rev 1 AMJ 20X2 – "JAA Guidance Material on Airworthiness Approval and Operational Criteria for the use of Navigation Systems in European Airspace Designated for Basic RNAV Operations", which is handled later in more detail.

Charting instructions for RNAV charts (B-RNAV and P-RNAV) concerning the Member States of EUROCONTROL are given in the document "Charting Guidelines for RNAV Procedures" and also this document will be handled later in more detail.

Together with EUROCONTROL and the Member States, JAA has developed additional definitions to enable the RNAV-based flight phases within TMA to be conducted more safely and efficiently. The P-RNAV procedure is a more advanced phase of basic area navigation, because B-RNAV is not very useful within TMA.

Precision Area Navigation, P-RNAV

In the P-RNAV procedure the airspace of TMA can be used more efficiently than in B-RNAV, since e.g. the distances between routes are shorter and turn radiuses smaller, and more waypoints can be used for routing. Because of this, the design requirements for aircraft equipment and the design and implementation requirements for P-RNAV procedures are more demanding than for B-RNAV procedures. The P-RNAV procedure cannot be used as a final approach procedure. However, the use of P-RNAV enables almost optimal routing within TMA, which is both safe, efficient and economical with regard to the requirements of air traffic.

Instructions for design criteria of P-RNAV procedures within TMA are given in the EUROCONTROL document "Guidance Material for the Design of Terminal Procedures for DME/DME and GNSS Area Navigation, Edition 2.2, December 1999".

Airworthiness and operational approval for Precision RNAV operations in designated European Airspace is defined in JAA Temporary Guidance Leaflet n:o 10, which will be handled later.

According to the EUROCONTROL RNAV concept the Member States are required to verify the following when granting P-RNAV approvals:

- All terminal P-RNAV procedures must be designed and implemented according to the guidelines given by both ICAO and EUROCONTROL. Functional and performance capabilities of RNAV systems and their safety levels must be taken into consideration. The lack of vertical navigation capability for aircraft has to be taken into account so that the traditional means of vertical navigation can continue to be used also in the future. In addition, P-RNAV procedures must support integrity checking by the flight crew on the charts by different markings (for example range and bearing from waypoint to navigational aids).
- All routes and procedures must be based upon WGS 84 coordinates.
- Design of the procedures and the supporting navigation infrastructure (incl. need for additional aids) has to be assessed and validated to the satisfaction of the responsible authority by demonstrating aircraft compatibility and adequate performance for the entire procedure. This assessment should also include a check flight where appropriate.

- If the procedure allows a choice of navigation infrastructure (DME/DME, VOR/DME or GNSS), obstacle clearance assessment must be based upon the infrastructure giving the poorest precision.
- The essential navigation aids by which the required navigation performance can be achieved for P-RNAV procedures must be identified in the AIP and on relevant charts.
- Those navigation aids that must be excluded from P-RNAV operations must be identified in the AIP and on relevant charts.
- For procedures which allow aircraft to rely only on GNSS, the acceptability of the risk of loss of P-RNAV capability for several aircraft due to satellite failure or RAIM holes must be considered by the responsible authority. Similarly, the risk must be considered where a single DME supports multiple P-RNAV procedures.
- The hazards of the terminal area and the feasibility of contingency procedures following loss of P-RNAV capability must be assessed. For this kind of a situation, a requirement for the carriage of dual P-RNAV system is identified in the AIP for specific terminal P-RNAV procedures, e.g. procedures effective below the applicable minimum obstacle clearance altitude, or where radar performance is inadequate for the purposes of supporting P-RNAV.
- Where reliance is placed on the use of radar to assist contingency procedures, its performance has to be shown to be adequate for that purpose, and the requirement for radar service must be identified in the AIP.
- Radiotelephone phraseology appropriate to P-RNAV operations must be promulgated.
- Navigation aids, including TACAN, that are not compliant with ICAO ANNEX 10 must be excluded from the AIP.

1.10.2 Design criteria for RNAV transitions

Basic Area Navigation, B-RNAV

B-RNAV design criteria have been published in the EUROCONTROL instructions "Instrument Flight Procedure Design Criteria for B-RNAV Operations in Terminal Airspace". It gives detailed design criteria for implementation of B-RNAV operations in designated terminal airspace.

In Section 2. "ANT (Airspace and Navigation Team) Policy Statement" of the instruction there is a statement that for the implementation of B-RNAV routes it is required that:

- The routes must be, as appropriate, above Minimum Sector Altitude (MSA), Minimum Flight Altitude or Minimum Radar Vectoring Altitude (MVA).

- The initial portion of the departure procedure must be a non-RNAV procedure up to a conventional fix beyond which the B-RNAV procedure can be provided in accordance with the criteria given above.
- The B-RNAV portion of an arrival route must terminate at a conventional fix in accordance with the criteria given above, from where the final approach is performed with an alternative, appropriately approved procedure.
- In implementation of the routes, operating procedures of the operators must be taken into consideration.

The instruction defines how the obstacle clearances, the number of waypoints, waypoint types and minimum distances between them and the initial and termination fix criteria of B-RNAV routing must be taken into consideration already in the planning phase. According to the instruction, the navigation performance of the B-RNAV procedure should be clearly identified on the transition charts.

According to the instruction, the minimum distance between waypoints in an RNAV transition is 15 NM when the aircraft is making a turn of 90° on a Fly-by waypoint. If the change of direction is 50°, the minimum distance between waypoints is 11 NM. The definition is based on the assumption that the speed of the aircraft is equal to or less than 250 KT and altitude equal to or less than 10 000 FT. In Helsinki-Vantaa, the distance between HK707 and HK702 is 5 NM. The same instruction again emphasizes that a B-RNAV transition must be clearly identified as such on the charts.

In addition to what has been mentioned in ICAO ANNEX 11, Air Traffic Services, EUROCONTROL gives the basis for the design of airspace for the Member States regarding the minimum distances between parallel B-RNAV routes in the document "Guidance to States on Basic RNAV Route Spacing". EUROCONTROL has, after taking into consideration the theoretical risk assessment and the possible operational risks, concluded that the following minimum route spacing is applicable in the European airspace:

- 18 NM for opposite direction routes
- 16.5 NM for same direction routes
- 15 NM, when the aircraft are on adjacent and opposite routes on different altitudes and when the percentage of climbing and descending traffic is 40% or less.

Route spacing reductions to 10-15 NM are expected to be possible in ECAC Basic RNAV airspace by putting higher reliance on the ATC radar intervention capabilities. The circumstances in which such a reduction of route spacing is applied will need to be assessed on a case-by-case basis depending on the capabilities of the individual ATC centers. Before implementation, States should verify that the route spacing does not unduly affect controller workload.

Precision Area Navigation, P-RNAV

Design criteria for the P-RNAV transition procedure have been published in the EUROCONTROL instruction "Guidance Material for the Design of terminal procedures for DME/DME and GNSS Area Navigation, Edition 2.2, December 1999". According to the document, the procedures have been designed to be performed with aircraft approved for P-RNAV and whose crews have respective training. If the procedure is performed with an aircraft approved for B-RNAV, the aircraft is not necessarily able to stay in the safety area reserved for the procedure and it is not necessarily able to get into a situation where final approach can be performed safely.

The previously mentioned instruction has been made on the basis of requirements defined in the fourth meeting of EUROCONTROL working group Terminal Airspace RNAV Application Force (TARA). The purpose of the instruction is to give general information about the requirements and capability of RNAV procedures and to define DME/DME and GNSS RNAV procedures for Terminal Airspace. The intention is not to resolve any of the institutional, certification or operational issues that affect RNAV. It is hoped that the instructions will help procedure designers to produce flyable RNAV procedures. These instructions are an interim issue pending the development of guidance material for the design of RNP RNAV terminal procedures.

In paragraph 6.6.3 of Chapter 6.6 "Procedure Descriptions" in the P-RNAV design criteria instructions it is stated that:

> *"An RNAV procedure (including a SID*/STAR) must be clearly identified as such on charts and in ATC clearances. If a specific navigation infrastructure (e.g. Basic GNSS only) is associated with a procedure, this must be clearly annotated on the chart".*
>
> * SID, Standard Instrument Departure
>
> * STAR, Standard Instrument Arrival.

According to the instruction, the Member States of EUROCONTROL must define in the charts what navigation infrastructure has been taken into account during the procedure design as follows:

a) RNAV denotes that both DME/DME and Basic GNSS sensors may be used

b) RNAV $_{(DME/DME)}$ denotes that only DME/DME sensors may be used

c) RNAV $_{(GNSS)}$ denotes that only Basic GNSS sensors may be used

d) RNAV $_{(Except\ class\ A\ GNSS)}$ denotes that both DME/DME and Class B and C Basic GNSS sensor may be used

e) RNP $_{(x)}$ will denote that the procedure is for RNP-x capable aircraft only.

1.10.3 Aeronautical publications regarding RNAV operations

Aeronautical Information Circular (AIC)

FCAA has issued the following Aeronautical Information Circulars (AIC) regarding RNAV operations: A6/1991, A16/1996, A33/1997, A37/1997, A15/2001, A16/2001 and A7/2002.

AIC A6/1991 (2.5.1991) dealt with the requirements for equipping the aircraft in the European airspace with RNAV equipment and aimed to standardize the requirements. As an attachment to the circular was an AIC issued by EUROCONTROL, containing information about the history of area navigation and the implementation schedule for RNAV procedures. The requirements for both B-RNAV and P-RNAV procedures were defined in the circular. Additionally, the AIC gave information and instructions for developing Aeronautical Information Services (AIS) for the operation of aircraft equipped with RNAV devices. The requirements for RNAV equipment were meant to be standardized in the European airspace so that the preparation of legislation should have been finalized by 1 January 1993 and that the requirement to equip the aircraft with these devices would be effective from 1 January 1 1998.

AIC A16/1996 (7.11.1996), which replaced AIC A6/1991, contained information on the implementation of B-RNAV procedures in the airspace of European Civil Aviation Conference (ECAC) member states with navigation performance RNP 5. The circular stated that the Member States of ECAC were expected to decide about the obligatory equipping of aircraft with RNAV devices required for RNP 1 in 1998. The RNP 1 procedure was supposed to be implemented in 2005 at the earliest.

AIC A33/1997 (16.10.1997), which replaced A16/1996, contained detailed information about the implementation of B-RNAV in the airspace of ECAC Member States. The circular informed about an AIP amendment concerning the requirement according to which B-RNAV equipment (RNP 5) in compliance with JAA Temporary Guidance Leaflet No 2 rev 1 are obligatory when operating in the airspace of the Member States of ECAC from 29 January 1998. In addition it informed Air Operators about the requirements on how to obtain an approval for B-RNAV operations in the airspace of ECAC Member States.

It was stated in the circular that: *"In Finland the carriage of B-RNAV equipment approved for RNP 5 operations will become mandatory for all civil IFR traffic operating in controlled airspace at or above FL 245 within Tampere and Rovaniemi UIR. According to preliminary plans, the carriage of B-RNAV equipment approved for RNP 5 operations between FL 95 – FL 245 will become mandatory on 1.1.2001 at the latest."*

About future development, the circular mentioned that: *"The benefits to be derived from RNAV applications will be increasingly extended to Terminal Airspace from 1998. The accuracy and functional requirements for such operations are defined in EUROCONTROL Doc 003-93. Such operations will require a performance higher than that available from B-RNAV, but they will not become mandatory before 2005."*

AIC A37/1997 (11.12.1997) replaced A33/1997. This circular informed that, due to difficulties that had emerged in the implementation of B-RNAV, the Member States of ECAC have agreed to postpone the implementation of the procedure until 23 April 1998. There were no other changes to A33/1997. The circular A37/1997 is still effective.

