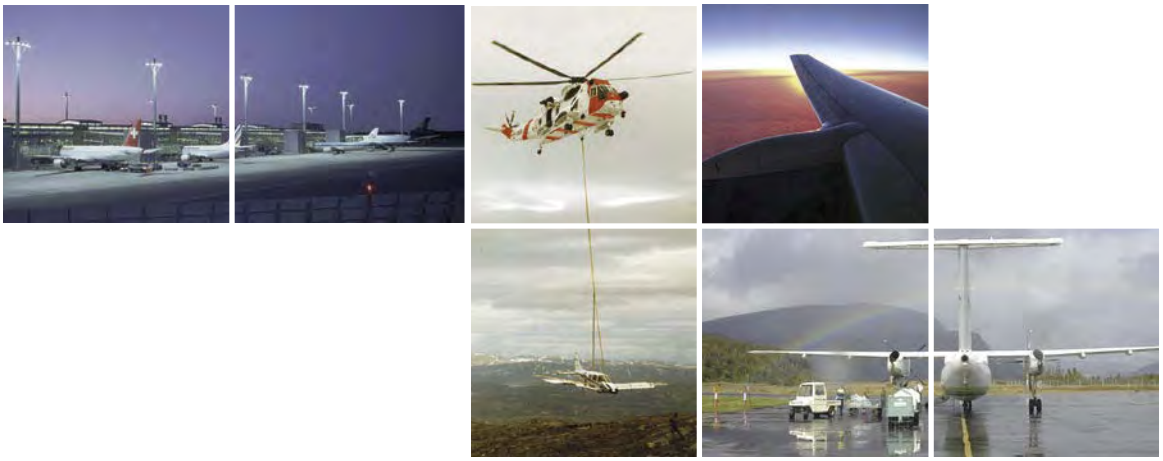
aibn Accident Investigation Board Norway

Issued September 2011

REPORT SL 2011/25



REPORT REGARDING SERIOUS INCIDENT OVER SVENSHEIA IN VEST-AGDER COUNTY, NORWAY 7 JANUARY 2006, AIRPROX BETWEEN SAS925 AND KLM1174

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This report has been translated into English and published by the AIBN to facilitate access by international readers.
As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

The Accident Investigation Board has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety should be avoided.

Photos: AIBN and Trond Isaksen/OSL

CONTENTS

REPORT ON SERIOUS INCIDENT

Aircraft:	1. Airbus 330-300 2. Fokker 70
Nationality and registration:	1. Danish, OY-KBN (SAS925) 2. Dutch, PH-JCT (KLM1174)
Persons on board:	1. 13 crew and 258 passengers 2. Unknown number of crew and 76 passengers
Owner:	1. SAS Scandinavian Airlines (SAS) 2. KLM Royal Dutch Airlines (KLM) Cityhopper
Incident site:	At flight level 340, north of Svensheia (SVA) in Oslo AoR, over Søgne in Vest-Agder County.
Incident time:	Saturday 7 January 2006, 1342 hours

All hours stated in this report are local time (UTC + 1 hour) unless otherwise indicated.

NOTIFICATION REGARDING INCIDENT

The Accident Investigation Board Norway (AIBN) was notified by telephone by SAS, Sweden, approx. two hours after the incident.

SUMMARY

SAS925 and KLM1174 were on crossing courses over Svensheia in Southern Norway. Both flew at the assigned altitude, flight level 340. The air traffic controller on duty discovered the conflict as the aircraft were approx. 8-9 NM from each other, and instructed both to turn 30 degrees right, which only SAS925 did. About the same time, both aircraft received instructions from the airborne anti-collision system TCAS (Traffic Collision Avoidance System) to climb and descend respectively. The risk of a collision was avoided by the flight crew following their respective TCAS RA instructions (Resolution Advisory). As a result of this, the minimum horizontal distance between the aircraft, without vertical separation of 1,000 ft. was safeguarded, was 2.7 NM.

Through this investigation, the Accident Investigation Board believes it has identified the causes of the violation of separation minima, which can be linked to the Air Traffic Control Service. There were system weaknesses related to the layout of the Flight Progress Board and distribution of Flight Progress Strips, which made the air traffic controller's conflict search difficult. Furthermore, it was identified that the ground-based safety net STCA (Short Term Conflict Alert), that was supposed to notify the air traffic controller if the defined separation minima were in the process of being violated, issued warning later than assumed.

The national Air Navigation Services provider (ANSP) Avinor has implemented a number of improvement measures following the incident. The Accident Investigation Board has

found that the measures, as they are currently implemented, contribute to the prevention of similar incidents. No safety recommendations are issued in this report.

1. FACTUAL INFORMATION

1.0 Background information

The incident took place at flight level (FL) 340, 2-3 NM north of Svensheia in Vest-Agder County. Svensheia (SVA) DVOR/DME is a key reporting point for en route traffic crossing Southern Norway. The air space is part of Oslo AoR, Sector Skagerrak.

KLM1174 was en route from Trondheim Airport Værnes (ENVA) to Amsterdam Airport Schiphol (EHAM) at flight level 340. Magnetic heading was 191 degrees. The aircraft was cleared directly towards the reporting point ARTIP in the Netherlands, so that it would pass approx. 2-3 NM north of SVA.

SAS925 was en route from Copenhagen Airport Kastrup (EKCH) to Washington Intl. Airport Dulles (KIAD), also at flight level 340. Magnetic heading was 305 degrees. The aircraft was cleared directly towards the reporting point GUNPA in the North Sea between Shetland and Norway, so that it would pass approx. 2-3 NM north of SVA.

Figure 1: Flights SAS925 and KLM1174 in Sector Skagerrak[1], Oslo ATCC.

1.1 History of the flights

1.1.1 Chronological course of events seen from the ATCO's working position

1.1.1.1 Flight Progress Strips for the two flights KLM1174 and SAS925 were available well in advance before the aircraft entered Sector Skagerrak. Control data for both flights were correct, with the exception of the route indications on the Flight Progress Strips which were not correct, because both aircraft had been re-cleared by adjacent sectors for direct routes.

1.1.1.2 After the direct route "ARTIP" for KLM1174 had been coordinated by telephone with the air traffic controller (ATCO) in the adjacent sector, the ATCO in Sector Skagerrak wrote "ARTIP" on the Flight Progress Strip (See Figure 2).

[1] *The sectorization of Oslo AoR was changed with implementation of Oslo ASAP (Advanced Sectorization Automatic Project), 7 April 2011.*

1.1.1.3 The Copenhagen ATCC (ATCC) had recorded entry point KOPIN for flight KLM1174, but on the Flight Progress Strip it was recorded as TUGSU in Sector Skagerrak. Due to the discrepancy, the ATCO in Sector Skagerrak had the ATC assistant establish a telephone contact with the relevant ATCO at the Copenhagen ATCC. The ATCO in Sector Skagerrak was then involved in establishing a new exit point for the flight plan for KLM1174, so that the flight plan could be exchanged electronically between the two air traffic control centres.

Figure 2: Copy of relevant Flight Progress Strips.

1.1.1.4 Two Flight Progress Strips were used for SAS925, one entering the sector via AMSEV and one exiting the sector via SVA. The first Flight Progress Strip was removed when SAS925 reported to the sector. SAS925 was then represented by one Flight Progress Strip, in a blue flight progress strip holder[2], which was in the SVA section, to the right on the flight progress board (see figure 3).

1.1.1.5 As the direct route was not recorded in the flight plan data system, KLM1174 was only presented with one Flight Progress Strip, which displayed route SKI-TUGSU (See Figure 2). The ATCO placed the Flight Progress Strip for KLM1174 in the left section, in a blue Flight Progress Strip holder. As a result, the Flight Progress Strips for the two flights SAS925 and KLM1174 were not in the same section on the traffic board.

[2] *In accordance with RFL II GEN-7, instructions for recording of flight progress strips (FPS), chapter 5, blue is used for northbound IFR flights (091-270 degrees), whereas yellow is used for southbound IFR flights (091-270 degrees).*

Figure 3: Showing the Flight Progress Board in Sector Skagerrak, with five sections, and the use of yellow and blue Flight Progress Strip holders (Note: The Flight Progress Strips are not from the actual incident).

1.1.1.6 Cleared flight level, 340, for both flights were written on the Flight Progress Strips by the air traffic controller (ATCO) as the flights reported on the Sector Skagerrak frequency. The flight direction was noted by the ATC assistant, whereas the direct route indication was entered by the ATCO. It was only the Flight Progress Strip for KLM1174 that was signed direct route indication, ”ARTIP”.

1.1.1.7 The flight crew on KLM1174 checked in on the Sector Skagerrak frequency at 1329 hours, and reported that they were at FL340. The ATCO Sector Skagerrak responded with ”KLM1174 Oslo Roger”.

1.1.1.8 7 minutes later, the flight crew on SAS925 checked in on the same frequency, and reported that they were at 32 300 ft., climbing to FL340, heading towards reporting point GUNPA. The ATCO Sector Skagerrak responded with ”Scandinavian 925 Oslo Roger”. However, the flight crew did not report having reached FL340. The two aircraft were on crossing courses, and SAS925 was in the process of reaching the same flight level as KLM1174.

