**Federal Department of the Environment,
Transport, Energy and Communications** **No. 1781**

Final Report of the Aircraft Accident Investigation Bureau

on the accident

to the Saab 340B aircraft, registration HB-AKK

of Crossair flight CRX 498

on 10 January 2000

near Nassenwil/ZH

This report has been prepared for the purpose of accident prevention. The legal assessment of accident causes and circumstances is no concern of the accident investigation (art. 24 of the air navigation law).

This report is a translation of the German language.

The valid formulations for this report exist in the German language.

According to art. 22 – 24 of the Ordinance relating to the Investigation of Aircraft Accidents and Serious Incidents (VFU), the investigation report dated October 21, 2002 of the Aircraft Accident Investigation Bureau was submitted for examination by the Federal Aircraft Accident Review Board (Review Board). The Review Board declared the investigation report as the final report.

Bundeshaus Nord, CH-3003 Berne

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Final Report

Operator:	Crossair Limited Company for Regional European Air Transport, CH-4002 Basle
Aircraft type and version:	Saab 340B
Nationality:	Switzerland
Registration:	HB-AKK
Owner:	Cinderella Aviation LLC, Isle of Man, U.K.
Place of the accident:	Au, community of Nassenwil ZH Swiss co-ordinates: 677 850/258 250 Latitude: N 47° 28’ 12” Longitude: E 08° 28’ 17” Elevation: 424.25 m/M 1392 ft AMSL
Date and time:	10 January 2000 at 16:56:27.2 UTC

Synopsis

Brief presentation

On 10 January 2000, at 16:54:10 UTC, in darkness, on runway 28 of Zurich airport, the Saab 340B aircraft of the Crossair airline company, registered HB-AKK, began its scheduled flight CRX 498 to Dresden. Two minutes and 17 seconds later, after a right-hand spiral dive, the aircraft crashed on an open field near Au, Nassenwil ZH.

The ten occupants (three crew members and seven passengers) were fatally injured by the impact. The aircraft was destroyed. A fire broke out and there was damage to farmland.

Investigation

The accident occurred at 16:56:27.2 UTC. The Swiss air rescue service (REGA) alerted the duty service of the Swiss Aircraft Accident Investigation Bureau (AAIB) (*Büro für Flugunfalluntersuchungen* – BFU) at 17:05 UTC. The investigation was opened on 10 January 2000 at 20:15 UTC in cooperation with the Zurich cantonal police.

The Swiss AAIB set up an investigation group to investigate air accidents of a catastrophic nature involving large aircraft.

According to Annex 13 to the Convention on International Civil Aviation (ICAO Annex 13) the States of Manufacture of the aircraft have the option of delegating accredited representatives to the investigation. Both Sweden as the State of Manufacture of the aircraft and the United States of America as the Country of Manufacture of the engines availed themselves of this opportunity. In addition the German Federal Republic was allowed to delegate a representative, since several victims of the accident were of German origin. Saab, the aircraft manufacturer (Sweden), and the airline concerned, Crossair, cooperated with the investigation.

The investigation has determined the following causes for the accident:

The accident is attributable to a collision with the ground, after the flight crew had lost control of the aircraft for the following reasons:

- The flight crew reacted inappropriately to the change in departure clearance SID ZUE 1Y by ATC.
- The first officer made an entry into the FMS without being instructed to do so by the commander concerning the change to standard instrument departure SID ZUE 1Y. In doing so, he omitted to select a turn direction.
- The commander dispensed with use of the autopilot under instrument flight conditions and during the work-intensive climb phase of the flight.
- The commander took the aircraft into a spiral dive to the right because, with a probability bordering on certainty, he had lost spatial orientation.
- The first officer took only inadequate measures to prevent or recover from the spiral dive.