Between **11.12.1997 and 15.11.2001** no AIC was issued regarding the RNAV operations.

AIC A15/2001 (15.11.2001) refers to using precision area navigation equipment in Terminal Control Areas (TMA) of the Member States of ECAC. Regarding Finland, the circular states that the Civil Aviation Administration is planning to implement standard arrival and departure routes for P-RNAV at Helsinki-Vantaa airport on 11 July 2002. The implementation is connected with the opening of the third runway on 28 November 2002, after which conventional departure routes will be terminated. According to the circular, all RNAV TMA procedures that are published for the first time after March 2002 must be based on P-RNAV. If not otherwise informed by the State concerned, those aircraft using RNAV TMA procedures must be equipped with and use P-RNAV equipment from 20 March 2003. The circular states that an operational B-RNAV approval does not include a permission to operate on RNAV procedures designed according to P-RNAV criteria. Operation on published RNAV TMA procedures requires an approval according to JAA TGL 10. Approvals for Finnish aircraft are given by the Flight Safety Authority of Civil Aviation Administration. Foreign aircraft will be approved by the registration State according to JAA TGL 10 or an equivalent document. According to the circular, the captain of the aircraft is responsible for ensuring that the aircraft is operated on approved operational procedures only. The crews of those aircraft that are not appropriately approved for RNAV TMA procedures must inform the Air Traffic Control Unit of this when requesting route clearance or after having received a clearance for the RNAV procedure. Those aircraft which are not approved for P-RNAV procedures will be cleared for routings based on conventional navigation or they will be given radar vectoring for final approach or TMA exit point.

The EUROCONTROL AIC, which is an Attachment to the circular, contains a schedule for the implementation of P-RNAV equipment in TMAs of the Member States of ECAC and information for operators about how to obtain an approval for using TMA procedures in the airspace of States concerned. Additionally it is stated in Paragraph 2.12 of the Attachment that: *"Whilst no ECAC-wide mandate for the carriage of P-RNAV is foreseen, some States may require P-RNAV capability for IFR operations in notified airspace in order to improve airspace utilization, reduce costs and minimize environmental impact."*

AIC A16/2001 (29.11.2001), which replaced A15/2001, was completed with the missing addresses of the Air Navigation Services Department and Flight Safety Authority of Civil Aviation Administration on page 6 (6) in the Annex to the AIC, and included a correction in Paragraph 10.1: *"This AIC complements the AIC A37/1997 on B-RNAV implementation."*

AIC A7/2002 (15.7.2002) was issued after the incident under investigation, and dealt with a decision of the Civil Aviation Administration concerning the requirements for P-RNAV within Finnish Flight Information Regions from 28 November 2002. Rules and Decisions No 3/2002 (9 July 2002) of FCAA, which was attached to the AIC, was published in Finnish and Swedish only. AIC A7/2002 with its attachments was included in AIP Finland and the AIC was terminated with the amendment No 58/28.11.02 of AIP, in which the information is published also in English.

When the Helsinki-Vantaa RNAV transitions were published on 14 June 2001, the current AICs could be understood so that the transitions were based on B-RNAV.

Aeronautical Information Publication Finland (AIP)

According to AIP Finland Chapter GEN 3.3 - 3 Paragraph 7: "Area Navigation RNAV" (14.6.2001), area navigation within Finnish Flight Information Regions is adopted as a means of navigation as outlined below:

"JAA and/or certification authority of the operator's State will provide the requirements necessary for operations to obtain approval to operate in a B-RNAV environment in the European Region. In exceptional cases, where approval requirements are not available from the State of Registry or State of the Operator, ECAC member States may require that the operator(s) obtain certification from a member State of ECAC.

Additional information in respect of certification and operational approval for RNAV operations is contained in Temporary Guidance Leaflet No 2, Issue 1 (also known as AMJ20X-2 and No 10) published by the JAA.

In order to receive B-RNAV approval, onboard navigation equipment will be required to provide en-route lateral navigation accuracy and along track position fixing accuracy of +/- 5 NM or better for 95% of the flight time (RNP 5).

The navigation system use accuracy achievable by an RNAV system is normally dependent upon both the navigation aid infrastructure and the airborne equipment. It is responsibility of the operator to ensure that the required system use accuracy can be achieved when planning to operate in designated B-RNAV airspace.

In cases where required level of accuracy no longer can be maintained, the appropriate Air Traffic Services unit shall be informed without delay."

No P-RNAV requirements were published in the current AIP version at the time of the incident. The AIP could be understood so that RNAV operations in Finland were based on B-RNAV.

1.10.4 Implementation of RNAV transitions at Helsinki-Vantaa

Publication of transition charts

The EUROCONTROL instruction (Charting Guidelines for RNAV Procedures, Edition 1_G1_E1_C, Edition Date: September 2000 March 2000 February 2000) contains general instructions for the Member States for charting the RNAV procedures. In Paragraph 2 "General Requirements" of the instruction it is mentioned that, due to differences in the requirements of chart users, the providers of navigation data must be able to receive a detailed presentation and description of all flight procedures with such accuracy, that they can code the information accurately into the RNAV system of the aircraft. All significant information must be available either from the charts or from their written paragraphs and tables. The chart must be clear and easy to read for pilots in a dim and poorly lit cockpit. It must not contain any other information than what is required to perform the flight itself.

Each RNAV chart should comply with, in addition to the instruction "EUROCONTROL Guidance Material for the Design of Terminal Procedures for DME/DME and GNSS Area Navigation", also the requirement of Chapter 2.6 paragraph f) of the previously mentioned charting guidelines: *"Where part of a SID or STAR is designated as appropriate for B-RNAV equipped aircraft, it should be annotated on the chart itself"*. If the transition is designated for P-RNAV approved aircraft, there should be a label RNP1 on the chart.

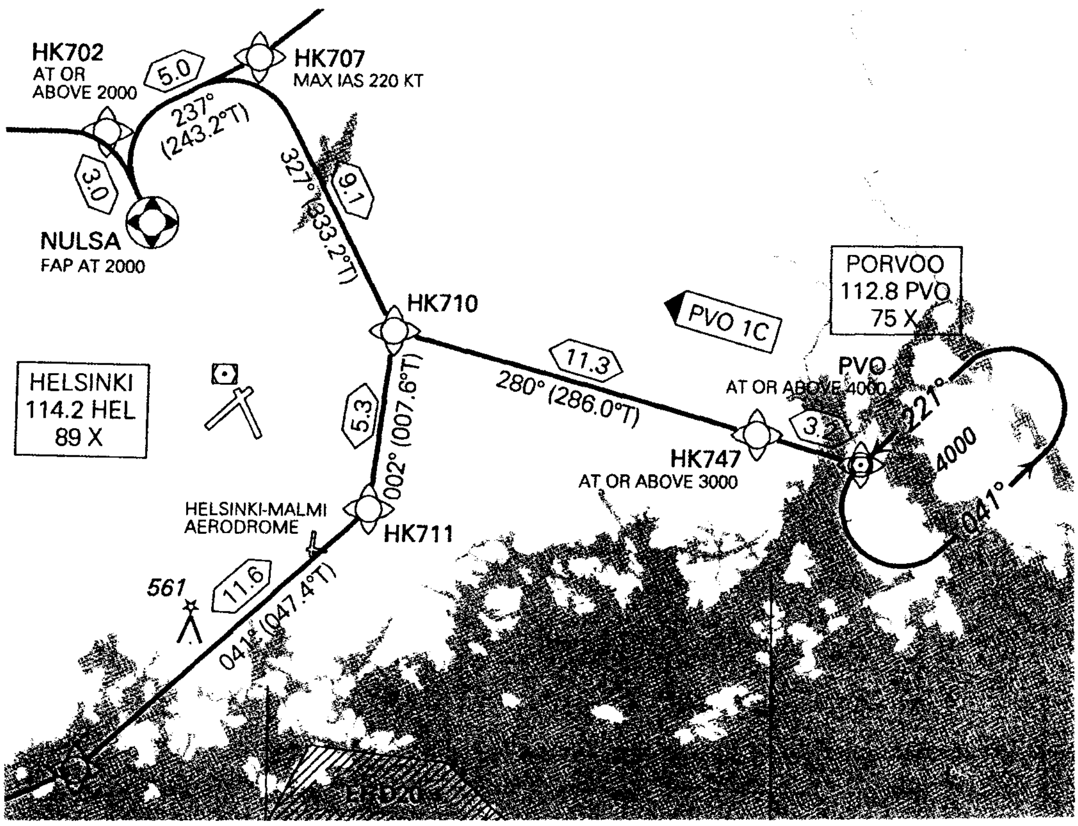
The charting guidelines for RNAV charts also specify the marking of Fly-over and Fly-by waypoints on the chart. The cockpit crews can identify the different waypoints from the charts by checking if the drawn route passes over the waypoint or goes by it.

Paragraph 5. "STARS" in the charting instruction recommends that the RNAV standard arrival route charts should be named as "RNAV STARS to Final Approach". It is mentioned in Paragraph 5.2 that "RNAV STAR charts or RNAV STARS to Final Approach" should be clearly identified as described in paragraph 2.6 of the instruction. Subparagraph m) of Chapter 5.3 contains a requirement for marking the RNP value for each portion of the transition route.

The transition routes for Helsinki were published in VOL 2, AD 2, Chapter EFHK AD 2.2.3 "Flight Procedures" of the AIP and were implemented on 14 June 2001. The transition charts are named as "RNAV Transitions" individualized depending on the runway in use. In this Chapter it is stated that arriving IFR traffic, during initial contact, must inform Helsinki APP about the type of the aircraft and the RNAV transition or radar heading given by the ATC. The transition is a published area navigation route defined with waypoints ending at the point where final approach can be initiated. It is stated in the notes of the previously mentioned Chapter that an aircraft flying the transition cannot perform the final approach without a separate clearance, and that the vertical clearances are given by the ATC. The radiotelephone phraseology which shall be used in RNAV transition has been published in the AIP.

In the Chapter of AIP containing information about the arrival clearance, it is stated that *"Arriving traffic will be cleared normally to follow RNAV transition route serving the runway in use. An aircraft unable to utilize the given RNAV transition route shall inform the ATC immediately, whichafter ATC clears the aircraft to leave Initial Approach Fix (IAF) on radar heading. ATC vectors the aircraft to the final approach if traffic situation requires or the aircraft is unable to utilize given RNAV transition route."* In addition to this, the procedures for the loss of radio contact when in RNAV transition have been published in the AIP.

Short RNAV transition routes for arriving aircraft for runway 15 have been published in the Chart EFHK AD 2.12-5 (RNAV TRANSITION 15) of VOL 2, AD 2 of the AIP. According to AIP, the PVO 1C transition route starts from Porvoo (PVO) VOR/DME and ends at the NULSA waypoint. The transition has six waypoints altogether. There is no accuracy requirement for the RNAV procedure on the chart.



Picture 2. Short RNAV transitions for runway 15 at Helsinki-Vantaa according to AIP

Initially both long and short transition routes had been implemented for the same runway at Helsinki-Vantaa airport. After the Malev incident Helsinki-Vantaa ATC made a quick analysis of the incident on 18 January 2002, in which it was suggested to withdraw from service the long transition routes due to flight safety reasons. Long transition routes were withdrawn from service on 11 July 2002.

Safety review of RNAV system

The Safety Assurance Document (SAD), made by a sub-project group (PROC) of the Third Runway (HelKO) of Helsinki on 29 March 2001 in connection with the implementation of the RNAV system at Helsinki-Vantaa, states to present the grounds and proof to support the argument that the RNAV STAR EFHK project is implemented as safely as possible by reasonable means.