1.1.1.9 At the same time, a third aircraft, with call sign KLM1144, was in Sector Skagerrak (see Figure 4). KLM1144 flew at flight level 320. The aircraft was in the process of leaving Sector Skagerrak in south by southwest direction, when the ATCO at 1341 hours instructed the flight crew on KLM1144 to switch to the relevant Copenhagen ATCC radio frequency.

1.1.1.10 A fourth aircraft, with call sign JXX102, was in the process of leaving the sector westwards at flight level 360 (see Figure 4). This flight had received revised flight level from 320 to 360 by Copenhagen ATCC.

1.1.1.11 The ATCO in Sector Skagerrak has explained that he had a mental image that the two flights, KLM1174 and SAS925, were at different flight levels, 340 and 360 respectively, and that the aircraft accordingly were separated vertically. He has further explained that he “was shocked” when he suddenly discovered on the radar screen that the two flights were at the same flight level 340, on crossing courses. His first thought was that SAS925

must have levelled off at FL340 when ascending to FL360, without reporting this to the ATCC.

Figure 4: Section of radar image at approx. 1340 hours. Flight KLM1174 and SAS925 are on crossing courses at FL340. The air traffic controller had prepared distance and direction (yellow line) from KLM1174 in the direction of reporting point "ARTIP". JXX102 flies at FL360, and is exiting Sector Skagerrak westwards. KLM1144 flies at FL320, and is exiting the sector in a SSW direction.

1.1.1.12 The time was almost 1342 hours when the ATCO Sector Skagerrak discovered the conflict between SAS925 and KLM1174. The distance between the aircraft was approx. 8-9 NM.

1.1.1.13 1342 to 1343 hours

When the ATCO discovered the conflict, he immediately contacted SAS925, and gave instructions for a 30 degree right turn. SAS925 read back that they were turning 30 degrees right.

The ATCO then contacted KLM1174, with instructions to turn 30 degrees right. The ATCO started the radio transmission with "KLM1144", but corrected this to "… 74". The flight crew on KLM1174 did not answer the call.

SAS925 contacted the section Skagerrak frequency and asked the ATCO to confirm the instructions regarding right turn. In the radio-communication, the TCAS instruction "climb" can be heard in the background.

The ATCO again contacted KLM1174 and gave instructions for an immediate right turn due to traffic.

On the radar screen in working position Sector Skagerrak the STCA [3] conflict warning (STCA PC, predicted conflict) was displayed (13:42:33 hours). The radar labels for the

[3] *Short Term Conflict Alert (STCA) "To assist the controller in preventing collision between aircraft by generating, in a timely manner, an alert of a. potential or actual infringement of separation minima", cf. Eurocontrol.*

two call signs SAS925 and KLM1174 turned yellow, and an arrow was displayed in the extension of each track. A straight line between the two tracks marked where the two aircraft would come closer to each other than 5 NM. At this time the distance was 5.9 NM.

KLM1174 contacted Sector Skagerrak and reported “TCAS descend”.

STCA conflict alert (STCA CA, conflict alert) was displayed at the next updated data on the radar screen (13:42:37 hours). The distance between the aircraft was then approx. 4-9 NM. Visually on the radar screen, the labels for SAS925 and KLM1174 had shifted from yellow to red.

SAS925 and KLM1174 followed their respective TCAS RA instructions, “TCAS climb” and “TCAS descend” respectively. The regulatory minimum requirements for vertical separation between aircraft of 1 000 ft. was achieved at 13:42:49 hours. The horizontal distance between the aircraft was then 2.7 NM.[4]

1.1.1.14 1343 to 1344 hours

SAS925 reported that they had performed “TCAS climb” and had visual contact with the other aircraft. The ATCO confirmed receipt of the message and instructed SAS925 to resume own navigation towards the reporting point GUNPA. SAS925 returned to cleared cruising altitude FL340.

KLM1174 reported immediately afterwards that they had performed “TCAS descend” and that they were returning to FL340. The ATCO confirmed receipt of the message and instructed KLM1174 to resume own navigation towards the reporting point ARTIP.

The ATCO then contacted the operational supervisor in the control room, and informed him of the fact that he had had a TCAS incident in Sector Skagerrak. The ATCO was relieved from the working position two minutes later.

1.1.2 Manoeuvring of SAS925

1.1.2.1 The Commander on SAS925 has explained in his report that they, south of Svensheia, received instruction from the Oslo ATCC to make a 30 degree right turn. The turn was performed from 305 degrees to 335 degrees. The flight crew made visual registration of an aircraft at "one o'clock" in direction towards them. The TCAS display in the cockpit showed that the other aircraft was on the same flight level. The flight crew received the TCAS RA instruction “Traffic – climb”.

1.1.2.2 The aircraft continued to climb until the flight crew received the TCAS instruction “Adjust vertical speed” followed by “Clear of conflict”. Ground speed during the climb was reduced from 529 to 525 kt. The TCAS RA climb instruction was active for 38 seconds (from 13:42:26 hours to 13:43:04 hours). Playback of the aircraft's flight data recorder (FDR) shows that SAS925 climbed to pressure altitude 34 594 ft. - an increment of 590 ft.

1.1.2.3 The FDR shows that the aircraft commenced its right turn at 13:42:14 hours. During the seconds leading up to 13:42:35, the magnetic heading was changed from 305 degrees to 323 degrees. The course was then gradually adjusted back to 305 degrees, which was reached at 13:44:34 hours.

[4] *The applicable separation minimum in the actual airspace was 5 NM horizontally or 1 000 ft vertically.*

1.1.3 Manoeuvring of KLM1174

1.1.3.1 KLM1174 maintained a constant course of 191 degrees. The air traffic controller's second instruction regarding turning 30 degrees right was issued at the same time as the flight crew received the TCAS RA descend instruction. It is not known whether the flight crew heard the air traffic controller's two instructions for a 30 degree right turn. However, they did not turn, but followed the TCAS RA descend instruction. In its report, the flight crew has stated that they had visual contact with the other aircraft**,** and that they estimated the distance at passing to be 1 200 ft. vertically, 0 horizontally.

1.1.3.2 Reading of FDR data shows that the TCAS RA descend instructions lasted for 37 seconds (from 13:42:29 - 13:43:06 hours). During descent ground speed was reduced from 359 kt to 355 kt. KLM1174 descended to pressure altitude 33 329 ft. - a decrease of 690 ft.

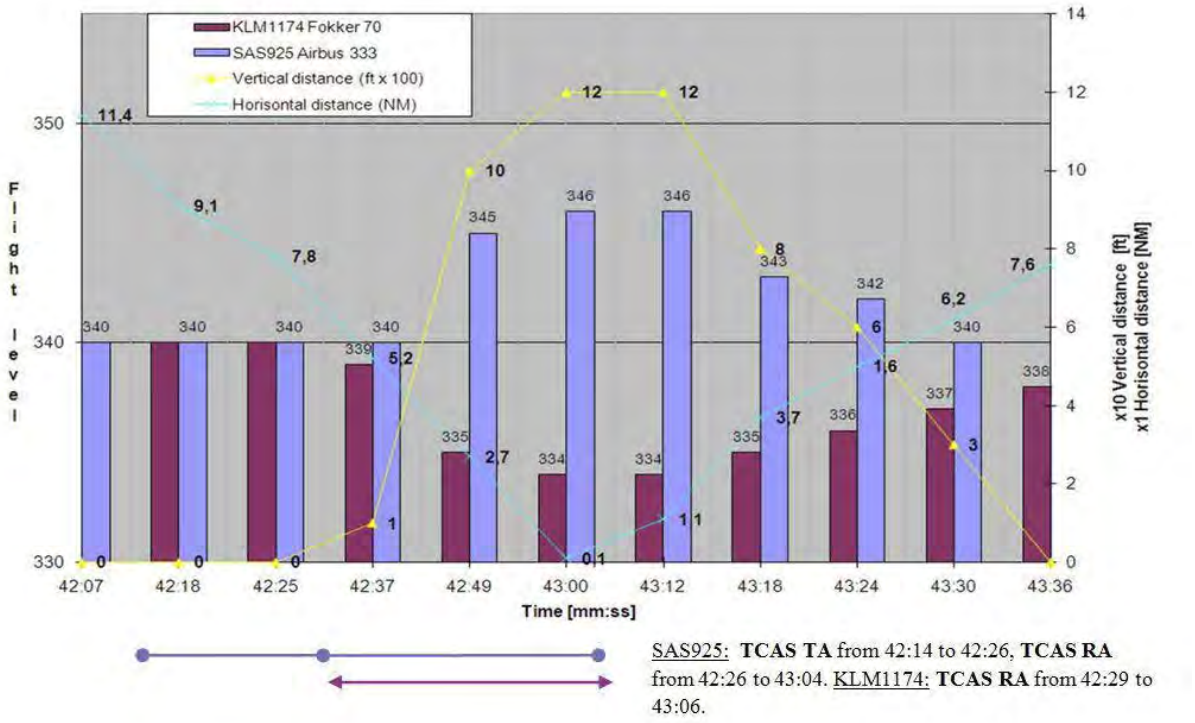

Figure 5: The blue and purple columns show how SAS925 and KLM1174 respectively responded to their TCAS RA instructions. Vertical separation of 1 000 ft. was achieved at 13:42:49 hours. The horizontal distance was then 2.7 NM. The aircraft passed almost right above each other. The smallest horizontal distance between the aircraft was 0.1 NM (12:43:00 hours). The vertical separation was then 1 200 ft. Note: The scale is not constant as regards number of seconds between each column.

