Aircraft Incident Report

B 4/2002 L

TCAS manoeuvre south of Jyväskylä on October 29, 2002

DC-9-83, OH-LPH

Airbus 340-600, G-VMEG

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SUMMARY

On Tuesday October 29, 2002, at 14.33 Finnish time a serious incident occurred about 50 km south of Jyväskylä, when a passenger aircraft Airbus 340-600 operated by Virgin Atlantic Airways Ltd, call sign Virgin 901 en route from Tokyo to London and a passenger aircraft MD-83, call sign Finnair 473, operated by Finnair Oyj en route from Kittilä to Helsinki, passed each other at about 11000 m on crossing tracks losing the separation minimum required by the authorities. The aircraft took avoiding action by following instructions from their TCAS (Traffic alert and Collision Avoidance System) - Virgin 901 up and Finnair 473 down. Both aircraft flew above clouds in visual meteorological conditions and saw each other. The Accident Investigation Board, Finland, appointed an investigation commission on October 30, 2002, to investigate the incident. Chief air accident investigator Tero Lybeck was appointed chairman and air traffic controller Martti Lantela, airline pilot Timo Uramaa and Ville Hämäläinen were appointed members of the commission.

Finnair 473 and Virgin 901 flew in accordance with their air traffic control clearances at FL (flight level) 360, Finnair 473 on track Haapajärvi - Jyväskylä - Orimattila and Virgin 901 on track Joensuu - Maarianhamina. Originally Finnair 473 should have flown at FL 340 and Virgin 901 at FL 380. Finnair 473 flew at a flight level higher than normally because the aircraft was light. Virgin 901 flew on a flight level lower than normally because there was other air traffic near to it and in the same ATS (Air Traffic services) route at FL 380. The executive controller (R1) responsible for air traffic and the planning controller (R2) did not notice in any phase that the two aircraft were approaching each other. Slightly before the two aircraft would meet R1 gave to Finnair 473 clearance to descend to a lower altitude, leaving the decision to start the descent to the pilots' discretion. After this R1 focused on other traffic, for which he was responsible. He became aware of the incident when the separation minima had been lost and Finnair 473 had started to descend.

In passing each other Virgin 901 flew at heading 240° and Finnair 473 at heading 171°. The shortest horizontal distance between the two aircraft was about 1610 m (0.87 NM, nautical miles) and the shortest vertical distance was 360 m (1200 ft). The evasive manoeuvres were normal. Finnair 473, however, started descent in accordance with its clearance immediately after TA but prior to RA. Both aircraft reported taking evasive action. When R1 became aware of the conflict and noticed that the aircraft would not collide, he intentionally avoided giving instructions to the aircraft so that they would not be contradictory to the TCAS RAs.

The chain of events resulting in a serious incident begun when R1 and R2 prepared themselves for their work and noted that the westbound traffic from Russia flying over Finland flew at FL 380, whereas the southbound traffic from Northern Finland was at lower flight levels. They noted that there should be no separation problems between the two traffic flows. This initial assumption probably contributed to the fact that neither controller eventually noticed the two aircraft approaching each other at FL 360 which deviated from their original flight levels. Another contributing factor was that the Short Term Conflict Alert (STCA) system was not in use in the air traffic control at the moment.

The investigation commission made three safety recommendations of which two were to the Finnish Civil Aviation Administration (FCAA). The FCAA should take the existing STCA systems into

use to the extent they can be used without a great number of nuisance alerts. The FCAA should also to acquire a well-functioning STCA system to all ATC units which give radar services. Furthermore, the investigation commission recommended that Finnair Oyj should take into account in the pilots' TCAS training the risks associated with changing from level flight to climb or descent in accordance with ATC clearance during TCAS TAs.

The draft report was sent for comments to the UK AAIB, the Finnish flight safety authority, the ANS department of the Finnish CAA, the ANS centre for South Finland and Finnair. The Finnish flight safety authority and Finnair had no comments. The comments of the ANS centre for South Finland and the UK Accredited Representative have been taken into account in the report. Tampere ACC activated the existing STCA system soon after the incident for use above FL 200. The ANS department of the FCAA noted that a better STCA system is estimated to be taken in use with a new Eurocat 2000 v2 system in November 2003 in South Finland and in summer 2004 in North Finland. The comments of the ANS department are enclosed in the Finnish report and available in Finnish at AIB Finland.

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LIST OF ABBREVIATIONS

Abbreviation	English
ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre
ATC	Air Traffic Control
BCAS	Beacon Collision Avoidance System
CCC	Military Command Control Centre
CFMU	Central Flow Management Unit
CPA	Closest Point of Approach
DME	Distance Measuring Equipment
ESACC	Tampere ACC rating
ESRSR	Tampere ACC en route surveillance radar rating
FAA	Federal Aviation Administration
FCAA	Finnish Civil Aviation Authority
FDA	Flight Data Assistant
FDPS	Flight Data Processing System
FIR	Flight Information Region
FMP	Flow Management Position
FMS	Flight Management System
FSA	Flight Safety Authority
GPWS	Ground Proximity Warning System
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organisation
JAA	Joint Aviation Authorities
LJKK	Air Traffic Controller's Handbook
MHz	Megaherz
MIL CTA	Military Control Area
MSAW	Minimum Safe Altitude Warning
MTCA	Medium Term Conflict Alert
NAV	Navigation
OLDI	On-Line Data Interchange
PF	Pilot Flying
PNF	Pilot Not Flying
R1	Executive Controller
R2	Planning Controller
RA	Resolution Advisory
RDPS	Radar Data Processing System
RVSM	Reduced Vertical Separation Minimum
SASS	Sector Assistant
STCA	Short-Term Conflict Alert
TA	Traffic Advisory
TCAS	Traffic alert and Collision Avoidance System
TMA	Terminal control Area
TRG	Training

TSA	Temporary Segregated Area
UTC	Co-ordinated Universal Time
VHF	Very High Frequency
VOR	VHF Omnidirectional Radio Range

1 FACTUAL INFORMATION

1.1 Sequence of events

Throughout the report times have been expressed in UTC (Co-ordinated Universal Time, Finnish normal time -2 h).

1.1.1 Initial situation in the air traffic control

The Tampere Flight Information Region (FIR) has been divided into five geographical sectors. Five identical air traffic controllers' sector suites for operative work are located in the Tampere ACC (Tampere Area Control Centre). The sectors can be combined or separated between the different ACC sector suites depending on the traffic situation. In addition, there is a feeder suite comprising two working positions. When necessary the feeder working positions are taken into operative use based on the forecast arriving traffic volume to Helsinki Terminal Control Area (EFHK TMA).

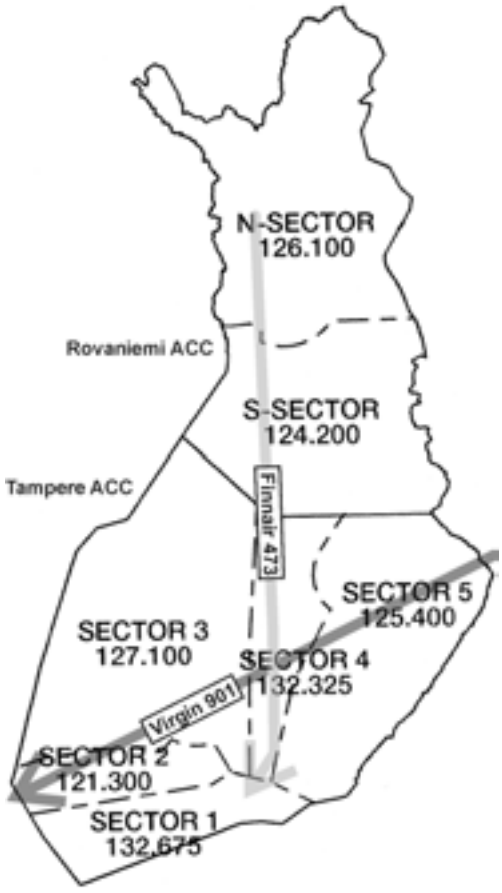

Figure 1. Sector division of Tampere and Rovaniemi ACC and aircraft tracks

It is the duty of feeder 1 controller to provide air traffic services within his responsibility area to aircraft arriving to the EFHK TMA via the LAKUT initial approach fix (IAF). It is the duty of feeder 2 controller to provide air traffic services within his responsibility area to aircraft arriving to the EFHK TMA via the KENON or ORIMAA IAFs. The feeder working positions give clearances to the arriving air traffic through the above-mentioned IAFs to the EFHK TMA on conditions agreed in advance with the approach control (EFHK APP).

On the afternoon of October 29, 2002, sector suite 2 was responsible for sectors 1 and 2. Sector suite 4 was responsible for sectors 3, 4 and 5. Both sector suites were manned by an Executive controller (R1), a Planning controller (R2) and a Sector assistant (SASS). In addition the Supervisor working position and the separate working positions of Flight Data Assistant (FDA) and Notice to Airmen (NOTAM) were manned.

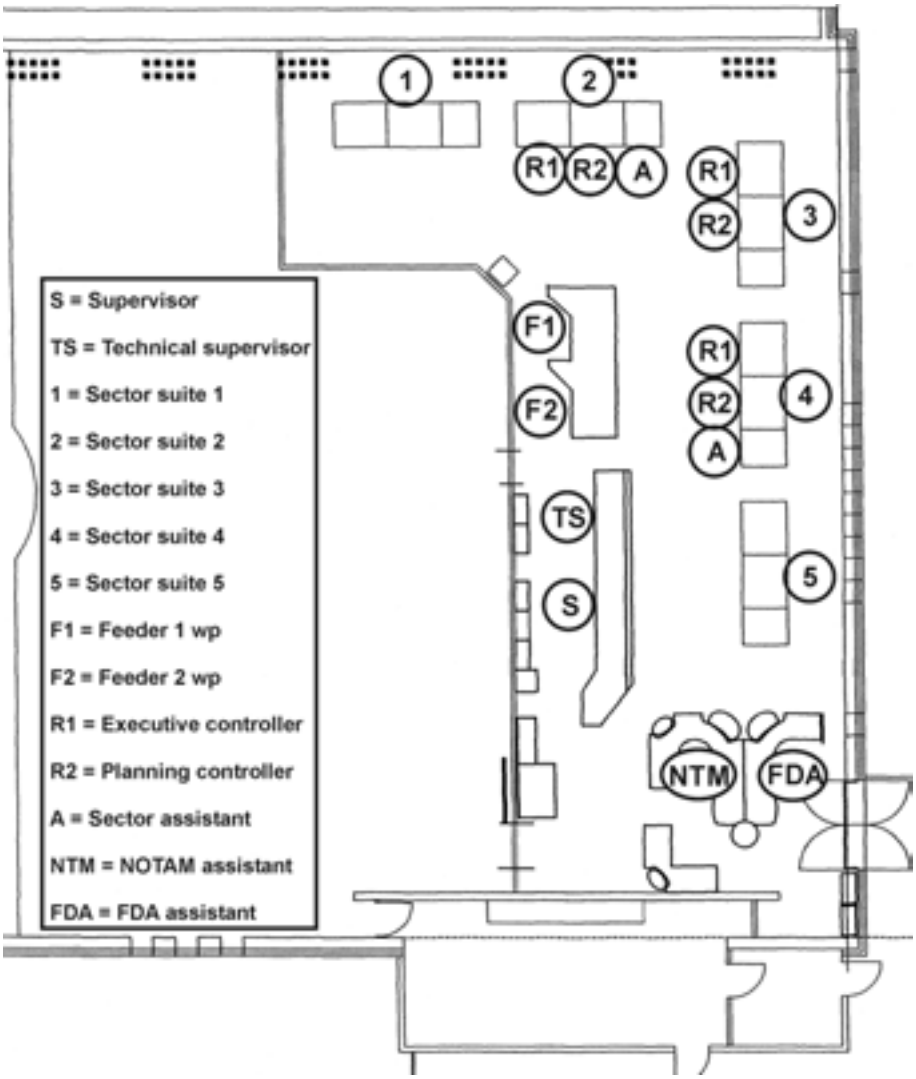

Figure 2. Sector suites and working positions at Tampere ACC

As the air traffic increased the ACC Supervisor decided to separate sector 3 from sectors 4 and 5 to reduce the work load in sector suite 4. Sector suite 3 was opened at