The basic strategy of the project was to develop the airspace and procedures so that the service and safety levels remain high. The goal of the project group was to change the internal procedures of Helsinki Terminal Area to correspond with the needs of the future. The change is estimated to reduce the need for additional changes due to the introduction of the third runway in Helsinki.

Those working procedures which were to be changed were assessed in the document by using risk analysis. Additionally the present working procedures, in conjunction with procedures which were to be changed, were assessed. The hazard analysis is presented in the hazard log of the document. Other changes were assessed by means of traditional simulation and check flights. RNAV STAR solutions were simulated in the Air Navigation Services Center for South Finland (EFES). In addition, several fast-motion (FAST-TIME) simulations were performed during the procedure observation by the computer program of FCAA designed for modeling the traffic of the aerodrome and airspace as a whole (Total Airport and Airspace Modeller, TAAM). The flyability of the RNAV STAR procedures was verified with A-320, MD-11 and MD-80 simulators. A field trial was performed on 14 December 2000 by eight Airbus aircraft on scheduled passenger flights by the company that participated in the trial. The investigators did not examine the approval documents of the test flight, and the code data of the Navigation Data Base (NDB) and its approval or the transition charts used in the trial were not studied either. However, according to the SAD all simulations had been appropriately prepared and verified afterwards by oral and written feedback.

The hazard log which was as Attachment D of the document contained the following entities:

- hazards found in the system
- sequence of events
- safety requirements
- means of completing the safety requirements and actions for reducing the hazard
- responsibilities for reporting or obligation of completing safety actions (and future follow-up).

The hazard log handles widely both the effects of malfunctions in the ground aids supporting the RNAV procedures and the ability of the aircraft and crew to follow the given RNAV transition. The hazard log defines the use of radar procedures as a basic procedure to resolve any malfunction situations.

The SAD did not specify if the accuracy requirements for Helsinki-Vantaa RNAV transitions were based on B-RNAV or P-RNAV procedures. The AIS publishing procedure was not handled in the SAD either. Regarding the test of dead zones of DME ground equipment, the document contained only the test results for Vihti DME.

Study on the P-RNAV capability of aircraft operating to EFHK

The FCAA subcontracted a study to clarify the P-RNAV utilization ability of air carriers operating in Helsinki-Vantaa TMA under the title "Operational Approval against JAA Temporary Guidance Leaflet 10, (published 01.Nov.2000) for Terminal P-RNAV until 14.6.2001, for aircraft operating to EFHK". The study included 31 enquiries to different carriers. The subcontractor of the study had received replies from 15 carriers by 25 February 2001. 16 carriers did not reply to the enquiry at all.

The study concludes that the implementation of the RNAV procedure on June 14^{th} 2001, does not allow enough time for operators to fully comply with P-RNAV requirements according to JAA TGL 10. According to the study, based on the own estimation of the carriers, almost 10 main operators would be able to receive P-RNAV approval during the year 2001 and at least 6 other operators during the year 2002. Some aircraft types were found to be inadequate for P-RNAV operation, of which DC-9 was operationally the most significant. According to the study, P-RNAV based standard RNAV arrival routes could not be used at 100% at first, due to which there should be conventional arrival procedures as an alternative procedure for non-P-RNAV aircraft.

According to the study completed on 28 May 2001, it should be taken into consideration when implementing and publishing RNAV STARS that the operators must improve the present RNP accuracy of the RNAV equipment of their aircraft. It was stated in the study that in any case, 97.5% of the operators could benefit from B-RNAV based procedures and 70.0% from P-RNAV based procedures.

Approval procedure of RNAV transitions

The Aeronautical Information Services unit prepared a proposal dated 29 March 2001 on "The Approval for publishing RNAV transitions of Helsinki-Vantaa" (Dnro 8/590/2001) to the Air Navigation Services Department (ANS) of FCAA. The proposal emphasized that *"This approval proposal only concerns the publishing of the previously mentioned material according to the AIRAC system in AIP Finland."*

As an attachment to the proposal, there was a memorandum prepared on 28 March 2001 by the Aeronautical Information Services unit concerning the approval mentioned above. According to the memorandum, the Aeronautical Information Services unit had informed the project group, responsible for planning the RNAV system, in writing about the ambiguities and problems found in the procedures. The project group replied in writing. The Aeronautical Information Services unit handled the replies and had included a limitation in the charts for the usage of GNSS Class A, added an instruction for the case of loss of radio contact and added a notification about the number of DME ground equipment in use.

Regarding the ambiguities and problems, which had emerged in the design of the RNAV-system, the Aeronautical Information Services unit had emphasized to the project group the requirements of the AIRAC system. The correction of the published material afterwards by a NOTAM does not enable keeping up the navigation data base of the aircraft.

The Air Navigation Services Department approved, according to the memorandum, the RNAV transitions of Helsinki-Vantaa to be published by revision No 43 in AIP Finland, effective from 14 June 2001.

According to the Air Navigation Services Department, the Flight Safety Authority has not given any specific orders for the design and implementation of Helsinki-Vantaa transitions. According to the department, it was considered as a normal duty of air traffic management, based on which the Air Navigation Services Department did not specifically approve them. The design was based on international practice. However, the Air Navigation Services Department has informed the Flight Safety Authority of the new procedures. According to the department, neither the Safety and Quality Committee of FCAA nor the Safety and Quality Commission of the Air Navigation Services Department handled the issues concerning the design and implementation of RNAV transitions in their meetings.

1.10.5 Flight Plan information and working instructions of Approach Control Office

MAH742 was operating according to a valid (11 August 2001 – 17 January 2002) Repetitive Flight Plan (RPL). The flights were planned to be operated with Boeing 737-300 aircraft. Differing from the RPL, the aircraft type was changed on 17 January 2002 with a Change Message (CHG) into Fokker 70. Any other changes were not made to the RPL. The RNAV navigation performance of the aircraft was not indicated in the RPL.

At the time of the incident, ATCO's of Helsinki APP were using an unofficial list made by the ATC Office concerning operators that could be given an RNAV transition in connection with the arrival clearance. The list was prepared by writing down those operators who acknowledged the given RNAV transition clearance. The information on the list had not been verified from the authorities of different countries.

APP was also following up those individual flights on which the aircraft, according to the radar, was not following exactly the transition route drawn on the screen. The meaning of the follow-up was to record problems and deficiencies for the design of the routes and development of training. The investigators were provided with a follow-up list starting from 18 August 2001 and finishing on 17 May 2002. During this period of time 39 flights had been recorded on the list. Two of them were Malev flights, neither of which was flown by a Fokker aircraft.

Helsinki-Vantaa ATC Office issued on 19 September 2002 a document called "Working Instructions or Orders by the Chief of Helsinki Air Traffic Control (LPOM) No 20/02, which states that:

"To operate on RNAV transitions, a P-RNAV approval is required from November 28th 2002. As some operators are still missing the required navigation performance to operate on transitions, utilization of the transitions will be limited to those operators holding the approval for TMA RNAV operations given by the authority of their home country."

The instruction now officially defined those operators, which could be given an RNAV transition clearance. However, the instruction still included such operators and aircraft types that, based on the Air Operators Certificate (AOC) of the company, had neither an Operational P-RNAV approval nor an airworthiness approval for the individual type. The new instruction has been effective from 29 September 2002. Also the Air Navigation Services Department had the understanding that an RNAV transition clearance could only be given to those aircraft known as qualified for P-RNAV.

The Air Traffic Controllers of Helsinki-Vantaa Airport were trained for RNAV transitions by on-duty training during spring 2001 by the Sub-Project Group (HelKo-PROC) responsible for the design of the third runway at Helsinki-Vantaa. The training material is extensive and clear. The material particularly emphasizes that, in case of any problems related to RNAV transitions, the aircraft must always be vectored by radar. Among other things, the material defines Helsinki-Vantaa transition routes as P-RNAV routes.

1.10.6 Operational and functional requirements for B- and P-RNAV operations

Regarding B-RNAV, JAA has published instructions for the Member States in the TGL "Leaflet no 2 rev 1 AMJ 20 X2 – JAA Guidance Material on Airworthiness Approval and Operational Criteria for the use of Navigation Systems in European Airspace Designated for Basic RNAV Operations, 21.5.1997".

It is not necessary for aircraft equipment used for B-RNAV-operations to identify Fly-by waypoints. According to EUROCONTROL design criteria, a B-RNAV-transition could be restricted to be used only by those B-RNAV approved aircraft that can conduct anticipated turns, i.e. identify a Fly-by waypoint. In these cases the transition charts should depict a note on the issue.

Additionally at least four waypoints should be saved into the FMS system of the aircraft. There are six waypoints in the PVO 1C transition (PVO, HK747, HK710, HK707, HK702 and NULSA).

Instructions for P-RNAV operations are given in JAA Document "Administrative & Guidance Material, Section One: General Part 3: Temporary Guidance Leaflet No 10: Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace, 1.11.2000".

For the case under investigation, the following table shows the most significant differences between the Airworthiness Approval and Operations Approval requirements for B-RNAV and P-RNAV.

In the Table **O** denotes optional, **R** required and **P** prohibited.

Function	B-RNAV	P-RNAV
Flight crew waypoint entry (en-route)	R	R
Navigation Data Base for TMA operations	O	R
Terminal leg data type entry from Database	O	R
Manual terminal leg entry by flight crew	P	P
Manual terminal leg modification by flight crew	O	P
Flight plan entry	R	R
Minimum number of waypoints	4	10
Display of whole flight plan route used in TMA	R	R
Ground aid selection	O	R
Manual position update in-flight	O	P
Indication of Navigation Mode for multiple input sources (GPS, VOR, DME/DME, IRS)	R	R
Navigation Position Display	R	R
95% containment	5 NM	1 NM
System integrity (per flight hour)	-	-
Continuity of Function (failures per flight hour)	10^{-4}	10^{-5}
Cross Track Deviation Display or Output	R	R
Automatic Flight Control System (AFCS)	O	R
Waypoint sequencing	R	R
TMA Fly-over turn execution	R	R
TMA Fly-by turn anticipation	O	R
TMA defined radius turn	O	O
"Direct to" function	R	R
Sensor Monitoring	R	R
Alert output for Equipment failure	R	R
Alert output for Mode reversion	O	O

Table 2. Most significant differences between B- and P-RNAV transitions

1.10.7 FMS system of HA-LMD

The Flight Management System of Malev Fokker 70 aircraft has been manufactured by Honeywell and the type is PS4052530-980. The FMS has two separate Flight Management Computers (FMC). The Navigation Data Base update current at the time of the incident was "27 DEC 2001 – 24 JAN 2002". Honeywell had entered into the data base e.g. the transition charts for Helsinki-Vantaa, one of which was PVO 1C. NDB data for Honeywell is provided by Jeppesen, which obtains the information from national AIP publications.

The FMS of Fokker 70 meets the requirements for B-RNAV operations according to JAA TGL 2, but does not meet the requirements for P-RNAV operations according to JAA TGL 10. The Hungarian Civil Aviation Authority had granted a B-RNAV Airworthiness Certificate (RNP 5) for HA-LMD, which was valid until 30 April 2002.

The NDBs of FMCs of Malev aircraft are checked in every Daily Check and they are always updated before the expiry date of the previous data file. The checks and updates are conducted for Malev by the JAR-145 subcontractor Aero Plex of Central Europe Ltd (ACE) at Budapest-Ferihegy airport. After this occurrence Malev had the NDB data checked on the request of the investigators. It was confirmed that waypoint HK707 had been designated as a Fly-by waypoint in the NDB used in HA-LMD on the date of the incident, 17 January 2002.

Fokker 70 aircraft use the sensors of IRS, VOR and DME systems for positioning. Primarily the system uses combinations of IRS and DME/DME systems and secondarily the combination of IRS and VOR/DME. If the previously mentioned combinations are not possible, only IRS is used as a sensor. The aircraft has two FMS, three IRS, two DME and two VOR systems. Information for both FMS units is retrieved from all above mentioned sensors.