The following factors may have contributed to the accident:

- The commander remained unilaterally firm in perceptions which suggested a left turn direction to him.
- When interpreting the attitude display instruments under stress, the commander resorted to a reaction pattern (heuristics) which he had learned earlier.
- The commander's capacity for analysis and critical assessment of the situation were possibly limited as a result of the effects of medication.
- After the change to standard instrument departure SID ZUE 1Y the crew set inappropriate priorities for their tasks and their concentration remained one-sided.
- The commander was not systematically acquainted by Crossair with the specific features of western systems and cockpit procedures.

In the course of the investigation, the Swiss AAIB drew up eleven safety recommendations for the attention of the Federal Office for Civil Aviation (FOCA) - *Bundesamt für Zivilluftfahrt* (BAZL):

- Operation of the flight management system (FMS)
- Procedure for the flight management system (FMS)
- Use of the autopilot
- Harmonization of departure procedures with Saab 340B operating procedures
- Transfer of foreign pilots' licences
- Validation of licences which were not issued under JAR-FCL
- Validation of foreign medical certificates
- Employment of foreign pilots with validated licences
- Clarification of aptitude for crew members
- Training and crew pairing
- Training and induction of direct entry commanders

1 Factual information

1.1 Prior history and history of the flight

1.1.1 Prior history for the last 24 hours

1.1.1.1 The aircraft

Immediately before the accident flight, HB-AKK was used on the Zurich-Jersey-Guernsey-Zurich route with a different crew from the one on the accident flight. This crew reported that the aircraft and its systems, including the navigation systems and the flight management system (FMS), had functioned without problems throughout the flight.

1.1.1.2 Flight crew

The commander of the accident aircraft was in charge for the fourth, and the first officer was in charge for the fifth working day in a series of flight rotations. Previously the commander had had two, and the first officer four days off. The accident flight was the ninth successive flight which the two pilots were carrying out with each other on their joint fourth day of work.

On the day before the accident, after a rest period of almost 22 hours, the flight crew reported for duty at their home base in Basle at 12:05 UTC. On this day the crew completed the four flights, Basle-Munich-Basle and Basel-Dresden-Zurich. They finished work at 22:34 UTC after a period of duty of 10 hours and 29 minutes and a block time of 5 hours and 34 minutes.

After a rest period of 13 hours and 31 minutes with an overnight stay in a hotel in Kloten, the flight crew logged onto the Crossair electronic data recording system for duty at 12:35 UTC at Zurich airport.

The crew made the first two flights to Nuremberg and back in aircraft Saab 340B HB-AKC. For the following Zurich-Dresden-Basle flights, the crew changed to the Saab 340B, registration HB-AKK.

1.1.2 History of the flight

Aircraft HB-AKK had landed in Zurich on 10 January 2000 as Crossair flight CRX 842 from Guernsey and reached stand F74 at 16:00 UTC, which is located near to the threshold of runway 28.

The aircraft was then prepared for the next flight at this stand. According to statements from the Swissport ground personnel the preparation of the aircraft took place without any special occurrence.

During its time on the ground, the aircraft was supplied with electric power by a ground power unit (GPU). An air-conditioning truck was not used and the aircraft was not de-iced.

The crew prepared for the flight using the computer-aided briefing system.

The following description of the history of the flight was reconstructed with the help of recordings from the cockpit voice recorder (CVR), digital flight data recorder (DFDR), voice radio communications and ATC radar (cf. Annex 1).

According to the available recordings, the commander, as planned by the crew, was pilot flying (PF) and the first officer was pilot non flying (PNF) throughout the flight.

At 16:39:14 UTC, flight CRX 498 to Dresden received from clearance delivery (DEL) the following ATC-clearance: "runway two eight, Dresden, Zurich East One Yankee Departure, squawk three zero zero four". The crew was then instructed to change to the apron (APR) frequency. Permission to start engines was given at 16:45:00 UTC by APR. At 16:49:22 UTC the first officer signaled readiness to taxi to APR. While the crew waited for taxi clearance, a few points of the taxi checklist were performed. At 16:50:30 UTC APR cleared flight CRX 498 to follow a Swissair Airbus A320 (SWR 014) to the holding position of runway 28. In accordance with this clearance, CRX 498 started to move. The flight crew performed the outstanding items on the taxi checklist and contacted the tower (TWR), which gave line-up clearance at 16:52:36 UTC.