12.25 hours sector 3 being its responsibility area. Sectors 4 and 5 remained the responsibility area of sector suite 4. As the air traffic kept on increasing, the Supervisor decided to alert feeder 2 working position to stand-by. At 12.38 hours the controller at feeder 2 reported to sector suite 4 that he was ready. Feeder 2 working position was, however, not taken into operation.

1.1.2 Action of Air Traffic Control

The traffic was in the beginning moderate in the responsibility area of controller sector suite 4 in the Tampere ACC. R1 and R2 noted from the flight plans that all westbound traffic from Russia flying over Finland would request flight level (FL) 380. The southbound crossing traffic from Northern Finland inbound Helsinki would fly at lower flight levels and not cause separation problems. The Air Traffic Control (ATC) strip of Finnair 473 was received 43 minutes and the ATC strip of Virgin 901 21 minutes before the entry into the sector. The ATC strips are received for traffic from east at least 10 minutes and for traffic from south and west at least 20 minutes before the entry into the sector. For domestic flights they are received immediately after departure. The flight plans are shown on the monitors of the sector suites 60 minutes before the estimated entry into sector.

Virgin 901 had departed from Tokyo to London at 03.11. It passed reporting point AGAMO located at the boundary between the Flight Information Regions (FIR) of Petrozavodsk and Tampere at 12.10 hours at FL 350 and contacted the Tampere ACC at sector 5 frequency 125.4 MHz. At this moment also the responsibility for air traffic control was transferred to sector 5 of the Tampere ACC. R1 notified Virgin 901 that he had radar contact, cleared the aircraft to climb to FL 360 and announced at the same time that this would be the final flight level. Virgin 901 had in its flight plan requested FL 380 after AGAMO.

Virgin 901 flew in the Tampere FIR on the ATS route UN866 (Joensuu - Maarianhamina). On the same ATS route, about 36 NM ahead flew Japanair 421, Boeing 747, at FL 380 and about 20 NM behind flew faster Japanair 401, Boeing 747, which R1 cleared to FL 380.

Finnair 473 had departed from Kittilä to Helsinki at 11.43 hours. FL 340 had been requested in the repetitive flight plan for the flight from Kittilä to Helsinki. Due to the light weight of the aircraft the pilots requested clearance to climb to FL 360 from the Rovaniemi ACC. The Rovaniemi ACC cleared Finnair 473 to FL 360 and informed R1 in the Tampere ACC about the changed flight level at 11.59 hours.

Finnair 473 contacted the Tampere ACC at 12.16 hours on sector 4 frequency 132.325 MHz and reported maintaining FL 360. R1 replied that he had radar contact and gave arrival clearance to Helsinki: ”Cleared ORIMAA 2E transition, runway 22L”. After Finnair 473 had passed reporting point NUTTU at the border of the Rovaniemi and Tampere FIRs, the air traffic control responsibility was transferred to sector 4 in the Tampere ACC. Finnair 473 flew on the ATS route UA22 (Haapajärvi - Jyväskylä - Orimattila). ATS

routes UN866 and UA22 cross each other about 39 NM south of VOR/DME radio beacon LUONET.

As sectors 4 and 5 had been combined to sector suite 4, the same controller was responsible for the air traffic services in both sectors. R1 and R2 had relayed the radio communications so that the communications on sector 4 frequency 132.325 MHz could be heard also on sector 5 frequency 125.4 MHz. The radio communications of the air traffic control and aircraft were heard on both frequencies.

When Finnair 473 was about 15 NM south of VOR/DME radio beacon LUONET, R1 gave to it clearance: ”When ready, descend to FL 130”. Finnair 473 acknowledged the clearance.

The equipment (Maestro) calculating arrival times to Helsinki-Vantaa IAF indicated that arriving traffic started to accumulate delays. To avoid flying in holding pattern ORIMAA, R1 changed the arriving sequence of Golden 615L, from Lappeenranta to Helsinki, and Finnair 473 and applied speed adjustment.

R1 noticed the loss of separation slightly before Finnair 473 reported its evasive action following the TCAS (Traffic alert and Collision Avoidance System) RA with: ”Rovaniemen alue, Finnairin 473, we are starting TCAS descent.” R2 noticed the loss of separation when R1 stated the fact aloud. Virgin 901 reported: ”Virgin 901, we are TCAS RA, TCAS RA climbing.” R1 replied to both messages: ”Roger.” He saw that Finnair 473 had left its cruising altitude, noticed that the aircraft would not collide and assumed that they would make TCAS avoidance manoeuvres. R1 did not issue any clearances in order to avoid conflicts between the clearances and the TCAS advisories. He estimated that Virgin 901 passed Finnair 473 slightly in front of it when Finnair 473 was approximately at FL 350 and descending.

Finnair 473 continued descending after complying with the RA because it had ATC clearance to descend to FL 130 and the distance to Helsinki was suitable for commencing descent. The pilots told that they would report the incident and asked the other aircraft’s call sign. Virgin 901 returned to FL 360 after complying with the RA. Also the pilots of Virgin 901 asked the call sign of the other aircraft and asked the air traffic controller whether he had heard their TCAS RA announcement. The air traffic controller’s answer was affirmative.

1.1.3 Action of Virgin 901

Virgin 901 passed reporting point AGAMO at 12.10 hours at FL 350 and flew on ATS route UN866. The air traffic controller cleared Virgin 901 to climb to FL 360 and announced that this would be the final flight level for Virgin 901. The first officer acted as Pilot Flying (PF) and the captain as Pilot Not Flying (PNF).

When TCAS generated a TA both pilots selected a smaller scale on the NAV display and started to observe the airspace to obtain visual contact with the intruder aircraft. It appeared on the NAV display at the same altitude and at 3 to 4 o’clock. Both pilots saw

the aircraft at a distance of about 3 NM. Almost immediately TCAS generated the ”Climb, Climb” RA. The first officer disengaged the autothrust and autopilot, increased thrust and started to climb. The captain focused on monitoring the climb and the intruder aircraft on the NAV display. The first officer saw that the intruder aircraft started to descend. The intruder passed Virgin 901 behind its tail descending. TCAS announced: ”Clear of Conflict.”

Virgin 901 captain estimated that the shortest horizontal distance between the aircraft had been 1 to 2 NM, whereas the first officer estimated that it had been about 1 NM. The pilots estimated that they reached FL 365 during the avoidance manoeuvre and returned to FL 360 after the conflict. The captain reported to the Tampere ACC: ”Virgin 901, we are TCAS RA, TCAS RA climbing.” R1 replied: ”Roger.”

After the conflict Virgin 901 called the Tampere ACC: ”Control, Virgin 901.” R1 replied: ”Virgin 901, you are now clear of traffic.” After this Virgin 901 asked the ACC: ”Did you copy that TCAS RA.” R1 replied affirmatively and asked Virgin 901 to switch to the Tampere ACC frequency 127.1 MHz. Virgin 901 acknowledged this and asked the Tampere ACC of the call sign of the intruder aircraft. R1 told that it was Finnair 473.

1.1.4 Action of Finnair 473

Finnair 473 departed from Kittilä at 11.43 hours towards Helsinki. On ground in Kittilä the pilots had decided to request FL 360 as their cruising altitude instead of FL 340 stated in the flight plan because the aircraft was light. During climb Finnair 473 was cleared to FL 360 on the pilots’ request.

According to the pilots the visibility was good at FL 360, the weather was clear and the sun was shining. The flight proceeded normally. The Rovaniemi ACC handed Finnair 473 over to the Tampere ACC which gave it arrival clearance to Helsinki: ”Cleared ORIMAA 2E transition, runway 22L.” Finnair 473 flew on ATS route UA22.

The first officer acted as PF and the captain as PNF. The crew completed the actions stated in the check lists at FL 360 to start descent. The aircraft was approaching the starting point of descent in accordance with the Flight Management System (FMS) and the first officer was about to begin his public address when TCAS generated the TA. The pilots saw on the TCAS and weather radar that the intruder aircraft was approximately at a distance of 6 to 7 NM, at 10 o’clock and at the same altitude. The captain obtained visual contact with the intruder and the first officer after a while. As Finnair 473 had already clearance to descend to FL 130, the crew commenced descent. The first officer started the descent by selecting the vertical speed mode on the flight control panel.

Finnair 473 started a slow descent. Almost immediately thereafter TCAS generated a ”Descend, Descend” RA and according to the first officer’s estimate, advised a rate of descent of 3000 to 3500 ft/min. The first officer disengaged the autopilot and increased the rate of descent to comply with the RA. The captain maintained visual contact with the intruder and reported to the Tampere ACC: ”Rovaniemen alue, Finnairin 473, we are starting TCAS descent.” As the rate of descent increased and approached the RA rate,

TCAS announced ”Adjust Vertical Speed”. The pilots estimated that Virgin 901 passed Finnair 473 in front of it at a horizontal distance of about 0.5 NM and at a vertical distance of about 500 ft.

Finnair 473 reported to the Tampere ACC: ”Tampere control, Finnair 473, we continue descent FL 130 and we make report of this.” R1 acknowledged this by saying: ”Roger”. Finnair 473 still asked the controller of the call sign of the intruder aircraft. The controller told that is was Virgin 901.