FMS provides the flight indicators with navigation information, if it has been selected as the source for navigation information. FMS can also be coupled to control the aircraft with Autopilot (AP). Then the lateral flight plan (NAV) and/or vertical flight plan (PROF) mode must be selected from the Flight Mode Panel (FMP). Normally FMC1 and FMC2 are synchronized by cross-talk busses. When both or either one of the navigation modes has been selected, the flight can be monitored either from the Primary Flight Display (PFD) or Navigation Display (ND).

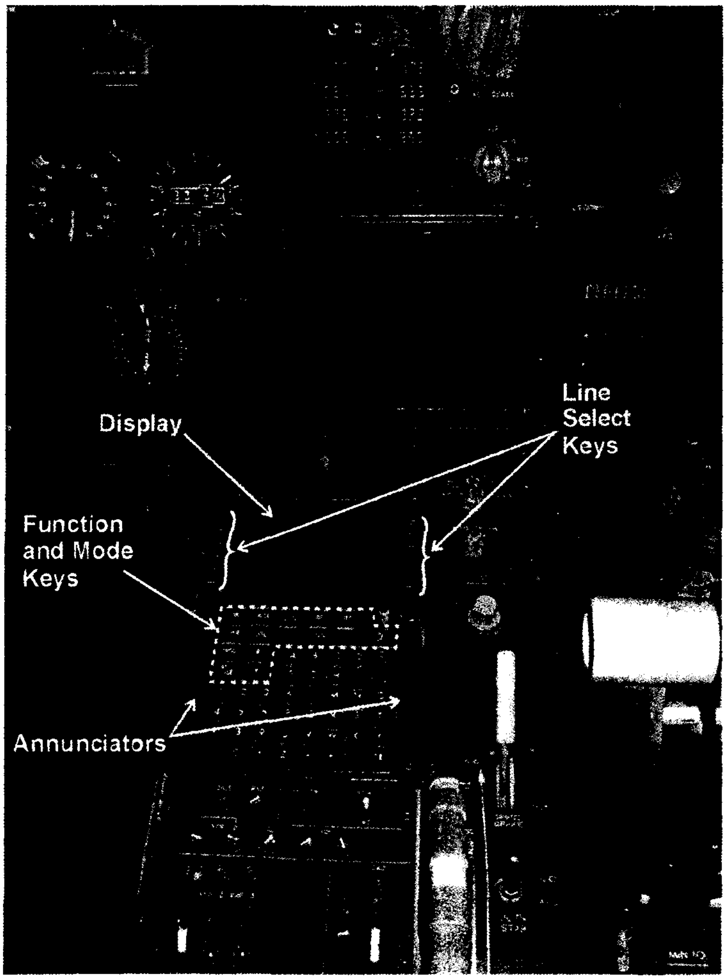
The FMS is disconnected during the flight when:

- NAV mode is manually switched off
- FMS power goes off
- FMS has a failure
- AP and both Flight Directors (FD) are switched off
- FMS Flight Plan has discontinuity information
- LOC mode goes on (is engaged) in the precision approach phase.

The following displays will be visible to the cockpit crew in case the FMS is disconnected or fails due to any reason mentioned above:

- When NAV mode is switched off or goes off, the aircraft will not follow the selected RNAV route. This is displayed on ND.

- When the power of FMS goes off or FMC fails:
  - "FMC FAIL" message will be displayed on CDU of the failed FMS. On the CDU of the functioning FMS will be displayed an "INDEPENDENT OPERATION" message. The indication of NAV and/or PROF mode is flashing on the PFD display.
  - An "AFCAS MODE" message will appear on the Multifunction Display Unit (MFDU) indicating that the selected mode is not functioning any more. Additionally the light of the AP function mode button goes off.
  - An orange "FAIL" attention light is illuminated on the CDU when either FMC or CDU fails. Selected mode (NAV/PROF) goes off and the above mentioned failure indications are displayed.
  - "MSG" information will appear on PFD, when the attention light is illuminated on CDU.
- When FMS data is not available for any reason, "MAP NOT AVAILABLE" will appear on ND.



Picture 3. CDU of Fokker 70/100 simulator

If the master FMC of the aircraft fails, the selected mode (NAV/PROF) goes out of function. After this, the second FMS will take care of the navigation, when the necessary selections have been made on the FMP. If any device used for navigation fails or gets into a phase where the system logic identifies that the device is not able to give reliable navigation information, the Flight Guidance System turns into basic mode. At the same time AP goes off. When the navigation responsibility is transferred to a functioning system, AP can be switched on again.

The navigation accuracy of FMS is reduced, if information cannot be retrieved from one or more sensors. The FMS will continue functioning, but the failure will be displayed on CDU.

A message will appear on the scratchpad of the CDU about the previously mentioned important failures or malfunctions and a signal light will be lit on some of the four annunciators beside the keyboard of the device. FAIL light will be illuminated when the CDU fails. DSPY light will be lit, when the page on the display does not correspond to the actual flight phase. MSG light will be lit when an important message appears or can be selected on the scratchpad of CDU. OFST light will be lit when the aircraft is flying an adjacent flight route deviating from FMC data. The last five messages due to any other reason than the actions of the crew will be saved in the FMS and they can be read one by one from the CDU.

The conclusion from the above mentioned facts is that pilots receive different notices and warnings about failures or malfunctions in the FMS. In this occurrence under investigation, according to the cockpit crew, no warnings were displayed.

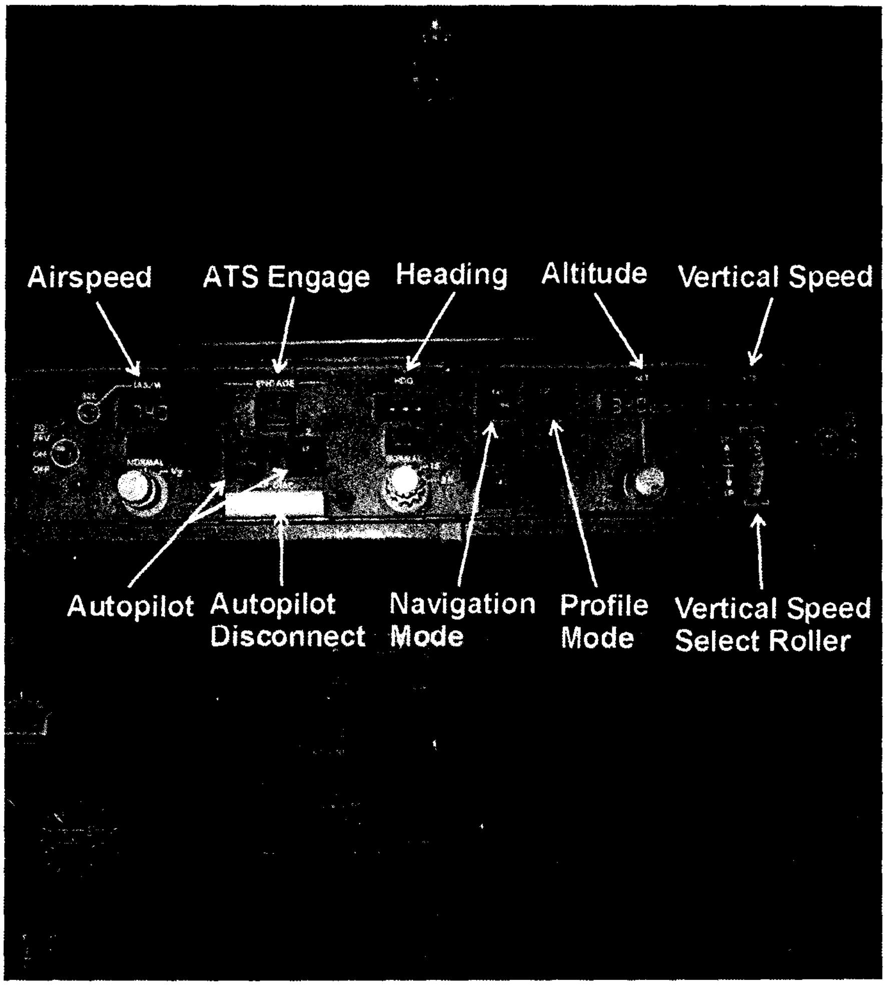
1.10.8 Simulator imitation of the occurrence flight

Simulator imitation of the flight was performed on 9 May 2002 in Schreiner's Aviation Training Center in Hoofddorp, Holland, where there is a Fokker 70/100 simulator made by Canadian Advanced Electronics (CAE). According to Fokker Services this simulator does not have a real FMC (hardware), but the functions are imitated with computer software. Due to this fact the tests made with the simulator did not give a reliable actual picture about the functioning of FMS in a real aircraft.

Six flights were performed with the simulator by following the same routing (from the direction of BALTI direct to HK710 and after that to HK707 and to HK702) as MAH742 flew on 17 January 2002. The FMS of the simulator initiated the anticipation turn for base leg according to the indicated airspeed during every approach. Honeywell's FMS update "27 DEC 2001 – 24 JAN 2002" was downloaded in the FMC of the simulator, the same update that was in HA-LMD at the time of the incident. Based on the observations made during the approaches, it became apparent that the update handled HK707 as a Fly-by waypoint without any exception. Flight conditions were specified as similar to those on 17 January 2002 regarding the indicated airspeed, altitude and both wind and other meteorological conditions. In the beginning of the flight simulations, the speed on downwind leg was set to IAS 280 KT (ground speed over 300 kt, tail wind 25 kt) and on base leg to IAS 220. Later on the variation of the speed was IAS 210 – 300 kt. The FMS of the simulator initiated the turn anticipation before waypoint HK707 during every flight, and did not fly over it like HA-LMD did when violating the separation minima at Helsinki-Vantaa on 17 January 2002.

The cockpit crew of MAH742 checked before the occurrence flight that the flight route in the FMS corresponded to the actual routing in the flight plan. When the crew received the information about the runway in use for approach at Helsinki-Vantaa, in connection with reading the Descend Check List, they checked the information from CDU and compared it with the information given in the Jeppesen transition chart. PF initiated landing preparations and checked, among other things, the selections of the navigation aids and FMS, selected the Minimum Descent Altitude/Height (MDA/H), prepared STAR and other approach charts and reported to PNF about the checks completed. The crew still checked the FMS data again after having listened to Helsinki-Vantaa ATIS information and, for the last time, after receiving the transition clearance from ATC.

PF told having selected the short PVO 1C transition route in the FMS and not the long transition route PVO 1D. The crew performed the whole flight with lateral navigation NAV mode on. PF adjusted the airspeed by selecting Autothrottle (AT) from the FMP. When ATC told MAH742 to maintain high speed, PF set the IAS to 280 kt, and maintained that selection all the time until 6000 ft. After that he adjusted the speed to 250 kt, because that is the speed limit of the aircraft below 5000 FT. After having been cleared to 3000 FT, PF set the IAS to 220 KT, to be able to slow down to the designated speed of 220 KT for the base leg turn given in the Jeppesen chart. At first, PF set the rate of descent to 1700 FT/MIN by using the roll selector of the FMP. For altitudes below 5000 FT, he set the rate of descent to 500 FT/MIN according to the standard operating procedures of the company.



Picture 4. Flight Mode Panel (FMP) of Fokker 70/100 simulator

PF disengaged the NAV function after HK707 by switching off the AP, whichafter he continued the flight manually by turning left to heading 180° as instructed by the ATC. PF noticed having flown over HK707. FMS had just initiated the turn for base leg in the PVO 1C transition, when ATC ordered the aircraft to make the turn.

According to PF, he did not see the anticipation turn drawn by the computer on the navigation display when approaching HK707. He saw the route as rectangular between HK710, HK707, HK702 and NULSA.