Take-off clearance was given at 16:54:00 UTC: "Crossair four nine eight, wind three zero zero degrees, three knots, cleared take-off runway two eight". According to the automatic terminal information service (ATIS) at 16:50 UTC the following meteorological conditions existed: wind 290° at 2 knots, visibility 6 km in drizzle, broken, cloud base at 500 feet above ground level, temperature 2 °C, dew point 1 °C, QNH 1032 hPa. The aircraft began its take-off roll at 16:54:10 UTC in darkness. The landing lights were on and the flaps were fully retracted.

After take-off at 16:54:31 UTC the landing gear was retracted. Then, on the commander's order, the flight director (FD) was switched on and the NAV mode was armed. Both pilots confirmed that the long range navigation system number 1 (LRN 1) was following the track (LRN 1 captured).

The commander controlled the aircraft in a stable climb with a pitch of 15° attitude nose up (ANU) and a speed of 136 knots indicated airspeed (KIAS). For the remaining flight, the autopilot was never engaged. Since the cloud base was indicated as 500 ft above ground level (AGL), it can be assumed that the aircraft, once above an altitude of approx. 1900 ft above mean sea level (AMSL) entered instrument meteorological conditions (IMC).

The initial flight path, at a heading of 276°, followed the centre line of the runway. After the request from TWR, CRX 498 switched to the departure control frequency (DEP) at 16:55:07 UTC. The radar recording then showed a deviation in the flight path by 5° to the south. However, this slight deviation was reduced before waypoint DME 2.1 KLO was reached by initiating a right turn.

At 16:55:15 UTC flight CRX 498 was cleared to climb to flight level 110. At 16:55:39 UTC, Zurich departure issued the instruction to turn to VOR ZUE: "four nine eight, turn left to Zurich East". The first officer confirmed by radio: "turning left to Zurich East, Crossair four niner eight". At the same time the aircraft reached waypoint DME 2.1 KLO. At this point the departure procedure ZUE1Y specifies a left turn, in order to capture and follow radial 255 of VOR KLO. At 16:55:45 the bank angle to the left reached a maximum of 16.9° on a compass heading of 270°.

At 16:55:47 UTC the first officer informed the commander that the LRN system was programmed from the present position to ZUE: "from present, LRN is to Zurich East, yeah". The commander confirmed with: "checked".

The left turn instruction from DEP was not mentioned.

After the aircraft had remained briefly at a 16° bank angle to the left, it began to roll to the right. From 16:55:47 UTC the bank angle rate amounted to 3°/s to the right.

In this phase the first officer was very busy carrying out the orders routinely issued by the commander ("CTOT/APR off, yaw damper on, bleed air on"). All relevant flight parameters in this phase indicated a stable climb with a pitch of 13-14° ANU. The communication being conducted internally did not give any indication of difficulties of any kind.

At 16:55:55 UTC, at a bank angle of 8.4° to the right, the bank angle rate increased and the nose of the aircraft began to drop from 14.2° to 10.8° ANU.

At 16:56:00 UTC the right bank angle attained a value of 31.0°, when the commander gave the order to set climb power: "set climb power". The first officer confirmed with a whispered "coming" and began to set the climb power – a procedure which takes quite some time.

Between 16:56:03 UTC and 16:56:10 UTC the commander stabilized the bank angle to the right between 39° and 42° by corresponding flight control inputs. The pitch reduced further and stabilized at a value of 1° ANU at 16:56:06 UTC as a result of corresponding elevator inputs for four seconds. As a consequence, the trajectory reached its maximum altitude of 4720 ft AMSL. According to information from the crew of the preceding flight SWR 014 the cloud top at that time was approx. 5000 ft AMSL. The speed of the aircraft involved in the accident increased to 158 KIAS.