Tampere ACC told Finnair 473 to reduce its speed to 250 kt. After this the ACC cleared Finnair 473 to continue descent to FL 100 and slightly later told it to contact Helsinki APP on frequency 129.85 MHz.

1.2 Injuries to persons

No injuries. Virgin 901 had a crew of 18 and 119 passengers. Finnair 473 had a crew of 5 and 25 passengers.

1.3 Damage to the aircraft

The aircraft were not damaged.

1.4 Other damages

No other damages.

1.5 Personnel information

1.5.1 Pilots

The pilots of both aircraft had valid licences and ratings required by their duties. Their flight experiences were not of importance from the point of view of the incident.

1.5.2 Air traffic controllers

The personnel in the ACC was sufficient and in accordance with the valid workshift list. In sector suite 4, under the control of which the incident occurred, worked two air traffic controllers and one sector assistant.

Supervisor:	Male, 46 years
Licences:	Air traffic controller, valid until January 11, 2003
Medical certificate:	FIN1, valid until January 11, 2003
Ratings:	ESACC, ESRSR valid until January 11, 2003
Air traffic controller R1:	Male, 34 years
Licences:	Air traffic controller, valid until August 12, 2003

Medical certificate:	FIN1, valid until August 12, 2003
Ratings:	ESACC, ESRSR, valid until August 12, 2003
Air traffic controller R2:	Male, 40 years
Licences:	Air traffic controller, valid until March 30, 2003
Medical certificate:	FIN1, valid until March 3, 2003
Ratings:	ESACC, ESRSR, valid until March 3, 2003

ESACC: area control rating at the Tampere ACC
ESRSR: en route surveillance radar rating at the Tampere ACC

1.6 Aircraft information

Finnair 473, DC-9-83, OH-LPH, twin-engined commercial jet aircraft with a 141 passenger seat configuration, owned and operated by Finnair Oyj, maximum takeoff weight 67 800 kg.

Virgin 901, Airbus 340-600, G-VMEG, four-engined commercial jet aircraft with a 311 passenger seat configuration, owned by Avaio Leasing Company Ltd, operated by Virgin Atlantic Airways Ltd, maximum takeoff weight 368 000 kg.

1.7 Meteorological information

The aircraft were flying at FL 360 (10 950 m) in visual meteorological conditions. The weather was clear and visibility good. It was daytime.

1.8 Aids to navigation

The navigation equipment had no impact on the incident.

1.9 Communications

Finnair 473 was on the Tampere ACC frequency 132.325 MHz. Virgin 901 was on the Tampere ACC frequency 125.400 MHz. R1 and R2 had relayed the frequencies so that the radio communications on the two frequencies were heard on both frequencies.

1.10 Location of incident

The aircraft passed each other at a distance of 29 NM from VOR/DME radio beacon LUONET on radial 171, south of the city of Jyväskylä. The co-ordinates of the location where the aircraft passed each other were 61° 46’ N and 025° 40’ E.

1.11 Flight recorders

Both aircraft were equipped with cockpit voice recorders and flight recorders.

Finnair 473

SSFDR Honeywell 980-4700-003, S/N 5585 (Solid State Flight Data Recorder)

Virgin 901

SSFDR Honeywell 980-4700-042, S/N 07589

Finnair 473 cockpit voice recorder runs for 30 minutes and that of Virgin 901 runs for about 2 hours. The data in the cockpit voice recorders of both aircraft had been erased. The commander of Finnair 473 did not consider it necessary to stop the recorder. It is not possible to stop the CVR on the flight deck of an Airbus 340-600 as the system circuit breaker is in the avionics bay.

The data in the flight recorders were received from Finnair Oyj and Virgin Atlantic Airways. Virgin Atlantic Airways also delivered the TCAS computer recording which provided data on how TCAS had functioned. Finnair 473 TCAS did not record the data.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Test and research

1.16.1 Aircraft tracks

The aircraft tracks were determined based on data from the Flight Data Recorder (FDR). Data recorded by the Virgin 901 TCAS provided additional information for determination. Accuracy of the determination was checked by comparing the determined tracks with the Tampere ACC radar display, with 5-second update time.

The Virgin 901 TCAS had stored three events i.e. the ”Traffic” TA, the ”Climb” RA and the ”Clear of Conflict” announcement. The times of these three events were retrieved from the memory as well as the altitude of Virgin 901 at the said moments. In addition

the differences in altitude and vertical speed, as well as bearing and distance in relation to Finnair 473 were retrieved.

The Virgin 901 TCAS generated a TA at 12.32.51 hours. Both aircraft were at FL 360 and at a horizontal distance of 6.4 NM. Finnair 473 started to descend 7 seconds later at 12.32.58 hours.

At 12.33.05 hours the Virgin 901 TCAS generated an RA, i.e. 14 seconds after the TA. Then the vertical separation of the two aircraft was 40 ft and the horizontal distance was 4.6 NM. The Virgin 901 TCAS determined the target value of vertical speed to be 800 ft/min. The pilots of both aircraft initiated their evasive manoeuvres in accordance with TCAS after two seconds at 12.33.07 hours and disengaged the autopilots. Finnair 473 reached a load factor (g) of 0.70. Virgin 901 reached a load factor (g) of 1.3.

Finnair 473 pitched down from level flight attitude by 4.5° and descended with a maximum rate of descent of 3700 ft/min. Virgin 901 pitched up from level flight attitude by 3.5° and climbed with a maximum rate of climb of 2600 ft/min. Immediately after this at 12.33.16 hours the Virgin 901 TCAS announced: ”Adjust Vertical Speed.” The vertical separation between the aircraft was 650 ft and the horizontal separation 3.3 NM. After this, Finnair 473 decreased its rate of descent and Virgin 901 its rate of climb.

The maximum altitude Virgin 901 reached was 380 ft above FL 360 at 12.33.22 hours. Then the vertical separation of the two aircraft was 1120 ft and the horizontal distance was 2.6 NM. Virgin 901 was straight ahead of Finnair 473 at 12.33.37 hours, when their vertical separation was 1150 ft and the horizontal distance 1.0 NM. The minimum horizontal distance between the two aircraft was 0.87 NM at 12.33.41 hours when the vertical separation was 1200 ft. The Virgin 901 TCAS announced: ”Clear of Conflict” at 12.33.43 hours. Two seconds later at 12.33.45 hours Finnair 473 was directly behind Virgin 901 and then their horizontal distance was 1.0 NM and vertical distance was 1290 ft.

1.16.2 TCAS operations

The Federal Aviation Administration (FAA) of the United States calls the system warning of mid-air collision hazard “TCAS”. In the International Civil Aviation Organisation (ICAO) and the Joint Aviation Authorities (JAA) the system is known as Airborne Collision Avoidance System (ACAS).

TCAS is a system independent of ground and aircraft navigation equipment, and it aims at attracting the cockpit crew’s attention to other aircraft cruising close to them and provides the crew with instructions for evasive manoeuvres if necessary to avoid mid-air collisions.

When the TCAS II (version 7.0) equipment is in the TA/RA mode, it adjusts its detection sensitivity in accordance with altitude. Between flight levels 200 and 420 the equipment is designed to generate a TA 48 s and an RA 35 s prior to reaching the Closest Point of Approach (CPA). At flight levels 200 to 420 TCAS defines the RA vertical speed so that

a vertical separation of 600 ft is created at the CPA between the TCAS aircraft and the aircraft to be avoided. If the two aircraft are in level flight, this can normally be achieved by adjusting the pitch angle by 2° up or down.

Virgin 901 received a TCAS TA 50 s and an RA 36 s prior to reaching the CPA. When the TA was generated, the closure speed of the aircraft was 449 kt (832 km/h).

1.17 Organisational and management information

1.17.1 Air Navigation Services Centre for South Finland

The operations manual of the Air Navigation Services (ANS) Centre for South Finland defines the Centre's duties, organisation and responsibility areas. The following sectors operate in the ANS Centre for South Finland: administration, traffic sector, aviation rescue, technical, as well as data system unit and special unit. The operations are led by the director of the ANS Centre for South Finland.

Traffic Sector is responsible for providing air traffic services, aeronautical services and aeronautical telecommunication services of the ANS Centre as well as for duties related to airspace coordination and control. The sector is responsible for cooperation concerning its own duties with other air traffic service units and airspace users. In addition, the sector is responsible for coordinating basic and refresher training required for its own duties. The manager of the ACC is the head of the traffic sector.

Supervisor in the ACC is a specifically or temporarily appointed air traffic controller with sufficient knowledge, skills and experience. He shall have valid ESACC and ESRSR ratings as well as sufficient knowledge and experience in aviation rescue service.

The supervisor acts as head of the shift and in that capacity manages the operations of the ACC as well as coordinates air traffic and aviation rescue services in the Tampere FIR. The supervisor, for example,

- manages and supervises operations in the ACC and that the given instructions and rules and regulations are followed
- is responsible that a sufficient number of working positions are manned to meet the requirements of the air traffic in terms of available personnel and equipment
- follows and supervises the internal working cycle during the shift so that necessary breaks are evenly distributed
- takes actions to clarify and repair defects or omissions in the air traffic service he has noticed
- performs the tasks belonging to the FMP (Flow Management Position)
- keeps the ACC log.

Executive controller R1 provides radar-based air traffic service to controlled flights in controlled airspace in the responsibility area of the Tampere ACC. He provides flight in-

formation services and rescue services both in controlled and uncontrolled airspace in the Tampere FIR and in the upper flight information zone. R1

- is in charge of providing radar-based air traffic service in his responsibility area and separating the aircraft in relation to each other and to allocated airspace
- agrees with the R1s of adjacent sectors upon new routes for aircraft en route
- hands over and accepts all traffic
- takes care of radio communications
- is in charge of using the Maestro system.

The air traffic controller performing executive controller's duties shall have valid ESACC and ESRSR ratings.

Planning controller R2 assists the executive controller in providing air traffic services in the responsibility area of the Tampere ACC. He provides flight information services and rescue services both in controlled and uncontrolled airspace in the Tampere FIR and the upper flight information zone. R2

- is in charge of updating strip desk and assisting R1 in detecting conflicts (paper strips are used and automatically produced)
- independently prepares ATC clearances for departing traffic and defines departure separations in relation to arriving and over-flying traffic, and approves ATC clearances for traffic departing from Stockholm and arriving to the Tampere FIR
- informs R1 of departing traffic and of ATC clearances prepared by him and forwards changes made by R1 to air traffic clearances so that R1 has updated data for providing air traffic services and for defining aircraft separations
- allocates airspace reservations, informs of them to R1 before they become valid and acts in accordance with instructions from R1 to change them
- independently coordinates air traffic in allocated airspaces touching each other
- takes care of reporting estimates and changes in them as well as operative actions of On-Line Data Interchange (OLDI)
- takes care of telephone communication in cooperation with the sector assistant excluding radar lines
- is responsible for following arrival and departure reports of VFR flights.