1.10.9 Special inspections of FMS equipment

Inspections by Honeywell

The investigators asked the representative of Honeywell Inc. in the U.S.A to check the Honeywell FMS and FMC systems for any technical fault.

The check was hampered by the fact that the representative of Honeywell did not have at his disposal any comprehensive information concerning the functioning of the system, such as information recorded by a Flight Data Recorder (FDR). Based on the information provided by the investigators to Honeywell, the company concluded that the FMS seemed to have functioned like it should never function in any circumstances. Their representative informed the investigators about several known possibilities for misuse that could have caused a similar behavior of the FMS as in this occurrence under investigation. However, the investigators eliminated the possibilities of misuse of the equipment based on the investigations and interviews conducted.

As a summary, it can be stated that it was not possible to identify the system malfunction. The incident is classified as "occasional, not planned function of the system" (System Anomaly).

Inspections by Fokker Stork

Also Fokker Service in Holland was asked to examine a possible technical system failure in the FMC of HA-LMD. As Fokker Service did not have enough details about the incident, a fault diagnosis could not be done.

1.11 Organizational and management information

1.11.1 Finnish Civil Aviation Administration

The Finnish Civil Aviation Administration (FCAA) is a state owned public utility company, the duty of which is to provide airport and air navigation services for the needs of both civil and military aviation and perform other commercial activities connected with the field of operations of FCAA.

The duty of FCAA is also to take care of general flight safety and issue regulations and rules associated with aviation, deal with air operator certificates and licenses as well as issues related to aircraft operations, airworthiness, registration and mortgaging and otherwise promote aviation, take care of development and oversight of aviation as well as other regulatory duties related to civil aviation. FCAA also takes care of civil aviation related international agreements and international cooperation when it is not within any other authority's competence.

At the time of the occurrence the valid working order for FCAA was dated 19 October 2000. According to the working order the fundamental organization of FCAA is formed by Concern Administration (Head Office), a separate regulatory unit responsible for flight safety (Flight Safety Authority, FSA), profit centers (airports, Air Navigation Services Centers and Avia College) as well as internal accountable profit units within FCAA. Additionally there are subsidiary companies within the public utility concern, the founding of which is decided by the board of the FCAA concern separately.

Head Office

The Head Office consists of the Director General (President), Secretariat, Administrative Department, Finance Department, Airports Department and Air Navigation Services Department as well as the International Affairs unit (regulations and operating licenses for international air transport).

FCAA has three management groups supporting the Director General:

- Management Group, consisting of Director General, Department directors, Director of FSA as well as other members appointed by the Director General.
- The Safety and Quality Committee of FCAA, consisting of Director General as Chairman and, as members, Directors of Airports and Air Navigation Services departments as well as Director of FSA. Additional participants in the Committee are the Quality Managers of Airports and Air Navigation Services departments as presenters and specialists.
- Management Group for Environmental Matters, consisting of Director General as Chairman and, as members, Directors of Administrative, Airports and Air Navigation Services departments, Environment Manager and Director of Helsinki-Vantaa Airport.

Air Navigation Services Department

The Air Navigation Services Department is responsible for the design, development and coordination of air navigation services (incl. aeronautical information and meteorological services), technical systems and environmental matters within the air navigation sector (noise, air traffic emissions, energy) as well as for all environmental matters of FCAA as directed by the Management Group for Environmental matters. The Air Navigation Services Department is also responsible for air navigation services and aeronautical information services at airports and en-route.

The Air Navigation Services Department has a General Staff group acting under the Director as well as the following units: Air Traffic Management, Air Navigation Systems, Aeronautical Information, Safety and Quality Management, Environment and Eurocat Support. Acting as one of the internal services units within FCAA, the Air Navigation Services Engineering Unit reports to the Director of Air Navigation Services Department.

Safety and Quality Assurance

The Director General of FCAA is responsible for the safety and quality of the whole public utility company. The Directors of Airports and Air Navigation Services Departments are in charge of safety and quality within their own sector. Each profit center is responsible for safety and quality within its own sector.

There is a Safety and Quality Committee in the Head Office for the management and follow-up of safety and quality. The chairman of the Committee is the Director General. The Directors of Airports and Air Navigation Services Departments are acting as members and the Quality Managers of the departments as secretaries. The duty of the

Committee is to manage and coordinate the establishment, development and maintenance of quality and safety systems as well as to oversee the operations of air safety and traffic area services in this respect. Each department in the Head Office audits and monitors the safety and quality of operations within its own sector and reports to the Director General in the Safety and Quality Committee.

The Air Navigation Services and Airports departments have their own Safety and Quality Commission. The Directors of different departments decide on the additional quality organization needed. It is the responsibility of the departments to deal with safety and quality matters arising within in their profit units and to ensure that corrective actions are planned, trained and implemented.

Quality operations of the profit units are implemented in the Safety and Quality Group. The manager of the profit unit is responsible for safety and quality within his unit and decides on the Quality Manager and other quality organization needed.

The organization of the Air Navigation Services Department includes a Safety and Quality Management unit, which is led by the Quality Manager. There are no written working instructions for the unit and it does not participate in the preparation of decisions in the sector. The unit is primarily responsible for managing occurrences and associated data, which include both the handling of Occurrence and Observation Reports and Flight Safety Reports of FCAA as well as internal investigation. Additionally it is responsible for presenting matters to the Safety and Quality Commission of the department and assists the Director General in the Safety and Quality Committee.

The start-up project of the 3rd Runway of Helsinki-Vantaa Airport

According to the project plan (2.11.2000 version 2.0) of the Air Navigation Services Department, a specific project (HelKo) was established for the design and adoption of the third runway at Helsinki-Vantaa. Its primary task was to gather together different factors relating to the operational use of the runway as a single entity and be responsible for ensuring that the tasks are carried out.

FCAA appointed the manager and the management group for the project. Members of the management group were the Director General, Deputy Director General, the Director of Air Navigation Services Department, Director of Helsinki-Vantaa Airport and Project Manager. The management group had the overall responsibility for implementing the project and creating the financial and operational prerequisites. The Assistant Director of the General Staff group within the Air Navigation Services Department was nominated as the Project Manager. In addition, the project included core, support and sub-project groups. The main goal of the project was to make the new runway arrangement ready for operation as to the procedures, operational documentation and the readiness of personnel, as well as to create the prerequisites for the desired operational capacity as defined by the Management Group. Sub-goals of the project were, among other things, the implementation of new departure and arrival procedures within the TMA as well as the introduction of associated flight routes, accomplishment of safety and risk studies and obtaining the required approvals from the authority.

The duty of the Core Group was to follow the proceeding of the subprojects and to coordinate the cooperation between them as well as to present any changes to the project for the Management Group. The duty of the Support Group was to follow the proceeding of the project and to look after the interests of the operators and the society with regard to the use of the runways.

The Project Group was responsible for the practical implementation of the project including training, authority approvals and publication procedures as well as for reporting on a monthly basis to the Management Group and associated projects. Additionally, it was responsible for conducting safety and risk studies of the subprojects as well as for internal and external communication concerning the project. The Project Group was also responsible for making any necessary changes in the project plan and presenting them to the Management Group.

The sub-tasks and subprojects dealt with the runway utilization, working procedures, stands for the aircraft, accomplishment of the noise abatement plan, maintenance operations of the aerodrome, prediction figures, ground traffic operations, communications as well as some other sub-tasks.

The person responsible for planning the "Runway Utilization" subproject was the Design Manager for airspace procedures. The tasks of the subproject included defining the RNAV transition procedures, carrying out safety and risk studies, training and preparations for the required authority approvals.

Flight Safety Authority

The operations of the Finnish Flight Safety Authority (FSA) are managed by the Director. He is assisted by a Development Team, which includes among others the Quality and Training Officer. The Operations and Quality Manual of FSA describes the Quality Assurance function within it's area. The duty of the FSA is to attend to general aviation safety as an aviation authority and to issue regulations and instructions to ensure flight safety. Its duty is also to process aviation related certificates and licenses as well as matters related to aircraft operations, airworthiness, registration and mortgaging. The Flight Safety Authority is also otherwise responsible for monitoring the safety of aviation and for the regulatory supervision and approval of air navigation services and airport operations.

The Flight Safety Authority consists of the Flight Operations Division, Technical Division, Administrative Services and the Airport and Air Navigation Regulations Division. At the time of the occurrence, the Airport and Air Navigation Regulations division was further divided into Airport, Air Traffic Control and Flight Calibration sections. According to the Operations and Quality Manual of the Flight Safety Authority, published on December 1st 1999, the Air Traffic Control Section:

- follows, prepares and applies international regulations within its own sector
- prepares and applies the Rules of the Air together with the Flight Operations Section

- oversees and inspects air traffic services training given by the Air Navigation Services Department from the flight safety point of view
- oversees and inspects standards and instructions prepared by the Air Navigation Services Department from the flight safety point of view
- oversees the procedure planning, systems and aeronautical information services of the Air Navigation Services Department from the flight safety point of view
- makes statements to the Training and Licensing Section concerning the training of Air Traffic Services personnel as well as their licenses, certificates of competence and ratings
- inspects the systems, devices, equipment, procedures and operations of Air Navigation Services units and their cooperation as well as prepares the associated operational approvals and other decisions
- prepares approvals related to the use of radio navigation equipment, systems and procedures
- investigates those failures and violations related to Air Navigation Services which are not investigated by the Accident Investigation Board Finland, and prepares the decisions made to address these failures or violations together with the Administrative Services.

With regard to the occurrence under investigation, the Air Traffic Control Section did not prepare the approvals for implementation of the RNAV procedures.

1.11.2 Malev Hungarian Airlines Plc.

General

The operations of Malev Hungarian Airlines Plc. (hereinafter Malev) are managed by the General Manager approved by the Hungarian Civil Aviation Authority (HCAA), whose direct subordinates are the responsible nominated post holders, Flight Operations director, Technical director and Ground Operations director, as defined in JAR-OPS 1. The company has a Quality System in accordance with JAR-OPS 1, managed by the Quality Assurance and Flight Safety Department Manager. The previously mentioned nominated post holders are responsible for training in their own sector, and for ensuring that the flight operations of the company are conducted with airworthy aircraft serviced according to the regulations. The information contained in this Investigation Report about the company is mainly based on Malev Flight Operations Manual (FOM), dated 15 July 2001. Malev had a valid Air Operator Certificate (AOC), issued by the Hungarian Civil Aviation Authority on 14 August 2001.

Flight Operations Department

The Chief Pilot of the company is acting as the Director of Flight Operations, whose direct subordinates are: Training Center, Flight Planning and Preparing Department, Type Departments of Boeing B767, Boeing B737 and Fokker F70 aircraft as well as Flight Attendants Department. The Type Departments are managed by the Chief Pilots of Type Departments.

The organization chart of Malev Flight Operations Department is clear, but the text in the FOM describing the management of the Flight Operations Department and the different organization charts in the manual do not correspond with each other. In the organization chart, the Chief Pilot has been marked in the same box as the Director of Flight Operations, but the combination of their duties is not explained in the text. Due to this the relation between the Chief Pilot and the Chief Pilots of Type Departments remained unclear for the investigators.

The Flight Planning and Preparing Department includes among others the Recording Group and Navigation Office. The Recording Group is responsible for the registers and data recorders, but its duties are not defined in detail in the FOM. The duties of the Navigation Group include, together with the Flight Operations Department, navigation planning, preparation, data processing and recording as well as flight monitoring and communication.

Flight Operations Manual, Part A (FOM-A)

The Malev FOM is compiled by the Documentation Section operating under the Flight Operations Department, which is also responsible for the necessary revisions and updating the manual.