1.2 Injuries to persons

None.

1.3 Damage to aircraft

None.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Flight crew

Personnel information and experience of the involved flight crews have not been obtained, as this does not appear relevant for the incident.

1.5.2 Air traffic controller Sector Skagerrak

1.5.2.1 The ATCO in Sector Skagerrak had long experience as an air traffic controller and was certified and authorised with all the necessary rights to exercise air traffic control service at the Oslo ATCC and the relevant sectors.

1.5.2.2 His service time was in compliance with regulations. The ATCO had been on duty the previous day, and before that, he had had two days off. According to himself, he had a good night's sleep the night before, and he felt rested.

1.5.2.3 He arrived at work at 0900 hours and had been on duty in sector South/East from 1030 until 1130 hours, followed by a break. From 1230 hours he had been on duty in Sector Skagerrak for just over an hour when the incident took place.

1.5.3 ATC assistant

The ATC assistant assisted the on-duty air traffic controllers in Sector South/East and Sector Skagerrak with handling telephone communications and flight plan data. He had the necessary training to exercise his duty in accordance with applicable regulations and instructions. The ATC assistant's decisions have not impacted the incident.

1.6 Aircraft information

There are no reports of technical irregularities with the involved aircraft. Both aircraft were equipped with anti-collision system TCAS II version 7 [5].

1.7 Meteorological information

The incident took place in daylight with good visibility.

1.8 Aids to navigation

No irregularities reported.

1.9 Communications

No irregularities reported and with normal, good readability.

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[5] "With effect from January 1, 2005, all civil fixed-wing turbine-engine aircraft having a maximum certificated take-off mass exceeding 5,700 kilograms, or a maximum approved passenger seating configuration of more than 19, will be required to be equipped with ACAS II. […]

The Airborne Collision Avoidance System II (ACAS II) has been introduced in order to reduce the risk of mid-air collisions or near mid-air collisions between aircraft. It serves as a last-resort safety net irrespective of any separation standards. […] Currently, the only commercially available implementation of ICAO standard for ACAS II (Airborne Collision Avoidance System) is TCAS II version 7.0 (Traffic alert and Collision Avoidance System)."
Source www.eurocontrol.int/acas

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The aircraft were equipped with flight recorders (Flight Data Recorder – FDR). FDR data were downloaded and were useful for the Accident Investigation Board's investigation.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not investigated.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Test and research

None.

1.17 Organisation and management

1.17.1 The airlines

The Accident Investigation Board does not consider it necessary to obtain and include information about the airlines in this case, as both aircraft were equipped with the anti-collision system TCAS which worked as intended, and both flight crews followed their respective TCAS RA instructions, according to ICAO's guidelines.

1.17.2 Avinor AS

Avinor AS operates 46 airports in Norway, of which 12 are in cooperation with the armed forces. The activity also includes air traffic control – Air Navigation Service – ANS [6]. Avinor was previously a part of the government-owned Norwegian Air Traffic and Airport Management, but was established as a separate public company, wholly-owned by the Norwegian State, on 1 January 2003. The ownership is managed by the Ministry of Transport and Communications.

Avinor is responsible for providing air navigation services in Norwegian airspace, including dedicated parts of the North Atlantic airspace.

[6] *Air traffic control – Air Navigation Service - is a general term for Air Traffic Management – ATM, aviation weather service – meteorology – MET and flight navigation service – Communication, Navigation, Surveillance -CNS.*

1.17.2.1 *Oslo Air Traffic Control Centre*

Oslo ATCC (Air Traffic Control Centre) in Norway FIR (Flight Information Region) is located in Røyken, southwest of Oslo, and is responsible for the Oslo AoR (Area of Responsibility) airspace. In addition to the area control service, the unit also handles approach to the airports Gardermoen, Rygge, Torp, Skien and Notodden.

1.17.2.2 *Reorganisations in Avinor "Take-Off-05"*

A government-initiated process was implemented in Avinor in 2003. Avinor's result improvement program[7], "Take-Off-05"'s objective was to reduce the annual operating costs by NOK 400 million, starting in 2006. At the same time, the Government made a demand that the changes would not result in a deterioration of safety or services.

In October 2004, the Avinor board decided to reduce the number of air traffic control centres in Norway from four to two. No air traffic controllers would lose their jobs, but workplaces would be moved for those who worked at the Oslo and Trondheim ATCC. Trondheim ATCC was closed down, and the area of responsibility was transferred to Bodø ATCC. It was decided that the Oslo ATCC was to close in 2008. Oslo ATCC's area of responsibility would be divided between the air traffic control centre in Stavanger ATCC and a new approach control for Eastern Norway, that would be located at Oslo Airport, Gardermoen. However, the move from Oslo ATCC was not implemented.

From the Norwegian governmental White Paper no. 15. 2006-2007, "About the activity in Avinor 2003 -2005" the following is quoted:

> *"Avinor AS was established on 1 January 2003. The company was in a difficult financial situation at the time. A cost-cutting programme, «Take-off -05», was to contribute to reducing costs. Reorganisations in connection with «Take-off -05» were mainly carried out within airport operations. There has been unrest in the air traffic control service and it has been difficult to carry out reorganisations. In 2005 there were several interruptions of services in this section of Avinor. In order to contribute to calm in the company, the managing director resigned at the end of 2005."*

1.17.3 The work situation in the control room

1.17.3.1 According to the air traffic controller involved, the working environment at Oslo ATCC had been characterised by frustration and dissatisfaction related to the future moving of workplaces for a long time, as established in "Take-off-05". However, the atmosphere in the control room was quiet and calm this morning.

1.17.3.2 At the Oslo ATCC there was a duty roster on the morning in question that included planning controllers (PC), who could be used as reinforcements together with radar controllers (RC), in sectors as needed. Because of periodic high absence due to illness, there were two or three additional air traffic controllers on the rosters compared with the regular staff roster.

1.17.3.3 Three ACC radar positions were operational (Sector North/west, Sector South/east and Sector Skagerrak). In addition, the working positions for Oslo Approach and Farris

[7] *The improvement program was discussed in the AIBN report "Safety in Norwegian aviation during the process of change" (SL RAP 35/2005)*

Approach were manned, as well as the working positions for operational and administrative supervisor.

1.17.3.4 The sectors South/east and Skagerrak were manned with three air traffic controllers who relieved each other so that two air traffic controllers manned their own position, while the third was on break. The position to the right of Sector South/east and Sector Skagerrak was manned by an ATC assistant, who assisted the two air traffic controllers with processing of flight plan data.

1.17.3.5 Sector Skagerrak was the sector at Oslo ATCC that had the most converging traffic at cruising altitude. Scheduled traffic volume in Sector Skagerrak in the hour before the incident was 15 movements per hour. The maximum sector rate was 28 movements per hour. The sector's workload can, however, not be described based on static volume of traffic alone. The air traffic controller's workload is also impacted by dynamic factors such as complexity (converging routes, climb/descend), a combination of various aircraft types, coordination volumes, as well as status of technical aids and weather conditions.

1.17.3.6 Neither the operative supervisor nor the air traffic controller in Sector Skagerrak considered the workload in the sector to be such that there was a need for reinforcements. If there had been such a need, it would be possible to add more resources in terms of staffing. However, a separate reinforcement position in the form of a planning controller in connection with the Sector Skagerrak working position had not been established.

1.17.3.7 The air traffic controller had been on duty in working position Sector Skagerrak for just over an hour when the incident took place. He described the traffic load in Sector Skagerrak at the time of the incident as low, following a previous period with moderate activity.

1.18 Other information

1.18.1 Management and display of flight plan data

1.18.1.1 The NATCON system at Oslo ATCC does not use electronic Flight Progress Strips. The Flight Progress Board with its sections, section divisions and paper Flight Progress Strips, helps the air traffic controller to keep a mental picture of the traffic situation in the applicable sector. Assuming that the number of Flight Progress Strips is sufficient, that they have been completed correctly and that section division is good, the Flight Progress Board is important for the air traffic controller in his/her work to detect and respond to any conflicts that may occur between aircraft.

1.18.1.2 During an interview with the air traffic controller in Sector Skagerrak, it emerged that the coordination with the adjacent sector prior to arrival of the two flights KLM1174 and SAS925 into own sector, had been routine. The course changes which had been coordinated were also passed on by the air traffic controller in Sector Skagerrak to the next sector; Copenhagen and Stavanger ATCC respectively.

1.18.1.3 During the Accident Investigation Board's interview with the air traffic controller Sector Skagerrak, he informed that working on flight plan data while also monitoring the radar could be challenging as regards to keeping dynamically updated on the traffic situation.

1.18.2 Direct routes

1.18.2.1 In order to provide good service to the airlines, it was common to meet requests from crews for direct routes, as long as this was compatible with the traffic situation. The use

of direct routes is also often regarded as being preferred by air traffic control, in order to prevent conflict situations.