16:56:10 UTC marked the beginning of a nine-second period which was characterized by destabilization of the attitude. It featured uncoordinated deflections of the ailerons to the left and right. Meanwhile, the elevator remained practically in the neutral position. Since the rightward deflections of the aileron were dominant, the bank angle increased from 42° to 80° to the right. Given the neutral position of the elevator, because of the high bank angle the pitch increased to 25° attitude nose down (AND). The aircraft therefore quickly lost altitude and its speed increased to 207 KIAS.

At 16:56:12 UTC the first officer made the commander aware that they should turn left to ZUE: "turning left to Zurich East, we should left".

At 16:56:15 UTC, at a bank angle of 65.8° to the right, the commander muttered unclearly: "oh-na-na". Three seconds later at 16:56:18 UTC, DEP requested confirmation that the aircraft was turning to the left: "Crossair four nine eight, confirm you are turning left". The first officer responded immediately: "moment please, standby". DEP then instructed the crew to continue the right turn: "ok, continue right to Zurich East."

In the final phase of flight, beginning at 16:56:20 UTC, the aircraft went into a spiral dive. As a result of massive aileron deflections, the aircraft attained a maximum bank angle of 137° to the right.

The engines still provided high power, since setting of climb power had not yet been terminated. At a speed of 250 KIAS the over speed warning horn sounded. At 16:56:24 UTC the first officer vigorously warned the commander to turn left: "turning left, left, left, left... **left**!"

At the end of the data recording at 16:56:25 UTC the aircraft still exhibited a bank angle of 76° to the right. The nose of the aircraft had dropped to 63° AND at an air speed of 285 KIAS.

Several witnesses observed the aircraft breaking out of the clouds in a steep descent and performing a right turn.

At 16:56:27.2 UTC the aircraft crashed in an open field near Au, Nassenwil, ZH. None of the three crew members and seven passengers survived the impact.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
fatal	3	7	-
serious	-	-	-
minor/none	-	-	

1.3 Damage to the aircraft

The aircraft was destroyed when it crashed onto open meadow land. After the crash some items of debris were still burning on the surface. The majority of the wreckage penetrated up to 3 m into the soft soil of the agricultural land. Smaller parts were spread in a fanlike formation in the direction of impact over an area of approx. 15000 m^2.

1.4 Other damage

There was damage to the land. Soil contaminated with kerosene was removed and the excavated material was taken to a secured tip. The site of the crash was then backfilled and reinstated.

1.5 Personnel information

1.5.1 Commander

Person:	Citizen of the Republic of Moldova, male, born 1958
Duty time:	End of duty on previous day (9 January 2000): 22:34 UTC Start of duty on day of the accident: 12:35 UTC Duty time on previous day: 10:29 hours Duty time on day of accident: 4:21 hours
License:	from the Civil Aviation Ministry of the Soviet Union, for pilots 2nd class, issued 2 January 1986, valid till 6 April 2000. Swiss validation, issued on 2 November 1999, valid till 6 April 2000
Instrument rating:	Category I, valid till 06.04.2000 Category II, valid till 06.04.2000
Last proficiency check:	26 October 1999
Last line check:	19 November 1999
Medical certificate:	from the Medical Centre of Civil Aviation of the Republic of Moldova dated 30 September 1999, valid till 6 April 2000, according to the decree on pilot personnel, pilot trainees, air traffic controllers, cabin personnel and training personnel in civil aviation, Moscow 1982

Flying experience:	8452:51 flying hours total
on powered aeroplanes	6962:33 flying hours
on helicopters	1490:18 flying hours
as commander:	4645:12 flying hours
on the accident type:	1870:12 flying hours
during the last 90 days:	139:06 flying hours, all on the accident type
on the previous day:	5:34 flying hours, all on the accident type
on the day of the accident	1:47 flying hours, all on the accident type
Flying time with Crossair	139:06 flying hours, all on the accident type, of which line introduction: 37:06 flying hours