JAR-OPS 1.420 "Occurrence reporting" requires that the commander or the operator of an airplane must submit a report to the Authority, unless exceptional circumstances prevent this, within 72 hours of any incident that endangers or could endanger the safety of operation. Additionally it is specified in paragraph (d)(1) "Air Traffic Incidents" that *"A commander shall without delay notify the air traffic service unit concerned of the incident and shall inform them of his intention to submit an air traffic incident report after the flight has ended whenever an aircraft in flight has been endangered by: (i) A near collision with any other flying device, (ii) Faulty air traffic procedures or lack of compliance with applicable procedures by air traffic services or by the flight crew, (iii) Failure of air traffic services facilities."*

Sub-chapter 11.2.1 "Serious Occurrences Categories" in the FOM defines near collision as a serious incident and sub-chapter 11.6 "Accident – Notification, Responsibilities, Reporting" determines that: *"Someone who get knowledge of an occurrence or irregularity during flight operation period is obliged to inform the Duty Operation Manager immediately.* Additionally in FOM subchapter 11.6.2 "Reporting", it is defined that incidents which have occurred in foreign states must be reported to:

- Flight Occurrence Watching Group of the Hungarian CAA
- Flight Safety Department of Malev
- Malev Operations Control Center
- Commanding group of flight crew, where necessary.

The FOM does not specify a time limit for submitting the report, as is stipulated in JAR-OPS 1. The captain of the aircraft did not report the occurrence according to the Flight

Operations Manual. He told about the incident to the company's Chief Pilot of F28 Type Department and to his substitute after having flown back to Budapest the next day.

According to the captain of MAH742, he did not report the incident to the Hungarian CAA, because he had not received any Resolution Advisory (RA) from the TCAS of the aircraft.

The investigators noticed that especially the following procedures required by JAR-OPS 1 for securing accident and incident investigation are missing from the Malev FOM:

- JAR-OPS 1.085 "Crew responsibilities", paragraph (f), subparagraphs (9)(i) Flight Data Recorder and (ii) Cockpit Voice Recorder.
- JAR-OPS 1.160 "Preservation, production and use of flight recorder recordings", paragraph (a) "Preservation of recordings".
- JAR-OPS 1 Subpart P, Appendix 1 to JAR-OPS 1.1045 "Operations Manual Contents", paragraph 2. "Operational Control and Supervision", subparagraph 2.1 (c) "Control, analysis and storage of records, flight documents, additional information and data".

1.12 Identification of potential threat of accident

The investigators noticed such deficiencies in the publications of Air Navigation Services, training of Air Traffic Controllers as well as in the transmission of flight plan data that could have contributed to a similar incident or even an accident. Due to this, and based on Article 10 of the Finnish Decree No 12.2.1996/97 on accident investigation, the investigators contacted the Air Navigation Services Department of FCAA in writing for the first time on 10 June 2002 to correct the deficiencies referred to above. Replies concerning the deficiencies were received orally, but in spite of requests, a written reply was not received. Due to this, the investigators prepared a new letter to the Director of Air Navigation Services Department on 26 September 2002. The reply was received on 11 October 2002.

2 ANALYSIS

2.1 Basics, design and implementation of Area Navigation (RNAV) procedures

A project group was founded for the design and introduction of the 3rd runway of Helsinki-Vantaa Airport. Sub-goals of the group were, among other things, the implementation of new departure and arrival routes in the TMA, safety and risk studies as well as obtaining the required approvals from the authority. The duties of the "Runway Utilization" subproject included the design, definition and safety and risk studies of RNAV transition procedures, as well as training and the preparation of required authority approvals.

The design work was based on EUROCONTROL documents for procedure design and charting. Based on these documents the utilization of airspace, routing of transitions, number of waypoints and the distances between them indicated clearly that the RNAV transitions at Helsinki-Vantaa were arrival routes in accordance with P-RNAV requirements. The previously mentioned instructions required that both B- and P-RNAV transition routes must be clearly identified as such on charts and in ATC clearances. This requirement was not fulfilled at the time of the incident, neither in the valid RNAV transition charts of Helsinki-Vantaa Airport nor in the ATC arrival clearance. The "P-RNAV Approval Required" identification marking on the charts was made in an AIP Finland revision, which was published as late as on 28 November 2002. Before this, the required navigation performance level for the P-RNAV procedures of RNAV-transitions at Helsinki-Vantaa was clearly identified only in the RNAV training material of ATC.

In addition to what was mentioned above, the procedural requirements for P-RNAV transitions were not published in the current AIP at the time of the incident as required by the instructions of EUROCONTROL. From AIC publications valid before the occurrence one could get the impression that RNAV operations within TMAs in Finland are based on B-RNAV. The investigators see that both the design and implementation of RNAV procedures at Helsinki-Vantaa and the current national publications (AIP and AIC) of Aeronautical Information Services were not consistent with each other.

2.1.1 Hazard Analysis of Safety Study

The RNAV-transition field trial mentioned in the Safety Assurance Document (29 March 2001) was performed with eight test flights by Airbus aircraft. According to the AOC of the carrier involved, the national authority had approved Airbus A321, A320 and A319 aircraft for both B- and P-RNAV with performance according to RNP1. At the time of the test, the RNAV transition charts of Helsinki-Vantaa had not yet been officially taken into service. It remained unclear for the investigators how the coding of aircraft NDB databases concerning the RNAV procedures of Helsinki-Vantaa was done, and by which transition charts and operational approvals the test could be done on scheduled flights with passengers onboard.

The SAD did not indicate at all how the differences between B-RNAV- and P-RNAV-approved aircraft would be taken into consideration in ATS operations. Additionally, the document did not handle the DME obstacle clearance examination or the publishing procedures of Aeronautical Information Services as required for the approval of Helsinki-Vantaa P-RNAV procedures.

2.1.2 Study of P-RNAV operational approval of the aircraft operating to Helsinki-Vantaa

With regard to RNAV transitions, the FCAA (Helsinki-Vantaa 3rd runway project, HelKo) had ordered during spring 2001 a study about the readiness of different airlines for P-RNAV operations according to JAA TGL 10. The feedback received from the airlines was based on their own estimations about operational and airworthiness capabilities. Neither the HelKo project nor the person who made the study checked with the Civil Aviation Authorities of different countries, which aircraft of different carriers were approved for operations according to B- and P-RNAV procedures when the RNAV-transitions of Helsinki-Vantaa were implemented on 14 June 2001. The feedback indicates that the airlines were estimating their readiness for P-RNAV operations much too optimistically. Due to this the conclusion of the study was also too optimistic.

2.1.3 Approval of RNAV transitions

The Aeronautical Information Services unit proposed to the Air Navigation Services Department the approval of RNAV transitions of Helsinki-Vantaa with document Dnro 8/590/2001. The proposal emphasized that the approval only concerned the publication of related material according to the AIRAC system in AIP. As an attachment to the proposal there was a memorandum made by the Aeronautical Information Services unit regarding the ambiguities and problems found in the procedures, on which the AIS unit and HelKo project had different opinions.

Both the FCAA public utility company and Flight Safety Authority have comprehensive quality systems, the purpose of which is to oversee the achievement of flight safety within their different fields of operations. According to the statement given by the ANS department, neither the Safety and Quality Committee nor the Safety and Quality Commission of FCAA handled the subjects related to the design and implementation of new RNAV procedures at Helsinki-Vantaa. In the investigators' opinion, these issues should have been handled within the different quality organizations of FCAA, because of the general importance of the matter, and especially because there had been some differences of opinion between the ANS department and HelKo project concerning the implementation of RNAV procedures. The implementation of new procedures always has a significant importance for flight safety. Concerning the incident now under investigation, the investigators see that the current organizations of the ANS department and Flight Safety Authority as well as the quality system of Flight Safety Authority have been either totally lacking the mechanisms for safeguarding the operations or they have not been functioning effectively enough. With appropriate safeguard mechanisms, the deficiencies found in the design and implementation of RNAV procedures might have been identified more certainly and could have been handled in time.

The Air Navigation Services Department approved the Helsinki-Vantaa RNAV transitions to be published in the AIP. According to the department, the Flight Safety Authority had not given them any specific regulations for the design and implementation of RNAV transitions and did not approve them separately. According to the statement given by the ANS department the procedures were based on an international practice and were regarded as a part of normal airspace management performed by the Air Navigation Services Department. The working order of FCAA defines that the duties of the Air Navigation Services Department include the preparation of proposals for approval of navigation procedures to the Flight Safety Authority. However, the working order does not contain any specified instructions on how the approval procedure should be carried out. In addition it does not specify which navigation procedures require an approval and which do not. When the ANS department informed the Flight Safety Authority about the new procedures, the Authority did not require any specific approval procedure from the ANS department for their implementation.

According to the working order of FCAA, the Flight Safety Authority is responsible for regulatory oversight and approvals within the Air Navigation Services sector. The Operations and Quality Manual of Flight Safety Authority requires the Air Traffic Control Section to perform preparatory work for authority approvals. It is the investigators' understanding that the implementation of totally new procedures should always entail extensive discussions and cooperation both within the authority itself and together with the design unit, because e.g. RNAV operations of air operators and their aircraft require separate approvals from the Technical Division and Flight Operations Division. Considering the duties of the Air Navigation Services Department and Flight Safety Authority as well as the flight safety aspects of navigation procedures, the approval procedure should have been followed.

After the incident under investigation the FCAA published an AIC No. A7/2002 (15.7.2002) dealing with the decision concerning the P-RNAV requirements within Finnish FIRs as of 28 November 2002. The FCAA rule No. 3/2002 (9.7.2002), attached to the AIC, was published in the FCAA Rules and Regulations series only in Finnish and Swedish. The information of the AIC was included in AIP Finland, and it was revoked with AIP revision 58/28.11.02. The information was now published also in English. The requirements for the P-RNAV procedure in Finland are published very clearly and in detail in this rule. In the opinion of the investigators, this rule should have been published already before the implementation of Helsinki-Vantaa RNAV transitions effective from 14 June 2001, because the ICAO, EUROCONTROL and JAA documents regarding RNAV procedures had been published by that time. They were in force during the design phase already.

The present instruction effective from 28 November 2002 requires that when performing the RNAV procedures published for the control zone and TMA as mentioned in the AIP, the aircraft (excluding state aircraft) and the operators must be appropriately approved for Precision Area Navigation unless otherwise ordered for special reasons by FCAA. So far these procedures have been implemented in Finland for Helsinki-Vantaa airport only.

2.2 Airworthiness approval and Operators Certificate for RNAV-operations

The JAA TGL 2 and 10 provide the basis and requirements for equipping aircraft with B-RNAV and/or P-RNAV devices. The instructions also serve as a basis for Civil Aviation Authorities when granting Air Operator Certificates and Airworthiness Approvals according to navigation performance requirements. The instructions give clear guidelines for operators, equipment manufacturers and aviation authorities. The instructions illustrate clearly the functional and operational limits of the aircraft equipment concerning RNP and other capabilities as presented in Part 1.10.6 of this report. The required navigation performance for Basic Area Navigation is ±5 NM and for Precision Area Navigation ±1 NM, so the difference of navigation performance between these two procedures is significant. Transition routes at Helsinki-Vantaa are designed and implemented based on P-RNAV where the required navigation performance is +/-1 NM. Because the Malev Fokker 70 aircraft was equipped for B-RNAV operations and the operator had an operational approval for B-RNAV granted by the Hungarian CAA, the Malev aircraft should not have performed Helsinki-Vantaa transition PVO 1C.

One of the most remarkable differences in equipment requirements between B- and P-RNAV airworthiness approvals is the number of waypoints that can be stored in the Navigation Data Base. The requirement for the FMS of Fokker 70, which is approved for B-RNAV operations, is to have the capability for storing only four waypoints, while the PVO 1C transition has six waypoints.