1.18.2.2 As KLM1174 had received clearance for a direct route to ARTIP in the Netherlands, the aircraft did not pass the original crossing point for the border between Oslo and Copenhagen AoR, as indicated in the flight plan.

1.18.2.3 There were no clear guidelines at Oslo ATCC for how direct routing should be visualised on the Flight Progress Board if the direct route resulted in an incomplete set of Flight Progress Strips being produced, as was the case for KLM1174.

1.18.2.4 The flight plan data system is not always manually updated for direct routes. Such an update would probably have resulted in the next air traffic control centre, Copenhagen ATCC, receiving timeout in its automatic transmission of the KLM1174 flight plan from the Oslo ATCC. This is because the exit point from Sector Skagerrak would not match Copenhagen ATCC's recorded entry point. Such discrepancies resulted in the need for coordination by telephone between the air traffic control centres - as was the case the actual day.

1.18.3 Identification and resolving of conflicts

1.18.3.1 Despite flying on converging routes, 191° and 305°, both aircraft, KLM1174 and SAS925, had the correct altitude in accordance with the semi circular flight level rule [8] (FL340). As a tool to identify conflict situations such as this, the air traffic controller had Flight Progress Strips located on the Flight Progress Board. In addition, he/she had radar functions such as MINSEP [9] and PTL available to determine the internal distance between the aircraft, and STCA functioned as conflict warning.

1.18.3.2 The are no established rules for which evasive manoeuvres the air traffic controller should instruct the Commander to carry out in various situations where loss of separation minima is in the process of occurring. The type of airspace, other nearby traffic, the type of aircraft, etc., will impact the decision.

1.18.3.3 Chapter 15, item 6.3 in RFL I ("Rules for air traffic control") applies to "Methods for aircraft equipped with Airborne Collision Avoidance System (ACAS)". From subsection 6.3.1 the following is quoted:

> *"The same methods will be used when exercising air traffic control to ACAS-equipped aircraft as those used for aircraft that are not equipped with ACAS. As regards the prevention of collisions, provisions regarding the establishment of described separation and information that may be relevant to provide regarding a conflict and potential evasive manoeuvres in particular, the method must be in compliance with the normal methods for air traffic control. When exercising the service, the possibility of the aircraft being equipped with ACAS must not be taken into consideration."*

[8] *For IFR traffic, the semi circular flight level rule means that magnetic heading between 0 and 179 degrees are to be flown at odd-numbered altitudes (in whole 1,000 ft.), whereas even-numbered elevations apply to headings between 180 and 359 degrees.*

[9] *MINSEP (minimum separation) displayed the minimum horizontal distance between two aircraft, if heading and speed remained unchanged. PTL (Predicted track line, a distance and direction) could be selected by the air traffic controller as part of a conflict search, and displayed the future horizontal position of the aircraft, assuming that heading and speed were maintained.*

RFL I, chapter 15, subsection 6.3.2, continues:

> *"If the flight crew carries out an evasive manoeuvre based on a proposed evasive manoeuvre (RA) from the aircraft's ACAS, the air traffic control service will not attempt to change aircraft's flight path before the flight crew reports that the instructions/clearances that were followed originally are resumed, but will provide traffic information as needed."*

1.18.3.4 In the document "CAP717 Radar control – Collision avoidance Concepts", the British air navigation service NATS provides recommendations for which evasive manoeuvres the air traffic controller should chiefly evaluate if various types of loss of separation minima is in the process of occurring. In the document's chapter 6.13 – "90° closure – both aircraft in level flight" one of the recommend solutions is:

> *"Turning both aircraft in the same direction, i.e. both left and both right, is likely to move the aircraft apart most quickly."*

1.18.4 Safety nets

1.18.4.1 Safety nets are additional safety barriers in the form of ground-based or airborne systems that will intervene if all other barriers for maintaining separation minima between aircraft have failed. An example of a ground-based safety net is Short Term Conflict Alert (STCA). Traffic Alert and Collision Avoidance System (TCAS) is considered an airborne system.

Many articles have been published on STCA and TCAS. Below are some extracts from an Eurocontrol article from 2007, "Hindsight No. 5":

> *"[...] Implementation details of STCA vary widely between ATC systems. They include different algorithms, warning times and type of alerts. STCA does not provide controllers with advice on how to resolve a conflict – this decision is always made by the controller. TCAS, in contrast, operates according to uniform, word-wide ICAO standard. TCAS produces vertical collision avoidance advice in form of Resolution advisory (RAs) which pilots are required to follow. TCAS is widely considered to be the last resort safety net against mid-air collisions. [...]"*

1.18.4.2 The aircraft's anti-collision system TCAS worked as intended. One aircraft (SAS925) received TCAS RA instructions to climb, whereas the other (KLM1174) was instructed to descend. The flight crews followed their respective TCAS RA instructions, in accordance with ICAO guidelines.

1.18.4.3 The air traffic controllers' radar processing and display system NATCON (Norwegian Air Traffic Control System) had implemented STCA. However, the function did not work as intended.

1.18.5 STCA implementation

1.18.5.1 We quote from the Regional regulations for Air traffic control at Oslo ATCC, Section 11, chapter 1 STCA, dated 27 November 2003:

> *"The main purpose of STCA is to notify the air traffic controller(s) regarding flights that either are in the process of, or already have, violated the established separation minima for the flights. Alarms associated with such violations will be*

displayed on the radar screen(s) of the air traffic controller(s) who control(s) the relevant flights at the time. […] "

1.18.5.2 An alarm should have been generated and distributed to the relevant radar display systems if it was determined that separation minima would be violated over the course of the next 25 seconds (STCA PC, Predicted Conflict), and if the separation minima had already been violated (STCA CA, Conflict Alert).

1.18.5.3 In the event of STCA PC, the relevant radar track labels will change colour from white to yellow. In the event of STCA CA the colour will continue to change to red. According to radar recordings from the day in question, the colour change took place. The alarm in the radar system status window was also displayed in accordance with the system specifications.

1.18.5.4 The air traffic controller did not register any audible alarm, neither with STCA PC nor STCA CA. Later examinations showed that the loudspeaker volume in working position Sector Skagerrak was turned down so low that it was not audible.

1.18.5.5 STCA conflict alert (STCA PC) was generated as late as 5-9 seconds before violation of separation minimum, and not 25 seconds before as warranted by the system specifications.

1.18.6 Implemented measures

1.18.6.1 Avinor implemented an immediate internal investigation of the incident in question over Svensheia on 7 January 2006. Their report contained seven safety recommendations, which were considered by Avinor. The incident was also reviewed by the Civil Aviation Authority in cooperation with Avinor in January 2006.

1.18.6.2 Over the course of 2006, all air traffic controllers at Oslo ATCC underwent training in emergency procedures, with special emphasis on quick intervention to maintain minimum separation during a STCA PC conflict warning.

1.18.6.3 The audibility of the alarms in all working positions at Oslo ATCC was checked. The volume adjustment knobs for the audio alarm were later modified, so that they could not be turned down. Until 2011, all types of alarms had identical audio. The Accident Investigation Board has been informed that this was changed with effect from February 2011. Since then, the audio alarms have been a computer voice stating the nature of the alarm. For STCA in particular, the alarm is: "Predicted conflict, predicted conflict" or "Conflict alert, conflict alert". In addition, the air traffic controller can verify the volume by performing an audio check.

1.18.6.4 Upon recommendation from the Civil Aviation Authority, Oslo ATCC decided to change the flight progress board in Sector Skagerrak. Zone search was introduced, as it emerged that point search did not work well in Sector Skagerrak.

Quote from Local regulations, Oslo ATCC – Air traffic control - INS -07, Sector Skagerrak:

"1.3.1 FPB has been set up with zone search. The air traffic controller must ensure that all flights are displayed with FPS in all zones that the flight in question touches. When using direct routes, the air traffic controller should request that the ATC assistant prints an additional FPS if this is considered necessary."

The change became effective in April 2007, and comprised dividing the sector in to three search zones (DANKO, SVA and LAVKO). According to information from Oslo ATCC division by means of zone search has been regarded as more suitable for conflict searches than the previous layout of the Flight Progress Board (see Figure 3). This applies in particular to traffic that has been given different routes than indicated on the Flight Progress Strip. The layout of the Flight Progress Board in Sector Skagerrak maintained unchanged from April 2007 until the introduction of new airspace structure in 2011 [10].

1.18.6.5 Standard staffing for Sector Skagerrak in 2006 was one air traffic controller, which still applied in 2011. As regards the physical furnishing of working positions at Oslo ATCC, at the time of the incident, a working position for the planner controller had not been established in connection with the sector Skagerrak. It has been established at a later date, which makes it easier to add a planning controller in addition to a radar controller, if the workload in sector Skagerrak should require it.

1.18.6.6 Avinor had, at the time of the incident, initiated a project to further clarify how double staffing with a radar controller (RC) and planner controller (PC) should be used at the Oslo ATCC. As a result of the project, detailed rules for how the RC/PC concept should be used in the various sectors were implemented. In terms of manning, two planner shifts for the morning and two planner shifts for the afternoon were introduced. There was at all times an operative assessment which decided which sector these should be used in.