The air traffic controller performing planning controller's duties shall have at least valid ESACC rating.

Feeder air traffic controller is responsible for air traffic services in the airspace allocated to him in the ACC sector. The feeder air traffic controller's duty is to feed aircraft from airspace in the Tampere ACC intending to land at the Helsinki-Vantaa and Helsinki-Malmi airports to the Helsinki terminal control area in accordance with EFES-EFHK cooperation agreement and information from the Maestro system.

The air traffic controller working in the feeder working position shall have valid ESACC and ESRSR ratings.

Sector assistant takes care of passing on clearance and airspace reservation requests to R2 and of passing on the air traffic clearances and reservations issued by the air traffic controller to the ATS units and other units. The sector assistant updates flight plan data in the Flight Data Processing System (FDPS).

An ATC assistant or ANS officer who has passed separately specified training can perform the sector assistant's duties. Also the air traffic controller can perform the sector assistant's duties. The sector assistant's tasks can be transferred to the R2 position.

Training manager acts as responsible manager of the training organisation. The traffic sector arranges initial, recurrent and refresher training to air traffic controllers within the training organisation. The training manager shall be an air traffic controller fulfilling qualifications specified in aviation regulation TRG M3-2 issued by the Flight Safety Authority (FSA) of the Finnish Civil Aviation Authority (FCAA).

The training manager is responsible that all training given by the organisation comply with the training licence conditions and valid rules and regulations, and that the training is arranged in accordance with the approved training program.

The training organisation arranges rating and recurrent checks required for issuing and renewing the air traffic controller licences and ratings.

Safety and quality group handles incident reports, deviation and occurrences reports, accounts concerning air navigation service centre, summaries from the head office of the FCAA and other matters related to safety. In addition, the group evaluates and follows the safety of the unit's operations based on the requirements set by the safety management system, and evaluates operation methods or changes in operation environment with impact on safety before applying the changes.

1.17.2 TCAS training for air traffic controllers in the ANS Centre for South Finland

The ANS Centre for South Finland arranges training for its personnel as stated in the training approval. The training manager plans and arranges initial, recurrent and refresher training concerning ACC operations.

The training program for the area control centre and area radar courses include training concerning alerting systems. As training sources are used Air traffic controller's handbook, and material from the ICAO and the FAA. Also airline pilots have given TCAS training. The training covers the following subjects:

- Aircraft systems: ACAS and GPWS (Ground Proximity Warning System)
- Air traffic control systems: STCA (Short-Term Conflict Alert), MTCA (Medium-Term Conflict Alert) and MSAW (Minimum Safe Altitude Warning)
- Actions based on Air traffic controller's handbook in ACAS avoidance situations
- Responsibility matters in complying with operating instructions

- Radio communications
- TCAS in the ACC airspace (FAA videotape)

At the end of 1999 training related to the ACAS II system was arranged to all air traffic controllers in the ANS Centre for South Finland.

At the end of 2000 RVSM training was arranged to all air traffic controllers in the ANS Centre for South Finland. Then also the operational differences of TCAS versions 6.04 and 7.0 were specifically discussed.

1.17.3 Sectoring and feeder instructions

The ANS Centre for South Finland has an "ATS Instructions, Rules and Regulations" folder (EOM) with instructions on how to open or close a sector suite, and on how to make changes in sectoring (part OPS-O No. 12/00). The instructions state for example: "when a new sector suite is opened, it has to be opened in time." The instructions state that the supervisor makes the decision on change in sectoring.

Instructions on feeder operations are given in the sector instruction (Part FEEDER, 22.5.2002). Item 3.1 of the instruction states: "Based on the traffic forecast the supervisor gives orders to put a feeder unit in stand-by. Then the feeder unit to be opened shall be manned. The feeder unit reports to the sector in question of being in stand-by." Item 3.2 states: "Either the ACC sector, supervisor or feeder sector decides on initiating the feeder unit operation."

1.18 Other information

1.18.1 TCAS history

Development of a system warning of mid-air collision was started in the United States in the 1950s. The BCAS (Beacon Collision Avoidance System) system was developed in the 1970s. The FAA started to develop a more advanced version, i.e. TCAS, in 1981. This has been further developed into TCAS II, which utilises the Mode S transponder.

The FAA performed a considerable number of simulations and safety analyses in developing TCAS II. Based on these simulations and safety analyses, TCAS II resolves almost all collision conflicts. However, its advisories are not always reliable because its operation is based on aircraft altimeter settings and assumes that the aircraft involved do not suddenly change heading or vertical speed. TCAS assists only if the crews of both aircraft on collision course comply with its advisories. The FAA investigations indicate that when TCAS II is correctly used, the number of mid-air collisions is below 10 % of the total number of collisions without the system.

According to ICAO Annex 6, from January 1, 2003, all turbine-engined aircraft of a maximum certificated takeoff mass in excess of 15 000 kg or authorised to carry more than 30 passengers shall be equipped with an airborne collision avoidance system

(ACAS II). From January 1, 2005, all turbine-engined aircraft of a maximum certificated takeoff mass in excess of 7500 kg or authorised to carry more than 19 passengers shall be equipped with an airborne collision avoidance system (ACAS II).

1.18.2 TCAS guidance

ICAO Annex 2, paragraph 3.2.2 (Rules of the Air, paragraph 3.2.2) states that the aircraft that has the right-of-way shall maintain its heading and speed, but nothing in this clause shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision avoidance manoeuvres based on solution advisories provided by ACAS equipment, as will best avert collision.

ICAO Doc 8168, part VIII, paragraph 3.1 (Flight Procedures) states that ACAS is intended to assist pilots in the safe operation of aircraft. Nothing in the procedures specified in 3.2 hereunder shall prevent pilots-in-command from exercising their best judgement and full authority in the choice of the best course of action to resolve a traffic conflict. Paragraph 3.2, part VIII in document 8168, states that

- pilots shall not manoeuvre their aircraft in response to traffic advisories only
- in the event of a resolution advisory to alter the flight path the search for the conflicting traffic shall include a visual scan of the airspace into which own ACAS aircraft might manoeuvre
- the alteration of the flight path shall be limited to the minimum extent necessary to comply with the resolution advisories
- pilots who deviate from an air traffic control instruction or clearance in response to a resolution advisory shall promptly return to the terms of that instruction or clearance when the conflict is resolved and shall notify the appropriate ATC unit as soon as practicable, of the deviation, including its direction and when the deviation has ended

Traffic advisories are intended to assist in visual acquisition of conflict of traffic and to alert the pilot to the possibility of a resolution advisory.

ICAO Doc 4444, paragraph 15.6.3.2 (Air traffic controller's handbook, paragraph 10.2.2) states that when a pilot reports a manoeuvre induced by an ACAS resolution advisory (RA), the controller shall not attempt to modify the aircraft flight path until the pilot reports returning to the terms of the current ATC instruction or clearance, but shall provide traffic information as appropriate.

ICAO Doc 4444, paragraph 15.6.3.3 states that once an aircraft departs from its clearance in compliancy with a RA, the controller's ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when

a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance, or

b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and issues an alternative clearance which is acknowledged by the flight crew.

Paragraph 10.2.3 in the Air traffic controller's handbook states also that

- the use of the system does not change the pilots' and air traffic controllers' responsibilities for air safety
- after receiving report that a controlled flight performs an evasive manoeuvre complying with an advisory, the air traffic controller shall not give instructions which are contradictory to the pilot's evasive manoeuvres
- when conditions allow, the air traffic controller shall give flight information to other aircraft affected by the evasive manoeuvres.

Paragraph 10.2.4 in the Air traffic controller's handbook concerning radio communications states: "The pilot should communicate to the ATC body of the advisory only when the advisory makes the aircraft deviate from the valid ATC clearance. The communication shall include the advisory direction (climb or descent) and thereafter the conclusion of evasive manoeuvre as soon as workload allows. However, the pilot is not required to report to the air traffic controller prior to initiating the evasive manoeuvre.

When the advisory has been caused by ATC clearance, the pilot's communication shall comprise:

a) name of the air traffic control unit

b) aircraft call sign

c) exact definition of the deviation."

1.18.3 Problems with TCAS avoidance

Investigations of the FAA indicate that a vertical separation of 300 to 500 ft between the two aircraft is sufficient in TCAS evasive manoeuvres. Pilots sometimes deviate significantly further from their original clearance than required or desired while complying with an RA. According to the FAA it is unlikely that an aircraft performing evasive manoeuvre would collide with a third aircraft at a close flight level because a conflict involving several aircraft has also been taken into account in designing TCAS II.

The FAA has also investigated interaction between TCAS and ATC. The pilots have often reported TCAS evasive manoeuvres too late and caused confusion in ATC. It has also occurred that the pilots do not always return to the cleared altitude immediately after the conflict has resolved.

Also Eurocontrol (European Organisation for the Safety of Air Navigation) has investigated the subject and states in its ACAS bulletin that a prerequisite for TCAS II system is that the pilots follow RAs promptly and accurately. According to the bulletin the reasons for pilots not complying with RAs can be, for example, an opposite ATC clearance, erroneous view of the traffic situation, faulty visual contact or when flying at the maxi-

mum altitude, the pilots do not want to make a climbing manoeuvre although advised so by the RA.

Complying with an ATC clearance opposite to the RA has resulted in serious accidents. A serious incident, classified as accident, took place in Japan on January 31, 2001, in which 9 persons were seriously injured and 91 persons suffered slight injuries. The pilots of a Boeing 747-400 received ATC clearance to descend and initiated descent. During the readback they received a “Climb” RA. The pilots complied with the ATC clearance and continued descent. At the same time the pilots of a DC-10 made evasive manoeuvre following a “Descend” RA, but changed the direction of evasive manoeuvre to climb when they saw that also the other aircraft was descending. Eventually the pilots of the Boeing 747 avoided collision by a very aggressive evasive manoeuvre. The shortest slant distance between the aircraft was 135 ± 30 m at FL 355.

A mid-air collision took place at FL 350 at the border of Germany and Switzerland on July 1, 2002, with 71 casualties. A Tupolev 154 was at FL 360 and got ATC clearance to FL 350. At the same time they received a “Climb” RA, but the pilots complied with the ATC clearance. A Boeing 757 on a crossing track at FL 360 received a “Descend” RA, with which the pilots complied. The aircraft collided.

1.18.4 Short-Term Conflict Alert of ATC

The existing radar equipment (EUROCAT 1000) in the ANS Centre for South Finland was taken into operative use in December 1992. It includes Flight Data Processing System (FDPS), Radar Data Processing System (RDPS) and Short Term Conflict Alert (STCA) system. The STCA region is divided into southern and northern areas with a boundary at the approximate latitude of 63° N. The southern and northern areas are also divided vertically into two areas with a limit at FL 200. The STCA does not allow to inhibit individual sub-areas, such as TMA, Military Control Area (MIL CTA) or Temporary Segregated Area (TSA) from the STCA area. The STCA system does not take into account the cleared flight levels of the aircraft. The STCA look-ahead-time is 90 s and warning time 60 s. The time parameters are similar in the whole radar network presentation area.