Even though all the preparations connected with the utilization of Helsinki-Vantaa RNAV procedures and their implementation indicated that they require P-RNAV capability from the operators, the transition chart markings required by the instructions were totally missing. The navigation performance requirement was not stated in the ATC clearance either.

2.3 Flight Plan

According to the instructions for completing the International Civil Aviation Organization (ICAO) Filed Flight Plan (FPL) form, the serviceable communication/navigation equipment of the aircraft must be entered in item 10 "Equipment". In this item must also be marked e.g. the RNP capability with letter R. It is mentioned in the note that entering the letter R in item 10 indicates that the aircraft fulfills the required navigation performance for a part of the route, for the entire route and/or for the area concerned. So a mere letter R does not indicate the RNP capability of the aircraft for the entire flight. Problems will arise, when a B-RNAV approved aircraft performs its route phase according to RNP5 requirements, but the Area Navigation procedures for TMA at the destination are based on P-RNAV. It is the investigators' understanding that in this kind of situation, the letter R should be entered in item 10 of the FPL of an aircraft operating to Helsinki-Vantaa, when the aircraft fulfills the RNP5 requirement for the route phase. Additionally item 18 should indicate the status of the flight (STS), for example STS/RNAV INOP, since the aircraft does not fulfill the RNP1 requirements within TMA. When the aircraft fulfills the RNP1 requirements, letter R in item 10 means that the aircraft will fulfill the requirements both for the route phase and terminal transition routes, as stated in AIC

B3/2001 Attachment 3, Paragraph 18 STS/ f) "*Aircraft, which are not equipped with serviceable RNAV equipment or the RNAV equipment of which do not meet the minimum requirements*" and in its example.

The procedures for the contents and use of Repetitive Flight Plans (RPL) that apply in Finland have been published in AIC B6/2002 (2.6.2002). It is stated in paragraph Q of AIC Attachment 1 that "*Enter any information required by the respective ATS authority according to FPL item 18.*" Based on this the item concerned should indicate STS/P-RNAV INOP, when the aircraft is approved only for B-RNAV operations. The RPL of MAH742 did not indicate that it had only a B-RNAV approval.

National exemptions and additional rules that have to be complied with in Finnish Flight Information Regions concerning the contents of the Flight Plan have been published clearly with examples both in AIP paragraph ENR 1.10-3 and in AIC B3/2001 as well as in AIC B6/2002. However, neither the writers nor the recipients of Flight Plans have been able to or have discovered how to make use of the possibilities given in the instructions. In the investigators' opinion, a procedure should be established for the processing of Flight Plan information to ensure that the units would be able to obtain correct and accurate data also on the aircraft's capability to perform RNAV procedures.

2.4 Actions of the Air Traffic Control Unit

Helsinki APP had an unofficial list according to which only those aircraft that were known to be P-RNAV approved were cleared for the RNAV transition. The list had been compiled with time on the basis of which carriers practically acknowledged RNAV clearances and how accurately they could fly along the given transition. Malev Airlines was also marked on this list, even though its aircraft were not approved for P-RNAV operations by the Hungarian CAA.

A closer review showed that there were also other carriers on the list that had no aircraft at all approved for P-RNAV operations. Additionally, there was one carrier on the list of whose aircraft only some were approved for P-RNAV operations. In spite of this, with a couple of exceptions, all aircraft of the carrier were permitted to fly RNAV transitions. The P-RNAV approval status of the carriers on the list was not verified from respective National CAAs.

The clearance for the PVO 1C transition that was given to MAH742 by APP ATCO was based on the previously mentioned list. MAH742 did not refuse the clearance, as the cockpit crew did not know that P-RNAV capability was required to fly Helsinki-Vantaa transitions. They thought that they were allowed to perform the RNAV transition given in the clearance based on their B-RNAV approval. It is the understanding of the investigators that the APP ATCO would have vectored MAH742 for an ILS approach to runway 15 if he had known that the aircraft was not approved to perform the given P-RNAV transition.

Due to the developing traffic situation APP ATCO decided on the arrival sequence of the aircraft at a rather early stage and organized MAH742 with higher speed to approach runway 15 before Air Force C21. ARR ATCO accepted the procedure, even though the quickly developing traffic situation was becoming difficult from the ATC point of view. At that point, MAH742 had 8 NM more to go than C21. MAH742 was cleared to 2000 feet while C21 maintained 4000 feet. The ARR ATCO and the ATCO trainee were aware of and followed actively the traffic situation developing between MAH742 and C21. As MAH742 flared the descent to decrease speed for final approach, the vertical separation planned by the ATC unit was not achieved early enough. Despite this the ARR ATCO did not interfere with the slow descent of MAH742. The ATCO could have told MAH742 for example to expedite descent through the altitude of 3000 feet when descending to the clearance altitude of 2000 feet. Another possibility could have been that ATC had cleared C21 to maintain 5000 feet, in which case the planned vertical separation of 1000 feet would have been easier to achieve. If the ATCO had acted like this the incident would probably not have occurred.

The investigators inquired the ATC section of Flight Safety Authority why B-RNAV approved aircraft were cleared for P-RNAV transitions at Helsinki-Vantaa. The section justified the procedure by the fact that the aircraft are under continuous radar control and thus it was acceptable to deviate from the P-RNAV requirement. However, according to ICAO and EUROCONTROL instructions, such a procedure is not acceptable. The FCAA has not issued any separate national instructions about the procedure either.

2.5 Possible error of cockpit crew or malfunction in Flight Management System

2.5.1 Cockpit crew

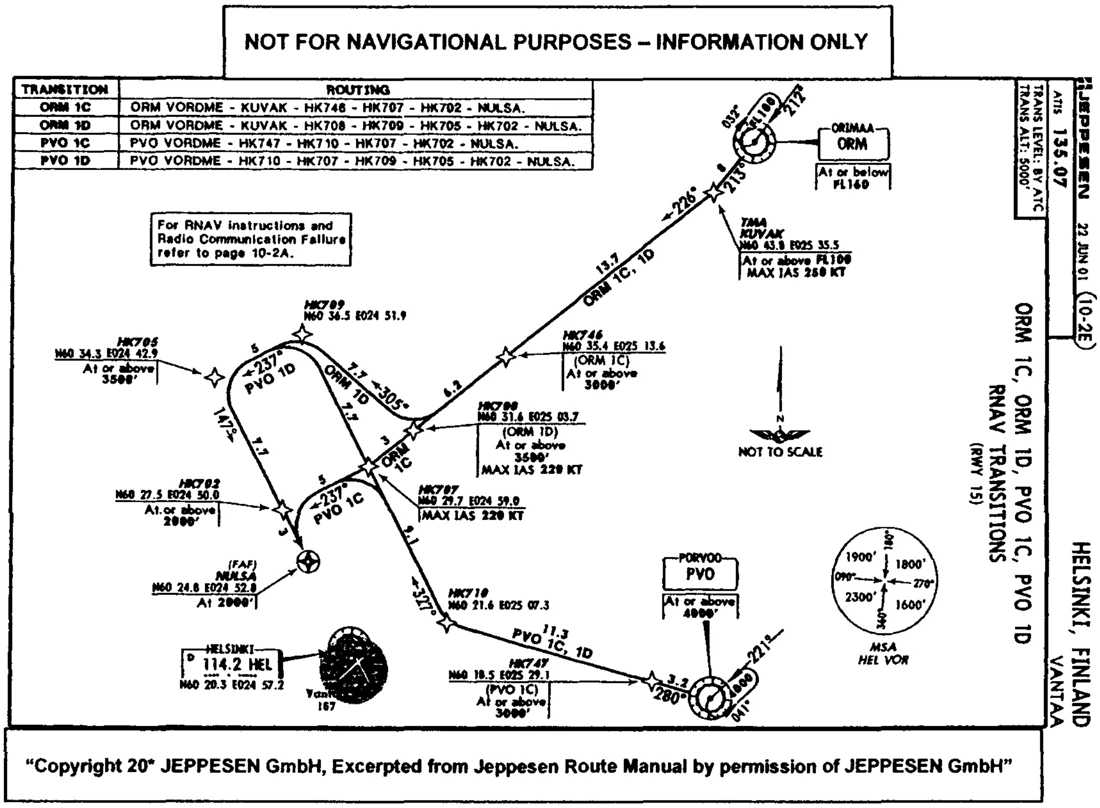
It is stated in Finnish AIP and AIC A 16/2001 that the captain of the aircraft is responsible for ensuring that any procedures are not performed without operational approval. Based on this, the captain of HA-LMD should have refused to perform Helsinki-Vantaa RNAV-transition PVO 1C, but because the required navigation performance was not indicated, the captain of the aircraft could justifiably assume that his B-RNAV rating was acceptable. It should be noted that capability for P-RNAV procedures is not achieved until both the pilots and the aircraft hold the previously mentioned ratings/approvals, and the carrier has the relevant operational approval.

In this occurrence under investigation the cockpit crew of Malev MAH742 could not possibly know either the requirement for the PVO 1C transition (B-RNAV/P-RNAV) or the navigation performance requirement (RNP5/RNP1), since FCAA had not published them in AIP Finland. Foreign Route Manual providers publish in their manuals information from different aerodromes based on the data given in Aeronautical Information Services publications by national CAAs.

MAH742 did not initiate a left turn before waypoint HK707 in the PVO 1C transition. The cockpit crew told that, at the same time when ARR ATCO ordered an immediate turn for MAH742, also the FMC of the aircraft initiated the turn. The aircraft had already passed HK707. PF disengaged the selected NAV function by switching off AP. After that he continued the flight manually by turning left to the heading ordered by the ATC unit. According to PF, he did not see the anticipation turn route of the transition drawn by the computer on navigation display when approaching waypoint HK707. Instead, he saw the route as rectangular between HK710, HK707, HK702 and NULSA. Based on this PF should have suspected a malfunction in the FMS and requested radar vectoring or another alternative arrival clearance from the ARR ATC unit. During the turn ordered by the ATCO the distance between MAH742 and C21 was in parallel course 1.85 NM at its shortest. At that time, MAH742 was 100 FT below the altitude of C21.

As MAH742 was just about to initiate the left turn over waypoint HK707, C21 was 3 NM directly ahead of it at almost the same altitude. If MAH742 had continued the flight directly, it would have passed C21 200 feet below and 2.2 NM behind it.

The cockpit crew used for navigation the Jeppesen chart shown in Picture 6, illustrating both the short transition route PVO 1C and the long route PVO 1D for runway 15. The information on the chart was in accordance with the data published by FCAA in AIP Finland. The investigators see that it could have been possible to mistake between the short and long transition routes effective at the time of the occurrence, especially because they were published on the same page of the chart. If the cockpit crew had chosen PVO 1D as their transition route, MAH742 would have flown over HK707 as it now did. However, the flight would have continued directly towards waypoint HK709. If the required navigation performance of Helsinki-Vantaa PVO 1C had been published in Jeppesen Route Manual as required in EUROCONTROL instructions, the cockpit crew of MAH742 could have noticed the accuracy requirement for the procedure and requested a new alternative arrival clearance.



Picture 5. Extract from Jeppesen Route Manual Page 10-2E, 22 JUN 01

Different possibilities for cockpit crew errors related to the use of AP and FMS could not be analyzed, because the recordings of the FDR were not available for investigation.

2.5.2 Flight Management System

The FMS of Malev Fokker 70 (HA-LMD) was only in compliance with the JAA TGL 2 requirements for B-RNAV operations, and therefore the aircraft was not authorized to perform P-RNAV transitions. Additionally the Hungarian CAA had granted Malev as an operator an approval for B-RNAV operations only, for which reason Malev should also not have performed P-RNAV procedures with its aircraft.