1.18.7 Implemented measures particularly related to STCA

1.18.7.1 Shortly after the incident, Avinor Air Navigation Services, section ATM/CNS Systems development uncovered that the value for the adaptation data parameter "Predicted ahead time" was set too low – 40 instead of 70 seconds. As a result, the time parameter was not sufficient for the STCA algorithm to search through the number of search areas that were defined in the system. (A detailed description of how the STCA algorithm functioned in connection with the search areas is described in Appendix B.)

1.18.7.2 In February 2006, section ATM/CNS Systems development notified the responsible Avinor unit for adaptation data about the issue, and what they believed was the cause of the late indication of the STCA conflict warning. A change of the parameter could be done following a system restart, something that was done regularly about every four weeks. The Accident Investigation Board has been informed that the adaptation data parameter was adjusted 1 year and 10 months after the incident.

1.18.7.3 Three days after the incident, the responsible unit for adaptation data in Avinor registered a STCA change proposal (NSCR 184, dated 10 January 2006); that various vertical and horizontal search areas should be processed differently in the system, in relation to horizontal separation minima, 3 or 5 NM. Such an adjustment was an improvement of the STCA function, beyond the existing system functionality. However, the change would not remedy the late indication of the STCA conflict warning, as happened on 7 January 2006.

1.18.7.4 Upon request from the Accident Investigation Board in January 2011, Avinor stated that it had taken some time to find out what kind of solution should be selected as regards STCA and the alert time. Some solutions required software updates, while others did not. Avinor emphasised that such changes required a process to investigate/verify that the

[10] *Oslo ASAP (Advanced Sectorization Automatic Project), title of new airspace organisation in Oslo AoR, with implementation date 7 April 2011.*

changes did not introduce new risks in the system, and that, as a result, the process takes some time.

1.18.8 MTCD – Medium Term Conflict Detection

1.18.8.1 Technology such as Medium Term Conflict Detection (MTCD) makes it possible to use flight plan data for conflict search differently than using Flight Progress Strips on the Flight Progress Board. Many air traffic control centres, including in Sweden, have implemented MTCD as a conflict search tool for air traffic controllers. The NATCON system, which is used by the three Norwegian air traffic control centres, does not have MTCD.

Quote from www.skybrary.aero

> *"Medium Term Conflict Detection (MTCD) is a flight data processing system added functionality designed to warn the controller of potential conflict between flights in his area of responsibility in a time horizon extending up to 20 minutes ahead. "*

1.18.8.2 The Accident Investigation Board was informed that the Swedish air traffic control centre in Malmø has implemented MTCD as a separate screen on their radar screens. The MTCD application is called CARD, and is integrated with flight plan data system. CARD does not generate audio alarms, but instead highlights flight pairs that potentially could be in conflict. The Accident Investigation Board has been told that the MTCD function is regarded as useful, but that the system also generates some false alarms when there is crossing traffic, as well as when there is much climbing and descending traffic.

1.18.9 Previous incidents

1.18.9.1 *Related incident over Svensheia (SVA) 10 August 2001*

On 10 August 2001, an airprox occurred 15 NM south of Svensheia (SVA) at flight level 350. A Boeing 737-400 and a Boeing 737-500 passed each other at a vertical distance of approx. 500 ft. and with a horizontal distance of approx. 1.5 NM. According to the Accident Investigation Board Report No. 49 there was an actual risk of mid-air collision.

The flight crew on one of the aircraft turned left as a result of the air traffic controller's instructions, and climbed to FL358 as a result of the TCAS RA instruction. The flight crew on the other aircraft had visual contact, and did not find it necessary to change heading or altitude. The on-duty air traffic controller discovered the conflict so late that the applicable separation minima had been violated. A contributing factor was that the merged sector South/Skagerrak required the air traffic controller's attention over a vast area. In addition to ordinary traffic, there was also military exercise activity in the area. Major activity on the radio and coordination tasks related to changes in flight paths, required the air traffic controller's attention just before the incident.

The radar conflict alert function STCA was not operational at the time of the incident, due to negative experience during the operational testing period.

Based on the recommendations from Avinor's internal investigation of the incident over Svensheia on 10 August 2001, several measures were implemented that, in the view of the Accident Investigation Board, would help prevent similar incidents. The measures included documented specific criteria for when and how the sector should be merged, or

alternatively use double staffing in the sector, in the form of radar controller (RC) in combination with planning controller (PC).

After the August 2001 incident, operation information was published, including clarification of local regulations regarding application of Flight Progress Boards and Flight Progress Strips: Potential conflicts should be able to be discovered already when receiving estimates, assuming that the Flight Progress Strips were correctly placed on the Flight Progress Board. Conflict search was another topic for annual periodic updates for air traffic controllers, both theoretically and in a simulator. The work to establish a good enough STCA function for operational use continued at the Oslo ATCC.

1.18.9.2 *The accident over Üeberlingen, 1 July 2002*

Two aircraft, a Tupolev TU154M and a Boeing 757-200 aircraft collided in mid-air over Üeberlingen, Germany. The collision occurred at flight level 350. All 71 people onboard the two aircraft died in the accident.

From the report published by the German Accident Investigation Board (BFU) in May 2004 the following is quoted:

> *"The following immediate causes have been identified:*
>
> *• The imminent separation infringement was not noticed by ATC in time. The instruction for the TU154M to descend was given at a time when the prescribed separation to the B757-200 could not be ensured anymore.*
>
> *• The TU154M crew followed the ATC instruction to descend and continued to do so even after TCAS advised them to climb. This manoeuvre was performed contrary to the generated TCAS RA."*

The report also identified several organisational factors at the air traffic control centre that contributed to the air traffic controller not discovering in time that the aircraft were on collision course. It was further pointed out that ICAO's recommendations for ACAS/TCAS were not clearly regulated and implemented in various countries.

Based on the Üeberlingen accident, the Oslo ATCC implemented training of all air traffic controllers at the unit. Air traffic controllers learned that in a TCAS RA situation they should avoid to instruct flight crews to manoeuvre vertically.

1.19 Useful or effective investigation techniques

No methods qualifying for special discussion have been applied in this investigation.

2. ANALYSIS

2.1 Flight crew dispositions

2.1.1 The risk of a collision between the aircraft was averted by the flight crews following their respective TCAS RA instructions in accordance with ICAO guidelines.

2.1.2 At initial contact with Oslo ATCC, Sector Skagerrak, SAS925 reported at FL323, climbing to FL340. In the recorded communication, it emerges that the flight crew did not report when they had reached FL340. Whether this omission has been of significance for the incident is uncertain. The Accident Investigation Board would, however, point

out that if the crew had reported in at FL340, this could have served as a reminder for the air traffic controller regarding the potential conflict.

2.1.3 A review of the FDR print-outs, concluded that KLM1174 did not follow the air traffic controller's instructions to turn 30 degrees right. The Accident Investigation Board finds it likely that the KLM1174 flight crew did not hear the two calls from the air traffic controller. This also corresponds with the commanding officer's report, where no such radio transmission is mentioned. The probable cause of the flight crew not responding to the calls, could be a combination of the fact that the first call used the wrong call sign, ”KLM1144”, where the two final numbers of the call sign were corrected to ”74”, and the fact that the next call came at the same time as the flight crew's TCAS RA descend instruction.

2.2 The Air Traffic Control's dispositions

2.2.1 The recorded radio communication shows that the aircraft, in terms of communications, had been transferred from adjacent sectors before entering Sector Skagerrak. In the time from about 6 minutes before the incident the air traffic controller communicated with both aircraft. It appears from the respective Flight Progress Strips that both flights were cleared for FL340, and that both flight crews reported at and during climbing to this flight level respectively. The air traffic controller had furthermore written ”340” in the altitude column for both Flight Progress Strips

2.2.2 The aircraft radar position symbols and mode C information, which showed that the aircraft were on converging courses and at the same altitude, were continuously presented and updated on the radar screen. Still, the conflict between the aircraft was overlooked until just prior to when the air traffic controller gave instructions regarding evasive horizontal manoeuvre. Accordingly, the Accident Investigation Board believes that lacking situational overview on the part of the air traffic controller contributed to the violation of the separation minima.

2.2.3 The Accident Investigation Board has not identified any obvious reason for why the conflict was not discovered in time. However, potential factors that could have been of significance to this effect include:

a) *Call sign confusion*[11] - The final aircraft which the air traffic controller had communicated with before the incident, was KLM1144. Prior to the incident, this aircraft left Sector Skagerrak in a south by southwest direction. As with KLM 1174, KLM1144 was en route to Amsterdam, and flew at FL320. Incidentally, this was the call sign the air traffic controller wrongly used to call KLM1174 to give instructions for a 30 degree right turn.

b) *Assumption* - the air traffic controller has stated that he had a mental picture of KLM1174 and SAS925 being separated by flying at different flight levels, 340 and 360. Accordingly, the flights would not be in conflict with each other.

c) *Confusion* – The flight plan for a third aircraft, JXX102 that was previously reported at FL320, was revised to FL360 by Copenhagen ACC. According to the air traffic controller's statement, he could have made a mental connection with the change in flight level, and consequently thought that SAS925 and KLM1174 were separated vertically.