The STCA system generated a considerable number of nuisance alerts which did not indicate a real conflict but which had to be checked and verified by the air traffic controller. The controllers considered the nuisance alerts to disturb their work to such an extent that the system was only used occasionally. Most nuisance alerts were caused by the traffic at EFHK TMA because of the 3 NM separation minima. The STCA system was not in use in the Tampere ACC at the moment of the incident and it had not been used in several years before. No STCA user instructions had been written. In this case the STCA would have given an alert approximately 8 NM before the crossing of the flight tracks.

A new display system, Eurocat 2000, is being installed in the ANS Centre for South Finland and it includes for example STCA and MTCA. It is planned that the new equipment will be taken in use in November 2003.

2 ANALYSIS

2.1 ATC operations

2.1.1 Sector division

The Tampere ACC includes Flow Management Position (FMP) which provides the Supervisor with traffic volume forecasts for the ACC sectors, Helsinki-Vantaa airport and, if necessary, for other airports. The Central Flow Management Unit (CFMU) located in Brussels prepares the forecast based on flight plans. The forecast does not take into account military traffic, and consequently the actual traffic volume is generally higher than the forecast, which should be taken into account when sectoring is planned.

On the day of the incident at 12.00 - 13.00 hours the forecast traffic volume in the combined sectors 3, 4 and 5 was 29 flights and the capacity 20 flights per hour. The actual traffic was 36 flights. The forecast traffic in the combined sectors 4 and 5 was 19 flights and the capacity 20 flights per hour. The actual traffic was 25 flights. The forecast traffic in sector 3 was 16 flights and the capacity 20 flights per hour. The actual traffic was 20 flights. The total traffic volume was an usual short afternoon peak in these sectors.

The ACC supervisor decided to separate sector 3 from sectors 4 and 5 because the forecast indicated that the capacity of the combined sectors 3, 4 and 5 would be exceeded. Sector suite 3 with sector 3 as responsibility area was opened at 12.25 hours. After this the actual traffic volume at 12.25 - 13.00 hours in sector 3 was 15 flights. In the combined sectors 4 and 5 the actual traffic volume was 20 flights.

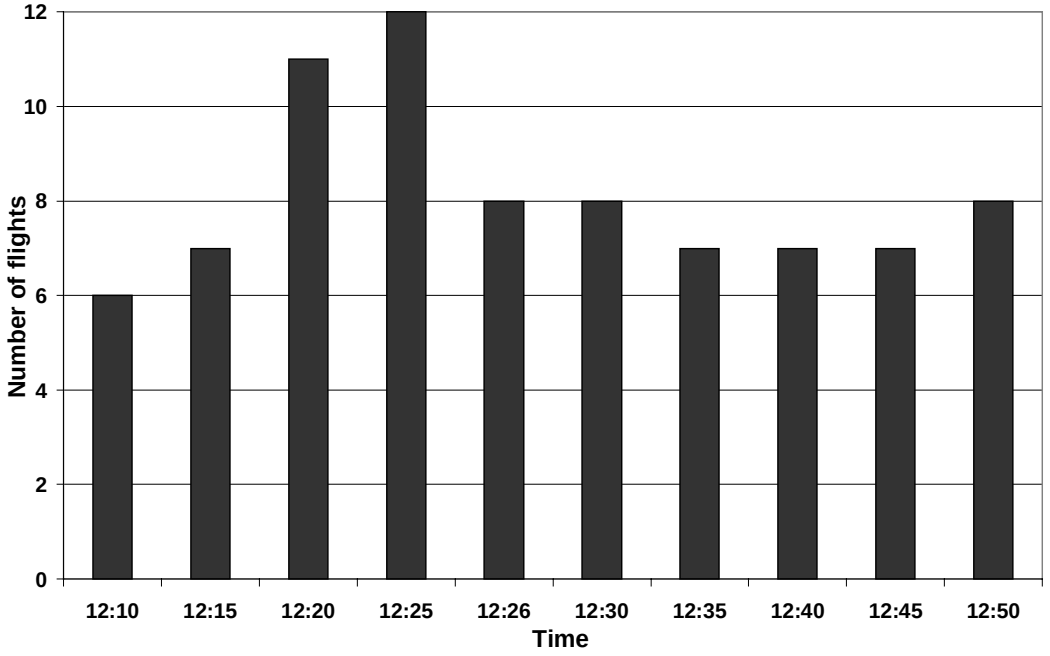

Figure 3. The traffic volume in sector suite 4 (sectoring at 12.25 hours)

The ANS Centre for South Finland has an “ATS Instructions, Rules and Regulations” folder (EOM) with instructions on how to open or close a sector suite and how to make changes in sectoring (part OPS-O No. 12/00). The instructions state that “when a new sector suite is opened, it has to be opened in time”. The supervisor makes the decision on changes in sectoring.

It is the opinion of the commission that separating sector 3 from sectors 4 and 5 should have been made 10 minutes earlier. The amount of traffic in sectors 3, 4 and 5 at 11.00 - 12.00 hours was 19 flights, i.e. close to the capacity of 20. The traffic forecast at 12.00 - 13.00 hours was 29 flights, which clearly exceeded the capacity of 20. The number of flights in the combined sectors 3, 4 and 5 was doubled at 12.10 - 12.25 hours. Sector 3 was split from sectors 4 and 5 at 12.25 hours. Sectoring during heavy traffic might have distracted R1 and R2 in their work, but it did not have any impact on the incident. Sectoring was completed about 8 minutes prior to the incident.

2.1.2 Feeder 2 working position

As the traffic volume continued to increase, the supervisor ordered feeder 2 working position to stand-by. At 12.38 hours feeder 2 controller reported to R1 in sector suite 4 that feeder 2 was standing by. Feeder 2 was not, however, taken into operational use. R1 in sector suite 4 decided to coordinate the arriving traffic from his sectors to Helsinki directly with the Helsinki APP.

It is possible that the decision of R1 not to take feeder 2 working position into operative use may have been affected by the short-term peak in the traffic forecast and the report from Helsinki-Vantaa that the capacity of arriving traffic was good, i.e. 28 arriving aircraft per hour during the said period. In the forecast the number of aircraft arriving to Helsinki-Vantaa at 12.00 - 13.00 hours was 16 from all sectors, and consequently it seemed unlikely that it would be necessary to resort to holding procedures over the IAF ORIMAA.

Over the IAF ORIMAA seven aircraft approached Helsinki-Vantaa from sectors 4 and 5 at 12.00 - 13.00 hours. Speed adjustment was applied to three of them and holding procedures were not needed.

It is the opinion of the commission that the operative use of feeder 2 working position was not needed in this case and taking it into use would not have essentially decreased the workload of R1 in sector suite 4.

2.1.3 Traffic planning

The traffic volume in sectors 3, 4 and 5 was ordinary afternoon traffic which mainly consisted of over-flying flights from northeast to southwest and of domestic flights arriving to Helsinki-Vantaa from the north. There were 9 over-flying flights in total at 12.00 - 13.00 hours and 6 flights arriving to Helsinki-Vantaa from the north. The southwestbound over-

flying traffic often requests FL 380 and usually does not cause problems in separation with domestic traffic.

R1 planned the separations of over-flying aircraft on ATS route UN866 so that the separation between them would be maintained as the flights proceeded to the next sector. All other over-flying aircraft except Virgin 901 were cleared to the requested FL 380 because the horizontal separation between them was sufficient. R1 cleared Virgin 901 to FL 360 because Japanair 401 flying about 20 NM behind it was faster. R1 cleared Japanair 401 to descend from FL 390 to FL 380 after reporting point AGAMO. R1 did not notice that Finnair 473 at FL 360 flew on a crossing ATS route UA22 from north to south, and that it would be at the crossing point of the ATS routes at the same time as Virgin 901.

According to the radar recording the horizontal distance between Virgin 901 and Japanair 401 was 20 NM after passing AGAMO. Japanair 401 was then 15 kt faster than Virgin 901. During flight, their speeds varied so that Virgin 901 was momentarily even some knots faster than Japanair 401. When R1 released Japanair 401 to sector 3, it was 15 NM behind Virgin 901 and 13 kt faster.

The over-flying traffic had been separated properly, but the separation between Finnair 473 arriving to Helsinki-Vantaa and the over-flying Virgin 901 was not confirmed because R1 and R2 did not in any phase notice that the two aircraft flew on the same altitude. A contributing factor might have been that when R1 and R2 came to their working position they noted that all over-flying traffic from east would request FL 380. This traffic flow should not have caused any problems with the crossing traffic flow arriving to Helsinki from Northern Finland because it was generally at lower flight levels.

The investigation showed that R1 could also have cleared Virgin 901 to FL 380 and have followed their horizontal separation on radar. When Virgin 901 and Japanair 401 were handed over to the responsibility area of the Stockholm ACC, their horizontal separation was still 16 NM.

2.1.4 How the conflict originated

Virgin 901 passed the AGAMO reporting point at the boundary of the Petrozavodsk and Tampere FIR at 12.10 hours at FL 350 and contacted the Tampere ACC. R1 in the sector suite 4 reported to Virgin 901 that he had radar contact, cleared the aircraft to climb to FL 360 and confirmed at the same time that this would be the final flight level. In its flight plan Virgin 901 had requested FL 380 after AGAMO but R1 did not approve it. R1 had decided to clear Japanair 401 to FL 380 as it flew about 15 NM behind Virgin 901, higher and faster than Virgin 901. R2 was aware of the new flight level of Virgin 901. He had notified sector suite 3 of the level change already at 12.07.20 by telephone. R2 was on the telephone with Rovaniemi ACC during 12.09.10 - 12.09.20 and with the CCC (military Command Control Centre) starting at 12.14.20. Virgin 901 contacted Tampere ACC at 12.11.00. The ATC strip of Virgin 901 was correctly marked with FL 360.

Finnair 473 was on scheduled flight to Helsinki. In the repetitive flight plan from Kittilä to Helsinki FL 340 had been requested. The pilots, however, requested from Rovaniemi ACC clearance to climb to FL 360 because the aircraft was light. Rovaniemi ACC cleared Finnair 473 to FL 360 and reported the new flight level to Tampere ACC at 11.59.00. R1 answered the telephone, possibly because R2 was busy with other duties. R2 was on the telephone with Kauhava ATC during 11.57.30 - 11.57.40 and with Kuopio ATC starting at 12.00.10. It is possible that R2 updated his stripdesk based on what he heard about the telephone conversation of R1 with Rovaniemi ACC. It is also possible that R1 mentioned the level change to R2 later on or that R2 noted the level change when Finnair 473 contacted Tampere ACC and entered Tampere FIR at FL 360. The ATC strip of Finnair 473 was correctly marked with FL 360.