The FMS of Fokker 70 can go off during the flight, if the NAV and/or PROF functions are manually switched off, FMS power goes off, FMS fails, AP is switched off, FMS flight plan information is discontinuous or the localizer or glide slope function is switched on during precision approach. There will be either a light or text signal to the cockpit crew about every event, and thus the crew gets information on various malfunctions from the FMS. It would have made it easier to determine a possible malfunction in the FMS of the aircraft, if the last five messages recorded in the FMS had been read right after the occurrence. Any individual system failure could not be shown to have existed in the FMS of the aircraft at the time of the occurrence. The lack of FDR and FMS data hampered the investigation considerably.

2.6 Securing Incident Investigation

According to the given instructions, the captain of MAH742 should have reported the incident that occurred at Helsinki-Vantaa to his own Civil Aviation Authority. The reporting should have been done within 72 hours of the occurrence according to JAR-OPS paragraph 1.420 "Occurrence Reporting". Malev had also specified the reporting procedure in sub-chapter 11.6.2 "Reporting" of the Flight Operations Manual (FOM), but the time limit for reporting was lacking from the manual. After the occurrence, however, the captain of the aircraft informed that he had disregarded the mandatory reporting because he had not received a Resolution Advisory (RA) from TCAS about the oncoming aircraft he had observed. No grounds for this procedure were found in the company's OM-A. In a telephone conversation after the occurrence, the Helsinki-Vantaa ATCO advised the captain to report the incident to the CAA as he had decided to do himself. Even in spite of this the captain did not file a report. The investigators are of the opinion that he should have filed the report.

It became evident in the investigation that the FOM of Malev was lacking instructions for securing accident and incident investigation as to extracting and preserving the recordings of Flight Data Recorder and Cockpit Voice Recorder. The recorder recordings of HA-LMD would have been of utmost importance for determining the causes of the occurrence.

3 CONCLUSIONS

3.1 Findings

1. The cockpit crews of the aircraft and the Air Traffic Controllers had valid licenses and required ratings.
2. HA-LMD had a valid Airworthiness Certificate and a B-RNAV Airworthiness Approval (RNP 5) granted by the Hungarian CAA. Malev Airlines had an Operational Approval for B-RNAV. No malfunctions were detected in the aircraft or its equipment before the occurrence.
3. The FMC of Fokker 70 was in compliance with the requirements set by JAA TGL 2 for B-RNAV operations.
4. RNAV operation capability of the aircraft was not identified in the flight plan information of MAH742.
5. Helsinki APP cleared MAH742 to follow the PORVOO 1C RNAV transition route for runway 15 and ordered it to maintain high speed.
6. Helsinki APP was radar vectoring C21 for runway 15.
7. Helsinki APP transferred both MAH742 and C21 to Helsinki ARR in good time. ARR accepted the clearances given to the aircraft as well as their sequence of arrival.
8. The pilot flying (PF) of MAH742 saw the transition route after waypoint HK710 on the Navigation Display of the aircraft as rectangular without turn anticipation. Based on this the PF should have suspected a system malfunction in FMS and he should have requested radar vectoring or an alternative arrival clearance from the ARR control unit.
9. Based on a TCAS observation, MAH742 reported to ATC unit about traffic that was 5 NM ahead and 100 FT below it.
10. Both aircraft were operating in visual flight conditions, and the crew of MAH742 saw the oncoming aircraft on an intersecting flight path. The prevailing weather conditions had no significance in the chain of events.
11. MAH742 did not initiate the anticipation turn according to the RNAV transition procedure before waypoint HK707. No reason for this could be determined. There was no technical malfunction or fault in the aircraft or its systems.
12. A temporary failure in FMC or an error of the crew could not be totally excluded in the investigation.

13. To prevent violation of the required radar separation minimum of 3 NM, the ARR ATC unit ordered MAH742 to turn immediately left to heading 220° and C21 to turn right to heading 330°.

14. The aircraft passed each other with a distance of 1.85 NM almost at the same altitude.

15. Helsinki APP Control unit reported the incident as required by the Civil Aviation Authority and filed an occurrence and observation report to the Air Navigation Services Department.

16. The captain of the aircraft did not report the violation of separation minima to the Hungarian CAA according to the instructions of Malev FOM.

17. The recordings of MAH742 flight recorders were not available to the investigators, as they were not extracted for investigation. Malev had not given instructions in the company's FOM for the saving of flight recorder recordings in connection with incidents or accidents as required by JAR-OPS 1.

18. Helsinki-Vantaa transitions were designed and implemented according to P-RNAV requirements, but no navigation performance requirements were included in aeronautical publications.

19. EUROCONTROL instructions require that B- and P-RNAV procedures must be clearly identified as such on charts and in ATC clearances. The instructions were in force already before 14 June 2001, when the Helsinki-Vantaa RNAV transition procedures were implemented.

20. The Air Navigation Services Department had not acquired an approval of the Flight Safety Authority for Helsinki-Vantaa RNAV procedures and their implementation. According to the working order of these units, the approval procedure should have been followed.

21. The current organizations of the Air Navigation Services Department and Flight Safety Authority, as well as the quality assurance systems of the public utility company of FCAA and Flight Safety Authority, were either totally lacking the mechanisms for safeguarding the operations or they were not functioning efficiently enough with regard to the approval methods of navigation procedures.

22. The Flight Safety Authority did not require the Air Navigation Services Department to obtain a separate approval for the RNAV procedures.

23. AIP Finland did not define Helsinki-Vantaa transition route PVO 1C or other Helsinki RNAV routes as P-RNAV routes.

24. MAH742 should not have performed Helsinki-Vantaa transition route PVO 1C as it did not hold a P-RNAV approval. However, the cockpit crew could not know about the P-RNAV requirement for the procedure.

13. To prevent violation of the required radar separation minimum of 3 NM, the ARR ATC unit ordered MAH742 to turn immediately left to heading 220° and C21 to turn right to heading 330°.

14. The aircraft passed each other with a distance of 1.85 NM almost at the same altitude.

15. Helsinki APP Control unit reported the incident as required by the Civil Aviation Authority and filed an occurrence and observation report to the Air Navigation Services Department.

16. The captain of the aircraft did not report the violation of separation minima to the Hungarian CAA according to the instructions of Malev FOM.

17. The recordings of MAH742 flight recorders were not available to the investigators, as they were not extracted for investigation. Malev had not given instructions in the company's FOM for the saving of flight recorder recordings in connection with incidents or accidents as required by JAR-OPS 1.

18. Helsinki-Vantaa transitions were designed and implemented according to P-RNAV requirements, but no navigation performance requirements were included in aeronautical publications.

19. EUROCONTROL instructions require that B- and P-RNAV procedures must be clearly identified as such on charts and in ATC clearances. The instructions were in force already before 14 June 2001, when the Helsinki-Vantaa RNAV transition procedures were implemented.

20. The Air Navigation Services Department had not acquired an approval of the Flight Safety Authority for Helsinki-Vantaa RNAV procedures and their implementation. According to the working order of these units, the approval procedure should have been followed.

21. The current organizations of the Air Navigation Services Department and Flight Safety Authority, as well as the quality assurance systems of the public utility company of FCAA and Flight Safety Authority, were either totally lacking the mechanisms for safeguarding the operations or they were not functioning efficiently enough with regard to the approval methods of navigation procedures.

22. The Flight Safety Authority did not require the Air Navigation Services Department to obtain a separate approval for the RNAV procedures.

23. AIP Finland did not define Helsinki-Vantaa transition route PVO 1C or other Helsinki RNAV routes as P-RNAV routes.

24. MAH742 should not have performed Helsinki-Vantaa transition route PVO 1C as it did not hold a P-RNAV approval. However, the cockpit crew could not know about the P-RNAV requirement for the procedure.

25. Helsinki ARR Control unit did not pay enough attention to the developing incident between MAH742 and C21 by using safeguard measures to prevent it from happening.

26. FCAA published the Helsinki-Vantaa transition routes with a P-RNAV marking in the AIP as late as on 28 November 2002, almost 18 months after the incident, although it was required by the EUROCONTROL instruction to be done already in transition charts published on 14 June 2001.

3.2 Probable cause

The reason for the violation of radar separation minima was that MAH742 did not follow the Helsinki-Vantaa PVO 1C transition route given in its arrival clearance. The aircraft did not initiate the anticipation turn before waypoint HK707. The cause of the incident could not be determined with certainty in the investigation. A technical malfunction or an error of the crew could not be excluded.

Contributing factors were:

- The pilot-in-command did not abort the lateral navigation conducted by the Flight Management System (FMS) and change into HEADING mode of the autopilot, or change into manual control and request radar vectoring, although he saw in the cockpit the transition route on the navigation display as rectangular, without anticipation turn routing.
- The P-RNAV requirement was not marked on RNAV transition charts of Helsinki-Vantaa. If the procedure had been identified as a P-RNAV procedure according to EUROCONTROL instructions, the cockpit crew of MAH742 could have noticed that they were not able to perform the given RNAV transition route within the limits of their certifications.
- ATC did not monitor the achievement of the planned vertical separation between MAH742 and C21 before the violation of radar separation minima occurred. If the vertical separation would have been achieved as planned, this incident would probably have been avoided.

4 RECOMMENDATIONS

The working order of the FCAA as well as the safety and quality manual of Flight Safety Authority define the approval procedures for air navigation procedures. However, the Air Navigation Services Department has in practice a notable power of consideration as to which items and procedures it will bring up to be approved by the Flight Safety Authority and which not. In the investigators' opinion, the Air Navigation Services Department and Flight Safety Authority are lacking mutual instructions in which the appropriate course of actions in issues related to the approval procedures would be clearly defined.

1. The current organizations of the ANS department and Flight Safety Authority of FCAA as well as the quality assurance system of both the public utility company and Flight Safety Authority should enhance the mechanisms for safeguarding the operations, by which for example any deficiencies in the design and implementation of flight procedures can be identified more certainly and handled in time.

National exemptions and additional rules concerning flight plan contents that must be complied with in Finnish FIRs have been clearly published with examples in AIP paragraph ENR 1.10-3 and in AIC B3/2001 and AIC B6/2002. However, the persons filing the FPLs or the recipients have not been able to or have not discovered how to make use of the possibilities given in the instructions. Procedures for handling FPLs should be established to ensure that the Air traffic Services units have at their disposal correct and precise information e.g. about the ability of aircraft to perform different RNAV procedures.

2. The Air Navigation Services Department shall ensure that flight plan information available to Air Traffic Service units is comprehensive enough.

The investigation showed that the Malev FOM was missing the instructions for securing the accident and incident investigation by extracting and preserving the recordings of FDR and CVR. The FDR information of HA-LMD would have been of vital importance for determining the cause of this occurrence.

3. The Hungarian CAA shall require Malev Airlines to revise the Flight Operations Manual, Part A (FOM-A) to contain procedures for the handling of FDR and CVR recordings as specified in the JAA requirement JAR-OPS 1.

The investigation showed that although the captain of the aircraft noticed the incorrect transition routing on Navigation Display, he neither requested radar vectors nor any other alternative clearance from the ATC. When observing some fault or malfunction in any system of the aircraft, the cockpit crew must always choose an alternative mode of action. The occurrence shall be reported in enough detail, so that the fault or malfunction can be resolved afterwards as quickly and accurately as possible. RNAV operations are quite new within the European airspace. Due to this the equipment manufacturers and designers of flight procedures need all information available on any occasional malfunctions and faults in the devices and systems to enhance their reliability as well as flight safety.

4. Malev Airlines shall require their cockpit crews to report as precisely as possible any faults and malfunctions detected especially in aircraft FMS in RNAV operations, as well as to inform flight safety authority and manufacturers of equipment of their observations.

Helsinki, October 2, 2003

Vesa Palm

Ari Huhtala