[11] Callsign confusion: It is a well-known phenomenon that similar callsign can be mixed. Read more about this www.skybrary.aero/index.php/Call-sign_Confusion.

d) *Complacency* - The time immediately prior to the incident in Sector Skagerrak was quiet, and characterised by monitoring rather than active air traffic control. The Accident Investigation Board is of the opinion that low alertness due to little activity may have been a contributing factor to the incident. The Accident Investigation Board can not, following the interview with the involved air traffic controller, point to any special factors that could have distracted him from monitoring the traffic situation.

e) *Multitasking* - the air traffic controller himself emphasised that it is easy to miss dynamic updates when balancing strategic (handling of flight plan data and coordination with next air traffic control centre) and tactical tasks (radar monitoring of flights).

2.2.4 The traffic load at the time was low following a previous period with moderate activity. The air traffic controller had several traffic conflicts in the time prior to the incident. He described these conflicts as “normal”. He solved these tasks through coordination with adjacent sectors, and by giving instructions to the flights in question. The Accident Investigation Board can see no basis for claiming that ”post peak stress” [12] was a contributing factor in the situation in question, considering that the air traffic controller in Sector Skagerrak himself assessed the traffic load this Saturday as moderate to low.

2.2.5 When the air traffic controller discovered that KLM1174 and SAS925 flew at the same flight level 340, loss of horizontal separation minima of 5 NM was already near occurring. A method to maintain separation between the aircraft had to be chosen quickly and the air traffic controller did not have time to make thorough assessments. It is the opinion of the Accident Investigation Board that the air traffic controller made the right decision when he chose to instruct both aircraft to carry out a 30 degree right turn, rather than instruction to climb or descend, as this could conflict with TCAS RA instructions. The Accident Investigation Board will furthermore praise the air traffic controller for having used the correct phraseology in TCAS situations.

2.2.6 The Accident Investigation Board's calculations show that the air traffic controller's instructions regarding horizontal evasive manoeuvre did not result in increased separation between the aircraft, as only SAS925, the fastest aircraft, followed the instructions. The Accident Investigation Board investigations show that the change of course actually led the aircraft closer to each other (see Appendix C). As both flight crews received TCAS RA and followed this, vertical separation was achieved, and the horizontal course change by SAS925 had no practical significance.

2.3 Sectorisation and staffing

2.3.1 At the time in question, Sector Skagerrak was staffed by one air traffic controller. In addition, there was an ATC assistant on duty, who also handled the adjacent Sector South/east. According to the available information, there was a redundancy of air traffic controllers during this shift. It is the view of the Accident Investigation Board that it could have been possible to staff Sector Skagerrak with two air traffic controllers, if necessary. Considering that the incident occurred during a period with little traffic, and that neither the air traffic controller in question nor the operational supervisor had pointed out a need for reinforcement, it is the view of the Accident Investigation Board that sector Skagerrak was satisfactorily staffed this Saturday morning.

[12] Post peak stress: It is a well-known phenomenon that during periods with a low work load following a preceding demanding and intensive work situation, the ability to concentrate, observe and recognise conflict situations can be affected negatively.

2.3.2 According to available information, Avinor has implemented measures and improvements at the Oslo ATCC that facilitate the use of a planning controller (PC) in addition to a radar-controller (RC). It should also be mentioned that the working positions have been reviewed, and as regards Sector Skagerrak, modifications have been carried out to handle double staffing during periods with a high workload. It is therefore the view of the Accident Investigation that the ANSP Avinor has carried out suitable measures to secure relief for the air traffic controller during periods with high workload.

2.3.3 There was organisational unrest at Avinor during the period in question, and working conditions at the Oslo ATCC were characterised by this. However, this morning the control room was calm, and the air traffic controller involved has stated that he could not point to anything in the working environment that would have affected him to the extent that it would have had any bearing on the incident in question. However, the Accident Investigation Board would still like to point out that organisational unrest can impact employees in the execution of their work in a negative way. It is particularly important to have focus on measures if the work that is being carried out is operational, safety critical work. To take into consideration additional staffing on the roster, as the Oslo ATCC had done during this period, is considered by the Accident Investigation Board to be a good risk-reducing measure.

2.4 Technical equipment and aids for air traffic controllers

2.4.1 Introduction

2.4.1.1 Human errors will and do occur. It is therefore important to facilitate systems in the form of technical equipment and ergonomic design of the workplace, in addition to organisational adaptations, to avoid that mistakes have serious consequences.

2.4.1.2 As far as the Accident Investigation Board has been able to identify, relevant technical aids, with the exception of the STCA function, were in operation and functioned normally prior to and after the incident. As regards STCA, the warning was too late and the sound in the loudspeakers at air traffic controller's working position was turned down too low.

2.4.1.3 Flight plan control data had been distributed, and the aircraft's radar position symbols and Mode C altitude were presented and updated continuously on the radar screen. However, in connection with the investigation of the incident, system weaknesses were identified, in the form of aids that did not sufficiently support the air traffic controller in the conflict search.

2.4.2 Flight Progress Board

2.4.2.1 There is no information indicating that the Flight Progress Strips for these flights were received late in Sector Skagerrak, i.e. data were available well before the aircraft entered the sector's area of responsibility. However, the route indication on the Flight Progress Strips was incorrect, because both aircraft had been re-cleared and given direct routes, which had only partially been noted on the Flight Progress Strips. The route change had been coordinated with the adjacent sector, but not entered into the flight plan system, which resulted in fewer Flight Progress Strips than normal being printed.

2.4.2.2 The fact that the Flight Progress Strips for the two flights KLM1174 and SAS925 were in separate sections on the Flight Progress Board contributed to conceal a potential conflict. Both SAS925 and KLM1174 had blue strip holders, which did not indicate a conflict either.

2.4.2.3 Therefore, the Accident Investigation Board cannot see that the Flight Progress Board was a good tool in the air traffic controller's planning and conflict search. The number of Flight Progress Strips was inadequate for the existing conflict to be presented in a good manner. The sectioning of the Flight Progress Board was facilitated for point searches, and not zone searches, which could better have visualised flights assigned direct routes.

2.4.2.4 Avinor has, following the incident, changed the sections on the Flight Progress Board in Section Skagerrak. Zone search concept was implemented and regulations introduced stating that the air traffic controller must ensure that all flights are visualised with Flight Progress Strips in all zones that the flights enter. The Accident Investigation Board is of the opinion that Avinor has implemented suitable measures to improve presentation and detection of conflicts when using the Flight Progress Board in Sector Skagerrak, and therefore waive any recommendations to this regard.

2.4.3 The loudspeaker in the working position

2.4.3.1 It has been established that that the audio alarm for STCA PC and STCA CA was triggered and activated in Sector Skagerrak in connection with this incident, but that the sound in the loudspeakers was not audible.

2.4.3.2 Considering that the STCA PC warning as such was given too late, and that the air traffic controller already had full focus on the situation, the Accident Investigation Board believes that absence of audio in this case did not have a negative impact. In the highly stressful situation that the air traffic controller was in, it was not evident that he would have noticed an audio alarm, as hearing is the first of the human senses to be suppressed in stressful situations. However, had the STCA PC alarm been activated 25 seconds before the separation minima were violated, the Accident Investigation Board believes that the associated audio alarm could have contributed to attracting the air traffic controller's attention.

2.4.3.3 The Accident Investigation Board would like to point out that the loudspeakers, where the volume was turned down, also should have presented audio alarms for other alarms that the air traffic controller could receive from the display system, including Transponder emergency codes “7500-hijacking”, “7600- radio failure” and “7700-emergency”. The Accident Investigation Board therefore believes that it is positive that the ANSP Avinor has changed the audio alarms to a computer voice that clearly states what kind of alarm is given, and that the air traffic controller is able to verify that the volume is sufficient through a sound check.

2.4.4 The STCA conflict warning function

2.4.4.1 In the incident in question, the Accident Investigation Board believes that the airborne safety net TCAS functioned optimally. The flight crews ensured vertical separation between the aircraft by following the TCAS RA instructions regarding “climb” and “descend” respectively.

2.4.4.2 The ground-based safety net, STCA, did not function in a satisfactory manner. The STCA notification time should, in accordance with the system specifications, be 25 seconds before violation of the separation minima. In this instance, STCA PC was presented when the aircraft were 5.9 NM apart, or 5-9 seconds before violation of the horizontal separation minima was a fact. STCA CA was activated when the distance was 4 NM. The Accident Investigation Board views it as obvious that this presentation of conflict

notification and alarm provided the air traffic controller with very limited help in issuing instructions of evasive manoeuvres.

2.4.4.3 The safety benefits of the conflict warning system STCA are dependent on air traffic controllers being given sufficient warning time regarding a potential violation of the separation minima in relevant situations, so that aircraft can be given the necessary instructions. With this recognition, it is obvious to the Accident Investigation Board that measures at the Oslo ATCC which could have contributed to reducing the consequences of human error should have been carried out at an earlier point in time.

2.4.4.4 The Accident Investigation Board therefore believes that the implementation of wrong value to the adaptation data parameter "Predicted ahead time" should have been corrected as soon as possible after February 2006, when it became clear that STCA generated the alarm too late, because this parameter was set too low.