Finnair 473 contacted Tampere ACC at 12.16.30 hours on sector 4 frequency 132.325 MHz and reported FL 360. R1 replied that he had radar contact and gave arrival clearance to Helsinki at the same time. R1 did not notice (neither did R2) that Finnair 473 and Virgin 901 had been cleared to the same flight level. R2 was on the telephone with CCC at 12.14.20 - 12.16.30.

Virgin 901 flew according to filed flight plan on ATS route UN866 at FL 360. Finnair 473 flew ATS route UA22 at FL 360. The two aircraft approached each other in an angle of 69° resulting in their flight paths crossing at a distance of about 74 km (40 NM) south of VOR/DME radio beacon LUONET. Radar flight data indicate that Virgin 901 flew at track 240° and Finnair 473 at track 171°.

At 12.27.50 hours R1 cleared Golden 615L (Saab 340) from Lappeenranta to Helsinki-Vantaa to fly after passing through FL 100 to KUVAK, requested it to maintain high speed, and stated that Golden 615L was number one to ORIMAA. R1 had decided that Golden 615L would be number one and Finnair 473 number two to ORIMAA.

At 12.30.30 hours R1 cleared Finnair 473 to FL 130. The clearance was, however, conditional: ”When ready, descend to FL 130” i.e. the pilots could initiate the descent at their discretion. Finnair 473 was then about 15 NM south of VOR/DME radio beacon LUONET. Virgin 901 was then at a distance of about 25 NM from Finnair 473. Neither R1 nor R2 noticed that radar separation with Virgin 901 would soon be lost. There was no other significant traffic with regard to the clearance of Finnair 473 to descend to FL 130. R1 had no telephone calls during 12.26.40 - 12.31.40 and R2 during 12.24.00 - 12.34.00. Both controllers and the sector assistant were in the sector suite during this time.

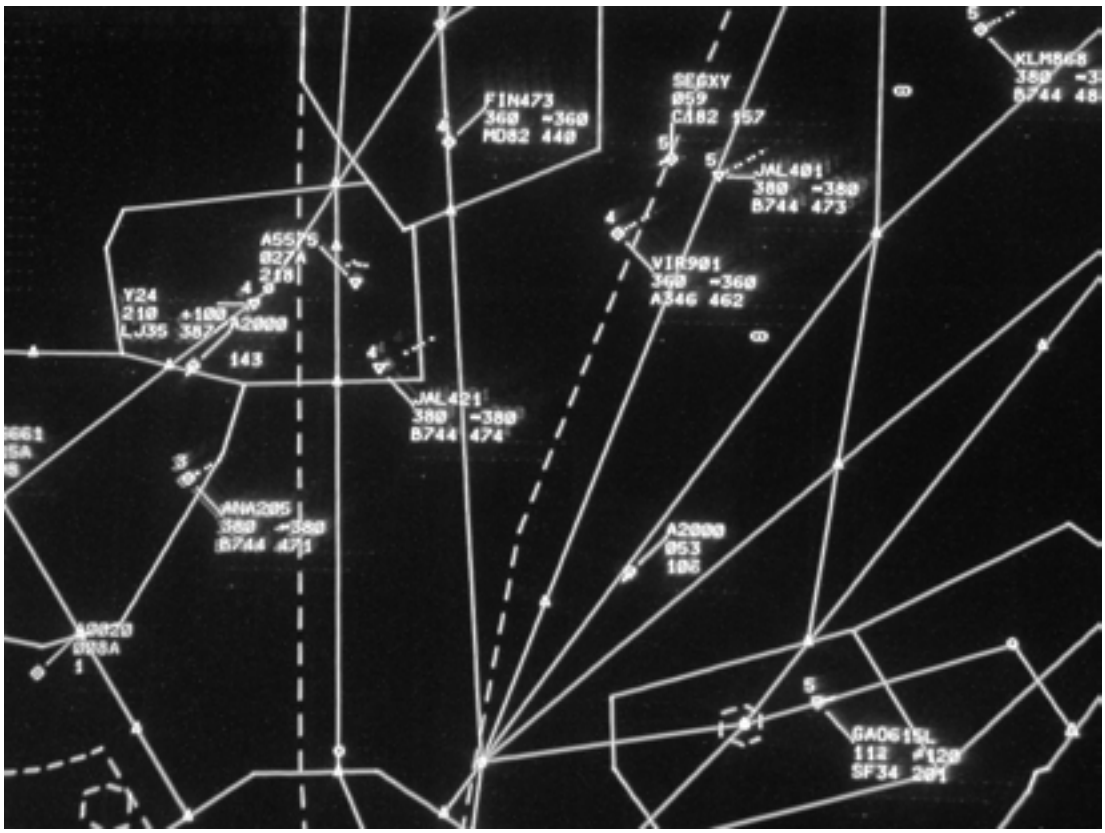

Figure 4. Part of R1 radar display at 12.30.30 hours

Radio communications of R1 on 125.400 and 132.325 MHz at 12.27.30 - 12.34.20 hours:

12.27.30	GAO 615L:	Tampere, iltapäiviä, Golden 615L passing flight level 85 for 120
	ACC:	Terve Golden 615L, Tampere, radar contact, runway 22 left
12.27.40	GAO 615L:	Runway 22 left for 615L
	ACC:	Tampere
12.27.50	ACC:	Golden 615L, proceed direct to KUVAK when passing 100, and keep up speed, you are number one to ORIMAA
12.28.00	GAO 615L:	When passing 100 direct to KUVAK, high speed for 615L, kiitos
	ACC:	Tampere
12.28.40	ACC:	Allnippon 205, contact Tampere 127.1
	ANA 205:	127,1, Allnippon 205
12.29.30	ACC:	Y 24, when ready descent to flight level 100
	Y 24:	Cleared down to 100, Y 24
	ACC:	Tampere
12.29.50	ACC:	And Y 24, arrival route is DIPAR 2B, runway 30

	Y 24:	Okay, DIPAR 2B runway 30, Y 24
12.30.00	FIN 416:	Tampere terve, Finnair 416, passing level 270 climbing level 360
	ACC:	Finnair 416, Tampere, radar contact, runway 22 left
	FIN 416:	22 left, Finnair 416
12.30.30	ACC:	Finnair 473, when ready, descend to flight level 130
	FIN 473:	When ready, descend to flight level 130, Finnair 473
12.31.10	GAO 615L:	Golden 615L, flight level 120 maintaining
	ACC:	Golden 615L
12.31. 40	Y 24:	Y 24, leaving level 210 down to flight level 100
	ACC:	Y 24
12.31.50	ACC:	Japanair 421, contact Tampere 127.1
	JAL 421:	127.1, Japanair 421
12.33.10	FIN 473	Rovaniemen alue, Finnairin 473, we are starting TCAS descent
12.33.20	ACC:	Finnair 473, roger

R1 noticed the loss of separation slightly before Finnair 473 reported its TCAS descent at 12.33.10 hours: ”Rovaniemen alue, Finnairin 473, we are starting TCAS descent.” R1 acknowledged the report briefly: ”Finnair 473, roger.” Finnair 473 captain incorrectly called the Rovaniemi ACC in the unexpected situation, but this had no effect on the incident.

Controller R2 noticed the loss of separation when R1 stated the situation aloud. One of the duties of R2 is to assist R1 in detecting conflicts, but in this situation R2 had not noticed how the incident had developed. He had however correctly marked FL 360 in the ATC strips of both flights. Paper strips are used and automatically produced. The strips did not show any same reporting points nor were they filed under the same designator.

R2 did not have a radar display of his own in the working position. This would have improved his ability to detect conflicts and to update strip desk. None of the R2 working positions in the sector suites in the ANS Centre for South Finland is equipped with radar display.

R1 noticed that the aircraft would not collide and assumed that they would perform TCAS manoeuvres. He did not issue any clearances in order to avoid conflicts between the clearances and the TCAS advisories. He told that his decision not to say anything was affected by the fact that he was familiar with the mid-air collision which took place at the border of Germany and Switzerland in July 2002. His actions after Finnair 473 TCAS report complied with the valid instructions.

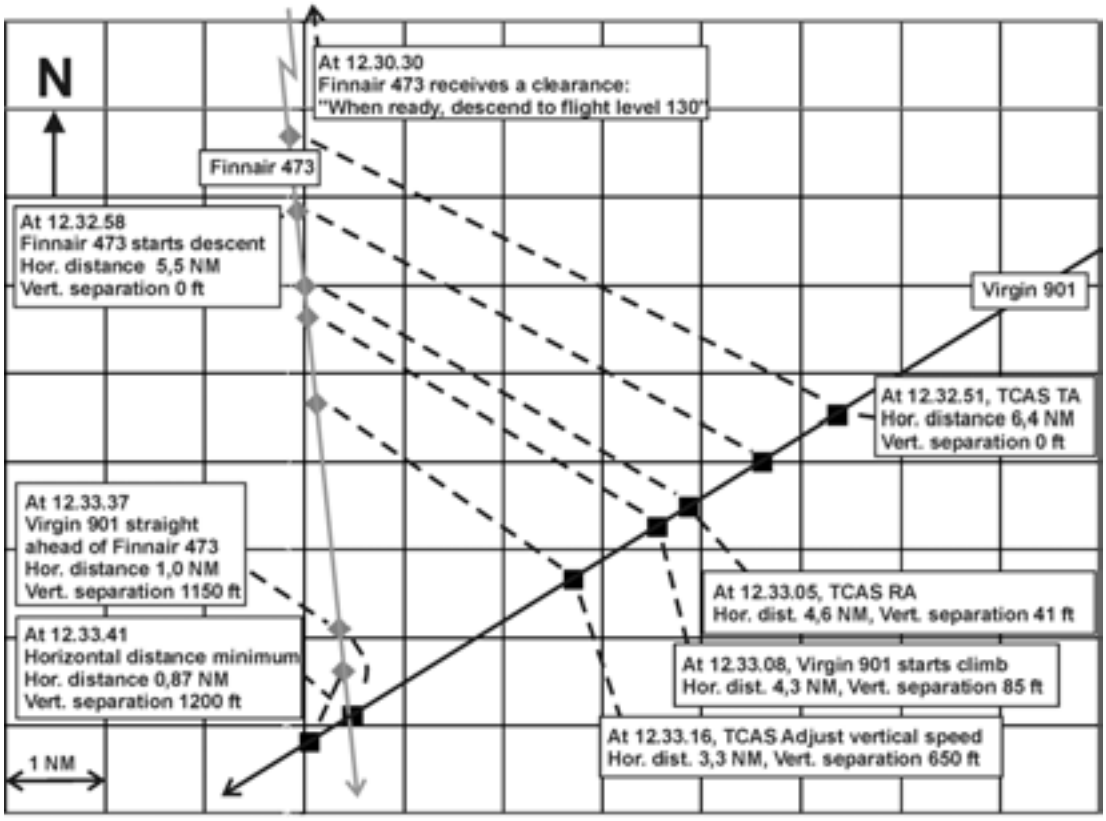

Figure 5. The flight tracks of the aircraft

At 14.33.40 hours Virgin 901 reported TCAS climb: ”Virgin 901, we are TCAS RA, TCAS RA climbing.” R1 acknowledged also this report briefly: ”Virgin 901, roger.”