2.4.4.5 Improvement of STCA beyond system specification required software upgrading, and the Accident Investigation Board finds it commendable that improvements were carried out one year and ten months after the incident.

2.4.4.6 Following an enquiry to the ANSP Avinor in September 2008, the Accident Investigation Board was informed that the Oslo ATCC had not recorded errors related to late STCA alarm after November 2007. Therefore additional safety recommendations related to the STCA function are not considered necessary.

2.4.5 MTCD – Medium Term Conflict Detection

2.4.5.1 As described in chapter 1.18.8 many air traffic control centres, such as the Swedish, have the conflict warning system MTCD installed as a separate screen on the air traffic controller's radar screen. By using this conflict tool the air traffic controller can be aware of potential future conflicts between aircraft at an earlier stage. However, it should also be noted that it has proved difficult to weed out false alerts.

2.4.5.2 The Accident Investigation Board is aware that Avinor is already considering whether it will be appropriate to implement MTCD in the NATCON system, and that a possible implementation must be weighed against other safety-related proposed changes, that the Accident Investigation Board has not reviewed. Therefore, the Accident Investigation Board is not putting forth a safety recommendation to carry out such an assessment.

3. CONCLUSION

In the course of this investigation, the Accident Investigation Board believes to have identified that the causes of the violation of separation minima between SAS925 and KLM1174 can be linked to the Air Traffic Control Service. The Accident Investigation Board's investigation has identified weaknesses related to the layout of the air traffic controller's Flight Progress Board, distribution of Flight Progress Strips and implementation of the radar system's conflict alerting function, STCA. These system weaknesses contributed to the air traffic controller's erroneous impression of vertical separation, not being corrected. The risk of a collision between the aircraft was averted by the flight crews following their respective TCAS RA instructions.

3.1 Findings

a) The aircraft were registered in accordance with the regulations, and no irregularities were reported. Both aircraft were equipped with the TCAS anti-collision system, which worked as intended.

b) The ACC radar position Sector Skagerrak was satisfactory manned.

c) The on-duty air traffic controller had valid authorisation papers for the service, and was rested. The workload in the sector at the time of the incident was low, after a previous period with moderate activity.

d) The on-duty air traffic controller had radio communication with both aircraft from about 6 minutes before the incident. Radio communication proceeded as normal.

e) Both SAS925 and KLM1174 flew at the assigned altitude, flight level 340. The on-duty air traffic controller failed to see that the aircraft were on converging courses at the same altitude.

f) The on-duty air traffic controller had a mental picture that the two flights were at different flight levels, 340 and 360 respectively, and that the aircraft accordingly were separated vertically.

g) Flight Progress Strips for visualisation of the scheduled flights on the Flight Progress Board were available well ahead of time.

h) The Oslo ATCC did not have clear guidelines for how flights given direct route should be visualised on the Flight Progress Board.

i) The Flight Progress Strips for both SAS925 and KLM1174 had been labelled "340", but the conflict was concealed by the fact that they were not placed in the same section on the Flight Progress Board.

j) The Flight Progress Board was organised for point search rather than zone search, and too few Flight Progress Strips had been produced for the flights in question. This resulted in difficulties to visualise the conflict in a good way on the Flight Progress Board.

k) SAS925 received a TCAS RA "climb" instruction, whereas KLM1174 received a corresponding TCAS RA "descend" instruction. Both flight crews followed their respective TCAS RA instructions. As a result of this, the minimum horizontal distance between the aircraft, without vertical separation of 1,000 ft. being maintained, was 2.7 NM.

l) There is no fixed provision for which evasive manoeuvre the air traffic controller should instruct the commander to carry out in different situations where separation minima are in progress to be violated. The on-duty air traffic controller was, however, aware that he should not instruct the flight crews to manoeuvre in the vertical plane in a TCAS RA situation.

m) Both flights were instructed to make a 30 degree right turn. Only SAS925 followed the instructions, which reduced the horizontal separation. Because both aircraft moved away from the other vertically, the horizontal course change had no practical impact.

n) The NATCON system at Oslo ATCC had not implemented MTCD, a function that could have assisted the air traffic controller to see the potential converging conflict between SAS925 and KLM1174 earlier.

o) The loudspeaker volume in working position Skagerrak was turned down so low that the air traffic controller's safety net STCA was only displayed through the radar screen, without the associated audio alarm.

p) STCA did not work as intended. The STCA conflict warning (STCA PC) was generated and presented to the air traffic controller as late as 5-9 seconds before the violation of separation minima, and not 25 seconds before as required by the system specifications.

q) STCA issued the alert later than the system specifications because the adaptation data parameter “Predicted ahead time” was set too low. However, an adjustment of the adaptation data parameter was not carried out until 1 year and 10 months after the incident.

r) The risk of collision between the aircraft was averted by the flight crews on both aircraft following their respective TCAS RA instructions in accordance with ICAO guidelines.

4. SAFETY RECOMMENDATIONS

The national Air Navigation Services provider (ANSP) Avinor has implemented a number of improvement measures following the incident. The Accident Investigation Board has, in connection with its investigation, reviewed Avinor's improvement measures, with particular emphasis on the layout of the Flight Progress Board in Sector Skagerrak, distribution of Flight Progress Strips, as well as implementation of STCA conflict warning. Through the investigation of this serious incident, the Accident Investigation Board has not uncovered requirements for additional safety recommendations.

The Accident Investigation Board of Norway

Lillestrøm, 28 September 2011

APPENDICES

APPENDIX A RELEVANT ABBREVIATIONS

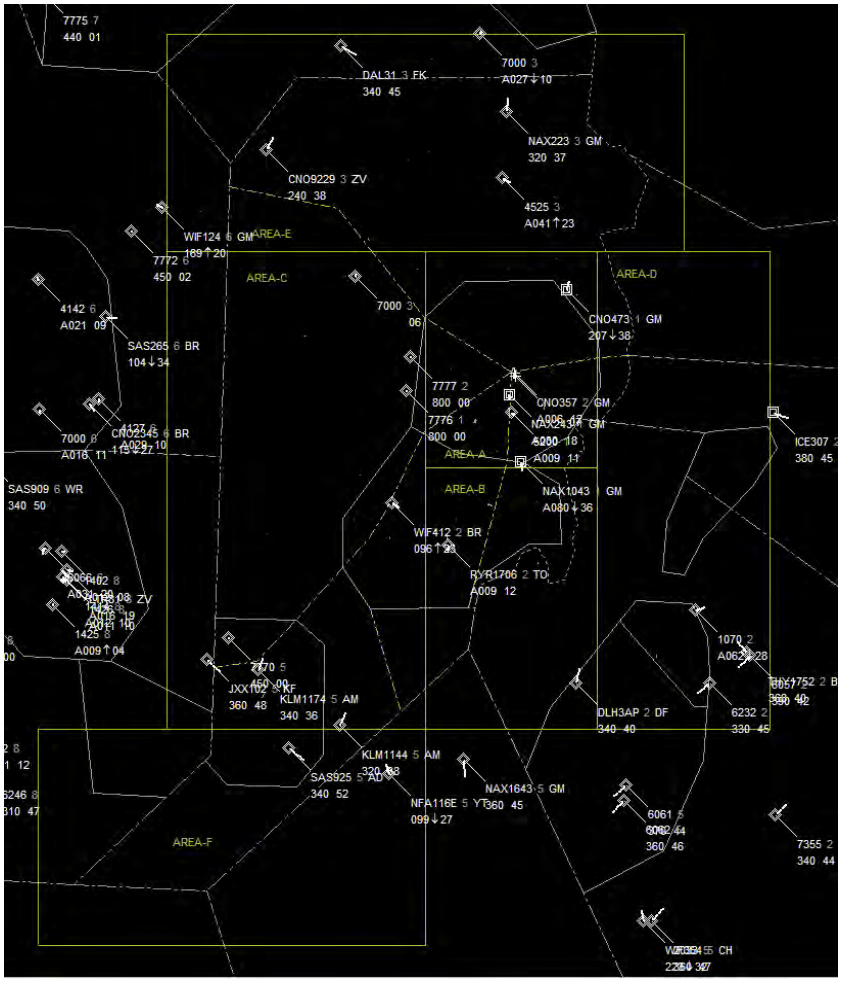
ACAS	Airborne Collision Avoidance system
ACC	Area Control Centre
AIRAC	Aeronautical Information Regulation and Control
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
AoR	Area of Responsibility
ATCC	Air Traffic Control Centre
ATM/CNS	Air Traffic Management / Communication Navigations Surveillance
BFU	Bundesstelle für Flugunfalluntersuchung - the German Accident Investigation Board
BSL	Provisions for civil aircraft
DME	Distance Measurement Equipment
DVOR	Doppler Very High Frequency Omni-range, radio navigation tool
ENOS	Oslo Air Traffic Control Centre
EKCH	Copenhagen Airport, Kastrup
EKDK	Copenhagen Air Traffic Control Centre
EHAM	Amsterdam Airport, Schiphol
FDPS	Flight Data Processing System
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight level
FPB	Flight Progress Board
FPS	Flight Progress Strip
ICAO	International Civil Aviation Organization
KIAD	Washington Intl. Airport, Dulles
MTCD	Medium Term Conflict Detection
NATCON	Norwegian Air Traffic Control System (radar and flight plan)
NATS	National Air Traffic Service in the UK
NSCR	NATCON Software change request
NM	Nautical Mile
PC	Planning Controller
PTL	Predicted Track Line

RC	Radar Controller
RDPS	Radar Data Processing System
RFL	Rules for air traffic control
SDD	Situation Data Display, display system for RDPS
STCA	Short Term Conflict Alert, conflict warning function in RDPS
STCA CA	STCA Conflict Alert – alarm for violation of applicable separation minima
STCA PC	STCA Predicted Conflict – alert regarding imminent violation of applicable separation minima
SVA	Call sign for radio beacon DME/DVOR at Svensheia, Kristiansand
TCAS	Traffic Alert and Collision Avoidance System, - anti-collision system in cockpit
TCAS RA	TCAS Resolution Advisory
TCAS TA	TCAS Traffic Advisory
TMA	Terminal area, airspace in a defined altitude over/near a controlled airport
UTC	Coordinated Universal Time
VMC	Visual Meteorological Conditions
VOR	Very high frequency Omnidirectional Radio range - radio beacon

Appendix B STCA search algorithm in the NATCON system

The STCA search area for Oslo AoR was divided into 6 subareas (see the figure below). One search sequence took 40 seconds, i.e. 5 seconds per subarea. The subareas Oslo TMA and Farris TMA (subareas A and B in the figure below) were searched twice and the other subareas once. Each subarea was searched for potential conflict pairs up to 40 seconds a head in time (the value of the adaptation data parameter Predicted Ahead Time).

If the time until a conflict was more than 40 seconds, the flights were not transferred to separate filter, and the conflict would be recorded in the next search sequence. Accordingly, notification in such cases would not be given according to the 25 second criterion prior to violation of the separation minima. The fact that the search areas that included Oslo TMA and Farris TMA were searched twice meant that in practical terms there were eight search areas. As a result, the algorithm searched 7 other areas between each time the Svensheia area was searched. For each 40 second cycle, the algorithm was outside the Svensheia area for 35 seconds and within the area for 5 seconds.



A “Predicted Ahead time” of 40 seconds was accordingly too short to safeguard the requirement in the system specifications which indicated a 25 second notification time before violation of defined separation minima. Given the number of search areas, the parameter should have been set at 70 seconds in order to safeguard the requirements in the system specifications. The calculation capacity of the RDPS servers had more than enough capacity to increase the adaptation data parameter to 70 (the maximum value was 150 seconds).

Too late notification of STCA PC and CA due to erroneous value for the adaptation data parameter “Predicted ahead time” could theoretically not occur in the subareas that included Oslo and Farris TMA, as these subareas were "visited" by the algorithm twice during each cycle. The maximum loss was 15 seconds (40 - 15 = 25 which was just enough in relation to a 25 second warning). Too late notification could only occur in relation to the ACC sectors that the algorithm visited only once within each cycle and one stood the risk of losing 35 of the 40 seconds.

APPENDIX C

Estimation of convergence point for SAS925 and KLM1174, theoretical observations

Convergence point with unchanged courses and constant flight level 340

Based on radar data from the Oslo ATCC and FDR data from the two aircraft, the Accident Investigation Board has estimated how SAS925 and KLM1174 would have passed each other in mid-air if their respective courses and speed had remained unchanged. The assessment also includes whether a horizontal change in the course of SAS925 affected the distance between the aircraft.

When the air traffic controller became aware of the conflict, the aircraft were, according to radar data, approx. 8-9 NM apart. Figure C shows the distance between the aircraft at this time, a line with a distance of 9 NM (A_1), and the respective magnetic headings of the aircraft (305° and 191°) form a triangle. The opposing angle to the 9 NM long line is estimated to 114° (< a). If none of the aircraft had changed horizontal courses or altitude, the point in this angle would have been the convergence point for the two flights. When using the sinus proportion[13] we find that SAS925 had 5.2 NM left before the convergence point, whereas KLM1174 had 5.5 NM left.

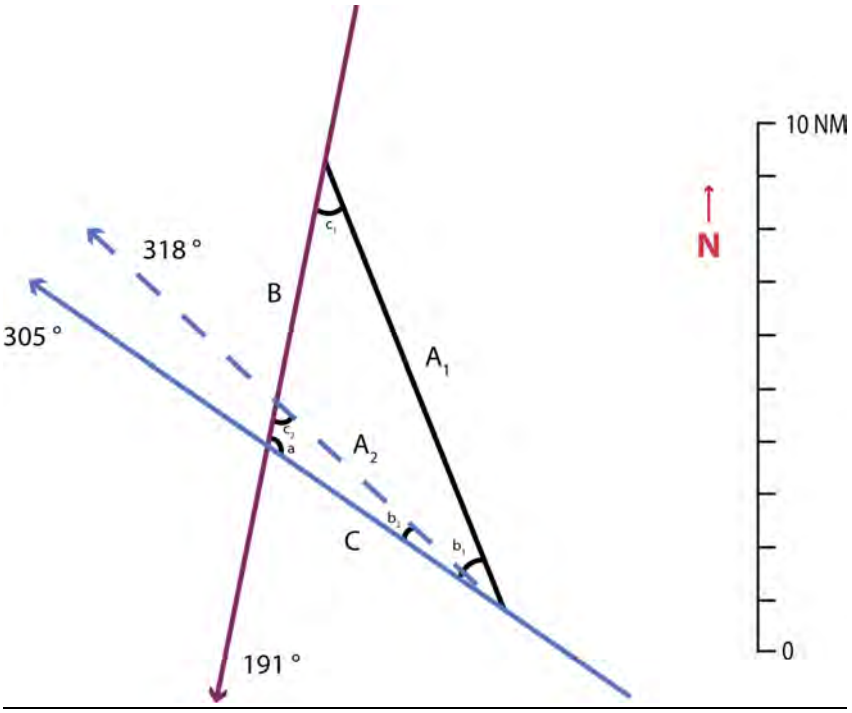


Figure C: Estimated convergence point for SAS925 (blue magnetic heading) and KLM1174 (purple magnetic heading), if the altitude, flight level 340, and courses had remained constant.

[13] The Law of Sines: When *A*, B and C form the sides of a triangle, and the opposing angles of the sides are *a*, *b* and *c*, the Law of sines states that $A / \sin a = B / \sin b = C / \sin c$. The angle a is the convergence point between the courses 191° (KLM1174's course) and 305° (SAS925's course). In our calculations we have used $A_1 = 9$ NM, $< a = 114°$, $< b_1 = 34°$, $< c_1 = 32°$. We then found the lengths B= 5.5 NM and C= 5.2 NM. Furthermore, the length C and the course change $< b_2$ was used to find various lengths for A_2, which is the new distance SAS925, must fly to cross the course of KLM1174, at various course changes.

Ground speed was 526 kt (271 m/s or 976 km/h) for SAS925 and 360 kt (185 m/s or 666 km/h) for KLM1174. From this follows that SAS925 and KLM1174 had 35 and 55 seconds left respectively to the convergence point. SAS925 would have passed the convergence point 20 seconds before KLM1174. Of which follows [14] that:

If the course and altitude for both aircraft had remained unchanged, SAS925 would have passed in front of KLM1174, at the same altitude and with a distance of approx. 2 NM. However, radar data show that the horizontal distance between SAS925 and KLM1174 was approx. 0.1 NM, and not 2 NM, when SAS925 passed in front of and above KLM1174 by 1 200 ft.

Convergence point with changed heading for one of the aircraft

FDR data shows that SAS925 gradually changed its heading, by approx. 1 degree per second, from 305° to 323° as a result of the air traffic controller's instructions to make a 30° right turn. KLM1174, however, did not change its heading.

The Accident Investigation Board has looked at what SAS925's heading change meant for changing the convergence point between the two flights had TCAS not had been active, and the aircraft had not changed altitudes. The results can be illustrated by the following table:

SAS925 magnetic heading changes in degrees	SAS925 will pass in front of or behind KLM1174	KLM1174's time and distance to the convergence point.
No course change (305°)	front	20 seconds (2 NM)
7° right (312°)	front	11 seconds (1.1 NM)
12° right (317°)	front	3 seconds (0.3 NM)
13° right (318°)	front	1 second (0.1 NM)
15° right (320°)	behind	3 seconds (0.3 NM)

Table 1 Estimated effect of horizontal course change for SAS925

Table 1 shows that the air traffic controller's instructions to both aircraft regarding a 30 degree right turn reduced the horizontal separation, because only SAS925 followed the instructions.

- without horizontal course change SAS925 would, according to estimates, have passed in front of KLM1174 with a distance of approx. 2 Nm.

- with horizontal course change for SAS925 alone, the distance between the aircraft became less than it would have been without course changes.

- an achieved horizontal course change of 12 -13° for SAS925 could have resulted in a mid-air collision with KLM1174.

The table does not show the distance between the aircraft if both had changed courses to the right. However, it is assumed that this would have increased the distance between the aircraft.

[14] *Average distance equals time multiplied by speed, s= t * v*