After the TCAS manoeuvre Finnair 473 reported that it would continue to descend to FL 130 as cleared by the ATC. At 14.34.40 hours R1 reported to Virgin 901: ”Virgin 901, you are now clear of traffic”. After this Virgin 901 asked whether R1 had received his report on TCAS manoeuvre: ”Did you copy that TCAS RA”, and R1 replied affirmatively. Virgin 901 did not report to the ATC of its return to comply with the ATC clearance, i.e. descending back to FL 360.

Without their TCAS manoeuvre the two aircraft would have passed each other at a horizontal distance of 0.87 NM at the same altitude. In this case the vertical separation between the two aircraft should have been at least 300 m (1000 ft) or a horizontal radar separation of 9.3 km (5 NM).

Both aircraft flew in class A controlled airspace in which flights are provided with ATC services, ATC clearance is required, the flights are separated from each other, and two-way radio contact to the involved ATS unit is required. The European airspace, including Finland, belongs to the Reduced Vertical Separation Minimum (RVSM) airspace where the vertical separation between aircraft between FL 290 and FL 410 is 1000 ft.

At the time of the incident the weather was clear and visibility good. Both aircraft flew in visual meteorological conditions and saw each other prior to performing TCAS manoeuvres.

Both aircraft reported their TCAS manoeuvres to the ATC. The ATC acknowledged the reports and acted in accordance with instructions (Air Traffic Controller's Handbook, pages 1091-1092 and radio communications, page 41). He did not try to change the flight paths of the aircraft during their evasive manoeuvres.

2.1.5 Psychosocial support in the ATC after the incident

The FCAA has published "Operations Model for Psychosocial Support in Accidents and Conflict Hazards". The ANS Centre for South Finland has appointed support persons and prepared operations instructions based on the operations model. The post trauma support person of the ANS Centre for South Finland arranged debriefing for the involved persons in the office of Medivire Työterveyspalvelut Oy on October 31, 2002.

2.2 How the two cockpit crews acted

2.2.1 Virgin 901

Virgin 901 received a TCAS TA at 12.32.51 hours at FL 360 flying southwest on ATS route UN866. The pilots selected a smaller scale on the navigation display and started a visual scan to obtain visual contact with the intruder aircraft. They saw the intruder on the navigation display at 3 to 4 o'clock at the same altitude at a distance of about 3 NM. Both pilots obtained visual contact with the intruder. When TCAS generated the RA "climb" at 12.33.05 hours, the first officer acting as PF disengaged the autopilot and autothrottle and initiated the climb according to the RA. The aircraft started to climb at 12.33.08 hours. Eight seconds later the aircraft was at FL 364 and TCAS advised "adjust vertical speed". The captain reported at 12.33.40 hours to the ATC of the TCAS evasive manoeuvre as instructed, but deviated from the recommended phraseology: "Virgin 901 we are TCAS RA, TCAS RA climbing." The correct phraseology to the ATC would have been: "Tampere Control, Virgin 901, TCAS climb". This had no effect on the incident. The captain focused on monitoring the climb during the evasive manoeuvre and on following the aircraft which had generated the advisory on the navigation display.

2.2.2 Finnair 473

Finnair 473 flew south on ATS route UA22 at FL 360 and was reaching the top of descent calculated by the aircraft's FMS. The first officer acting as PF was about to begin his public address when TCAS generated a TA at 12.32.51 hours. The captain acting as PNF saw on his TCAS display that the intruder aircraft was at the same altitude at about 10 o'clock. He also obtained visual contact with the intruder. The captain said to the first officer to commence descent. The ATC had, at 12.30.30 hours, cleared Finnair 473 to descend to FL 130 "when ready".

Also the first officer obtained visual contact with the intruder. The first officer started the descent by selecting the vertical speed mode on the flight control panel. Finnair 473 initiated descent at 12.32.58 hours. Slightly later, TCAS generated the ”descend” RA. The first officer disengaged the autopilot and autothrottle and increased the vertical speed complying with the RA. The captain reported to the ATC at 12.33.10 hours: ”Rovaniemen alue, Finnairin 473, we are starting TCAS descent.”

The captain used incorrect call sign in contacting the ATC in this unexpected situation, but this had no effect on the transfer of communication. His report of TCAS descent did not comply with radio phraseology. The correct phraseology would have been: ”Tampere Control, Finnair 473, TCAS descent.”

Finnair 473 initiated descent based on ATC clearance during the TA. The crew’s action was based on valid company operations manual. From the viewpoint of TCAS operation the situation is problematic.

2.3 Altitude change during TA

FAA publication “Introduction to TCAS II Version 7, 11/2000” states that above FL 200 TCAS generates TA 48 s prior to the closest point of approach (CPA). During the TA the pilots can obtain visual contact with the intruder based on altitude, distance and bearing data on the TCAS display. At the same time TA gives time for the pilot to prepare for the eventual evasive manoeuvre complying with TCAS RA. Evasive manoeuvres based on RA shall be performed manually and without autothrottle.

During TA the TCAS systems of the two conflicting aircraft coordinate with each other through mode S transponder the possible evasive manoeuvres so that one of the aircraft manoeuvres up and the other down. When TCAS has defined the manoeuvre directions, some time elapses before it generates RA (generally max 15 s). TCAS receives altitude data from the other aircraft transponder once per second, and consequently it does not immediately register change in the other aircraft’s flight path. After TCAS has defined manoeuvre directions some time elapses before TCAS changes them.

The TCAS instructions state that the pilots should not report TAs to the ATC or ask about the intruder. Thus the ATC does not know when an aircraft has received a TA. During TAs the pilots do not receive any preliminary information from TCAS whether the eventual RA is “climb” or “descend”. If the ATC gives a clearance to climb or descend during a TA, and the aircraft complies with the clearance, it is possible that TCAS no longer has time to take into account the change in the aircraft’s flight path and generates a RA to opposite direction. In all incidents known to the commission collision has always been avoided when RAs have been followed. If the ATC clearance and RA are contradictory, the RA shall be followed.

In the case it could have happened that when Finnair 473 during the TA initiated descent complying with the ATC clearance, TCAS had already decided to advise Finnair 473 to perform evasive manoeuvre up and Virgin 901 down. The operators should take this possibility into account in their training and guidance.

2.4 Communications

Doc 8168 states that aircraft crews have to report to the ATC the deviations from clearances, direction of deviation and return to their previously assigned clearance (TCAS descent or climb) “as soon as practicable”.

When an air traffic controller receives a report of TCAS manoeuvre as early as possible, this facilitates his decision-making. It is easier for him to avoid issuing the aircraft a clearance to climb or descend which could be opposite to the TCAS advisory.

In this case Finnair 473 reported TCAS manoeuvre about eight seconds after receiving the RA and Virgin 901 about 35 seconds after receiving the RA. There was other traffic on the radio frequency between the reports of Finnair 473 and Virgin 901. After the evasive manoeuvre Finnair 473 reported that it would continue its descent to FL 130.

In his written incident report the captain of Virgin 901 told that they did not receive radio communications during about 10 minutes prior to their TCAS manoeuvre. When they reported their TCAS climb and enquired about the call sign of the other aircraft, the radio contact was normal in both directions. Investigations indicate that the radio equipment in the Tampere ACC functioned well at the moment of the incident and that radio communications with the other aircraft were normal.

3 CONCLUSIONS

3.1 Findings

1. The air traffic controllers and pilots held valid licences and ratings required by their duties.
2. The airworthiness certificates of the aircraft were valid.
3. Finnair 473 was on flight from Kittilä to Helsinki with 30 persons on board. The aircraft was on ATS route UA22.
4. Virgin 901 was on flight from Tokyo to London with 137 persons on board. The aircraft was on ATS route UN866.
5. The incident took place in the responsibility area of sector suite 4 consisting of sectors 4 and 5 of Tampere ACC.
6. R1 was responsible for traffic in sector suite 4. Also R2 and sector assistant were seated in sector suite 4.
7. When R1 and R2 started their work in sector suite 4 they noted that all over-flying traffic from east would request FL 380 as filed in their flight plans, whereas all southbound traffic from Northern Finland would be on a lower altitude. R1 and R2 noted that these traffic flows would not require separation.
8. The requested flight level of Finnair 473 according to flight plan was FL 340. Due to the light weight of the aircraft the pilots requested FL 360 which was approved by the Rovaniemi ACC. Rovaniemi ACC phoned R1 in Tampere ACC and reported the flight level change.
9. Virgin 901 contacted Tampere ACC at 12.11 hours. The cruising altitude of Virgin 901 as filed in their flight plan was FL 380 in Tampere FIR, but R1 decided not to approve it due to other traffic on the same ATS route. R1 cleared Virgin 901 to FL 360 and reported radar contact.
10. Finnair 473 contacted Tampere ACC at 12.16 hours. R1 gave the aircraft arrival clearance to Helsinki-Vantaa airport and reported radar contact.
11. R1 did not in any phase notice that Finnair 473 and Virgin 901 were at the same flight level and approached the crossing point of the routes almost simultaneously. R2 did not notice in any phase how the situation developed.
12. R2 had written FL 360 on the ATC strips for both Finnair 473 and Virgin 901.
13. At 12.30.30 hours R1 gave Finnair 473 a clearance to descend to FL 130 at the pilots' discretion. Finnair 473 acknowledged the clearance correctly.
14. TCAS of Virgin 901 generated a TA at 12.32.51 hours and TCAS of Finnair 473 almost simultaneously. The pilots of both aircraft obtained visual contact with the intruder. The intruders were also visible on the TCAS displays of both aircraft.

15. The weather was clear and visibility good at the moment of the incident. Both aircraft flew in visual meteorological conditions.
16. Finnair 473 initiated the cleared descent at 12.38.58 hours during the TCAS TA.
17. TCAS of Virgin 901 generated an RA at 12.33.05 hours and TCAS of Finnair 473 almost simultaneously. Virgin 901 initiated climb according to the RA at 12.33.08 hours. Finnair 473 increased its descent according to the RA.
18. R1 noticed the conflict slightly before Finnair 473 reported its TCAS manoeuvre at 12.33.10 hours. R1 noted that Finnair 473 had left its cruising altitude and separation had been lost. Virgin 901 reported its TCAS manoeuvre at 12.33.40 hours.
19. On the radar display R1 noticed that the two aircraft would not collide. He decided not to give instructions to the aircraft which might have been opposite to the TCAS RA's of the aircraft.
20. R2 noticed the conflict when R1 said it aloud.
21. The two aircraft were at the closest each other at 12.33.41 hours when Virgin 901 had passed Finnair 473 in front of it. The horizontal distance was then 0.87 NM and vertical distance 1200 ft.
22. Finnair 473 initiated descent according to the conditional ATC clearance during the TCAS TA. This decision embodies the possibility that the RA could have been opposite to the descent initiated by the pilot. In this case the RA was, however, "descend".
23. In the incidents known to the commission collision has always been avoided when both aircraft have complied with the TCAS RA's. If the ATC clearance and RA are contradictory, the RA shall be followed.
24. The Short Term Conflict Alert (STCA) system was not in use in the ATC at the time of the incident. It was used only occasionally because it generated a considerable number of nuisance alerts.

3.2 Cause of incident

R1 and R2 noted in preparing themselves for their work that over-flying traffic from east would use FL 380 according to the flight plans, whereas the southbound traffic from Northern Finland would fly at lower flight levels according to the flight plans. This initial assumption contributed to the fact that neither air traffic controller noticed Virgin 901 and Finnair 473 approaching each other at FL 360 deviating from the original flight levels.

Another factor contributing to the incident is that the Short Term Conflict Alert (STCA) system was not in use in the air traffic control.

4 SAFETY RECOMMENDATIONS

In this case the Short Term Conflict Alert (STCA) system would have alerted the air traffic controller of the conflict 60 s (8 NM) before the flight paths crossed and the loss of separation could have been avoided. The system was not in use because it generated a considerable number of nuisance alerts. Tampere ACC reactivated the STCA system soon after this incident for use but only above FL 200 in order to reduce the number of nuicance alerts.

1. The FCAA should as soon as possible take the existing STCA systems into use to the extent they can be used without a great number of nuisance alerts.

2. The FCAA should acquire a well-functioning STCA system to those ATC units which give radar services.

Finnair 473 initiated its cleared descent during TCAS TA. Soon afterwards Finnair 473 received an RA to descend, but the advisory could also have been “climb”, making it necessary for the crew to change the direction of the manoeuvre.

3. Finnair Oyj should in its pilots’ TCAS training emphasise that if a descent or climb according to ATC clearance is initiated during TA, the eventual RA can be in the opposite direction. If the clearance and RA are contradictory, RA shall be followed.

Helsinki, August 6, 2003

Tero Lybeck

Timo Uramaa

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Ville Hämäläinen

Annex 1 Radio traffic

RADIO TRAFFIC ON EFES ACC FREQUENCIES 132.325 MHZ/125.4 MHZ, COMBINED SECTORS 4 AND 5 ON OCTOBER 29, 2002 AT 12.11 – 12.42 UTC

12.11.00	VIR 901:	Tampere control good afternoon, Virgin 901, flight level 350
	ACC:	Good afternoon Virgin 901, Tampere, radar contact, climb to flight level 360
12.11.10	VIR 901:	Flight level 360, Virgin 901
	ACC:	Tampere
12.11.20	ACC:	Virgin 901, 360 will be your final level
	VIR 901:	901 copied
12.13.00	JAL 401:	Tampere control, Japanair 401, over AGAMO
	ACC:	Japanair 401, Tampere control, radar contact
12.13.10	ACC:	Japanair 401, descent to flight level 380
	JAL 401:	Descend to flight level 380, Japanair 401
	ACC:	Radar
12.13.40	SEGXY:	Good afternoon Tampere, SEGXY 90, maintaining
	ACC:	Good afternoon SEGXY, Tampere, radar contact
12.16.30	FIN 473:	Iltapäivää Tampere control, Finnair 473, flight level 360
	ACC:	Iltapäivät Finnair 473, Tampere, radar contact, cleared ORIMAA 2E transition runway 22 left
12.16.40	FIN 473:	ORIMAA 2E 22 left, Finnair 473
	ACC:	Tampere
12.18.00	KLM 868:	Tampere control good day, KLM 868
	ACC:	Good day KLM 868, Tampere, radar contact, squawk 2005 and descend to flight level 380 confirm now 390
12.18.10	KLM 868:	We are at flight level 390, descending flight level 380, squawk 2005, KLM 868
12.18.20	ACC:	Tampere
12.21.10	ACC:	Allnippon 201, contact Tampere 121,3
	ANA 201:	121,3 thank you very much, Allnippon 201
12.21.40	KLM 868:	KLM 868, maintaining flight level 380
	ACC:	KLM 868
12.24.20	SEGXY:	Tampere SXY, standing by for descent
	ACC:	SXY, cleared for descent, QNH 1000 transition level 55
	SEGXY:	Leaving 90, QNH 1000 t-level 55, SXY
	ACC:	Tampere
12.25.30	Y 24:	Tampere radar, Y 24, climbing passing flight level 160 to 210
	ACC:	Y 24, Tampere, arrival route DIPAR 1B runway 30
	Y 24:	DIPAR 1B runway 30, Y 24
12.26.40	ACC:	SXY, contact Varkaus AFIS 120,4
	SEGXY:	120,4 SXY

12.27.30	GAO 615L:	Tampere iltapäiviä Golden 615L, passing flight level 85 for 120
	ACC:	Terve Golden 615L, Tampere, radar contact, runway 22 left
12.27.40	GAO 615L:	Runway 22 left for 615L
	ACC:	Tampere
12.27.50	ACC:	Golden 615L, proceed direct to KUVAK when passing 100 and keep up speed you are number one to ORIMAA
12.28.00	GAO 615L:	When passing 100 direct to KUVAK high speed for 615L, kiitos
	ACC:	Tampere
12.28.40	ACC:	Allnippon 205, contact Tampere 127,1
	ANA 205:	127,1, Allnippon 205
12.29.30	ACC:	Y 24, when ready descent to flight level 100
	Y 24:	Cleared down to 100, Y 24
	ACC:	Tampere
12.29.50	ACC:	And Y 24, arrival route is DIPAR 2B runway 30
	Y 24:	Okay, DIPAR 2B runway 30, Y 24
12.30.00	FIN 416:	Tampere terve Finnair 416, passing level 270 climbing level 360
	ACC:	Finnair 416, Tampere, radar contact, runway 22 left
	FIN 416:	22 left, Finnair 416
12.30.30	ACC:	Finnair 473, when ready descent to flight level 130
	FIN 473:	When ready descent to flight level 130, Finnair 473
12.31.10	GAO 615L:	Golden 615L, flight level 120 maintaining
	ACC:	Golden 615L
12.31. 40	Y 24:	Y24 leaving level 210 down to flight level 100
	ACC:	Y24
12.31.50	ACC:	Japanair 421, contact Tampere 127,1
	JAL 421:	127,1 Japanair 421
12.33.10	FIN 473	Rovaniemen alue, Finnairin 473, we are starting TCAS descent
12.33.20	ACC:	Finnair 473, roger
12.33.30	ACC:	Y 24, contact radar 127,0
	Y 24:	Radar 127,0, Y 24
12.33.40	VIR 901:	Virgin 901, we are TCAS RA, TCAS RA climbing
	ACC:	Virgin 901, roger
12.34.10	FIN 473:	Tampere control, Finnair 473, we continue descent flight level 130 and we make report of this
12.34.20	ACC:	Finnair 473
12.34.40	VIR 901:	Control, Virgin 901
	ACC:	Virgin 901, you are now clear of traffic
12.34.50	VIR 901:	Did you copy that TCAS RA?
	ACC:	Affirmative
12.35.00	ACC:	Virgin 901, contact Tampere 127,1, good bye now
	VIR 901:	127,1
12.35.10	VIR 901:	Do you have the other aircraft callsign to tell? The aircraft callsign that caused that TA, RA.
12.35.20	ACC:	Finnair 473
	VIR 901:	Thank you
12.35.30	FIN 473:	Tampere, 473, mikäs ton Virginian kutsu oli?

	ACC:	Virgin 901
12.35.40	FIN 473:	901 kiitos
	FIN 396:	Tampere päivää, Finnair 396, level 280
	ACC:	Finnair 396, Tampere, radar contact, runway 22 left
12.35.50	FIN 396:	22 left 396
	ACC:	Finnair 473, speed 250
	FIN 473:	Speed 250, Finnair 473
12.36.10	ACC:	Golden 615L, when ready descend to flight level 100, leave KUVAK on heading 215
12.36.20	GAO 615L:	Descend to flight level 100, leave KUVAK on heading 215 Golden 615L
	ACC:	Tampere.
12.36.30	ANA 209:	Tampere control, Allnippon 209, flight level 390 over AGAMO
	ACC:	Allnippon 209, radar contact, squawk 2006 and descent to flight level 380
12.36.40	ANA 209:	Squawk 2006 flight level 380, Allnippon 209
	ACC:	Tampere
12.37.20	ACC:	Golden 615L, proceed direct to KORSO
	GAO 615L:	Direct to KORSO, Golden 615L
	ACC:	Tampere
12.37.40	GAO 615L:	Golden 615L, leaving flight level 120 for 100
12.37.50	ACC:	Finnair 396, expect 3 minutes delay expected approach time at 12.55, time is now 38
12.38.00	FIN 396:	Time 55 expect approach, 396, we reduce speed
	ACC:	396
12.38.00	GAO 615L:	Golden 615L, left flight level 120 for 100
	ACC:	Golden 615L, keep up speed, contact Helsinki 129,85 terve
12.38.10	GAO 615L:	Will contact Helsinki 129,85, Golden 615L, hei
12.38.20	GAO 332:	Tampere radar iltapäivää, Golden 332, passing level 190
	ACC:	Golden 332, radar contact, runway 22 left
12.38.30	GAO 332:	Runway 22 left, Golden 332
12.39.30	ACC:	Finnair 473, continue descent to flight level 100
	FIN 473:	Flight level 100, Finnair 473
12.40.00	FIN 290:	Tampere päivää, Finnair 290, flight level 100 climbing 160
	ACC:	Päivää Finnair 290, Tampere, radar contact, runway 22 left
12.40.10	FIN 290:	22 left, Finnair 290
12.41.40	FIN 3361:	Tampere control, Finnair 3361, level 166 for 230 to ANTON
12.41.50	ACC:	Finnair 3361, Tampere, radar contact, climb to flight level 290
	FIN 3361:	Climb to 290, 3361
12.42.00	ACC:	Finnair 473, contact Helsinki 129,85 terve
	FIN 473:	129,85, Finnair 473 terve