Pilot training

1975 Selection by Aeroflot and entry into the Krementschug civil aviation school (Ukrainian Soviet Republic)
1977 graduation as civil aviation pilot
1985-1990 correspondence course at the Civil Aviation Academy in Leningrad, completed by diploma LE-85058 as civil aviation pilot-engineer.
05.02.1997-03.06.1997 conversion to Saab 340B at the Crossair Training Centre Basle
02.03.1998 Saab 340B Cat. II theory course at the Crossair Training Centre Basle
03.-04.03.1998 Saab 340B FMS theory course at the Crossair Training Centre Basle
13.03.1998 Saab 340B Cat. II simulator course at the Crossair Training Centre Basle
09.03.1999 proficiency check simulator Saab 340B Crossair Training Centre Basle
12.07.1999 proficiency check simulator Saab 340B (right-hand seat) Crossair Training Centre Basle
26.10.1999 proficiency check simulator Saab 340B (Swiss license validation) Crossair Training Centre Basle

1.5.2 First officer

Person:

Citizen of the Republic of Slovakia, male, born 1965

Duty time:

End of duty on previous day (9 January 2000):	22:34 UTC
Start of duty on day of the accident:	12:35 UTC
Duty time on previous day:	10:29 hours
Duty time on day of the accident:	4:21 hours

License:

from the Republic of Slovakia, for commercial pilots, issued on 24 October 1994, valid till 20 May 2000.
Swiss validation, issued on 16 September 1999, valid till 20 May 2000

Instrument rating:

Category I, valid till 20.05.2000
Category II, valid till 02.03.2000

Last proficiency check:	2 September 1999
Last line check:	1 October 1999
Medical certificate:	from the Kosice Air Force Military Hospital, Department of Aviation Medicine, issued on 20 May 1999, valid till 20 May 2000
Flying experience:	2332 flying hours total
on powered aeroplanes	1482 flying hours
on gliders	850 flying hours
on the accident type:	1162:26 flying hours
during the last 90 days:	168:44 flying hours, all on the accident type
on the previous day:	5:34 flying hours, all on the accident type
on the day of the accident:	1:47 flying hours, all on the accident type
Flying time with Crossair:	232:26 flying hours, all on the accident type, of which line introduction: 43:18 flying hours
Pilot training:	Between 1989 and 1996 he completed commercial pilot training at Aeroklub Spišska Nová Ves 14.03.-20.05.1996 multi engine and instrument rating, type rating L-200 at the University for Transport and Communications, Air Transport Division, in Žilina 02.06.1997-12.09.1997 conversion to Saab 340B at Tatra Air (SAS Flight Academy in Stockholm) 12.09.1999 proficiency check simulator Saab 340B (Swiss license validation) Crossair Training Centre Basle

1.5.3 Cabin attendant

Person:	French citizen, female, born 1974

1.5.4 Air traffic controller (TWR)

Person:	Swiss citizen, male, born 1963
License:	for air traffic controllers, issued by the Federal Office for Civil Aviation on 31 October 1990, last renewal on 15 September 1999, valid till 15 September 2000

1.5.5 Air traffic controller (DEP)

Person:	Swiss citizen, male, born 1955
License:	For air traffic controllers, issued by the Federal Office for Civil Aviation on 1 September 1982, last renewal on 1 September 1999, valid till 1 September 2000

1.5.6 Training, examinations and certification

1.5.6.1 Pilot training in the former Soviet Union at the Krementschug flying school

The training began with the selection process for the civil aviation flying school in Krementschug. As in all other schools in the former Soviet Union (FSU), candidates were selected on concluding the compulsory ten years of school education. On average there were 15 candidates for each training place. The candidates were all examined for health and basic academic knowledge.

Training at the specialist school in Krementschug extended over three years – unlike the four years of training at civil aviation colleges. The final examination was for pilot third class with flying experience on single-engined aircraft (JAK-18, AN-2) and without instrument rating.

The classification of pilots in the FSU extended from Class 4 to Class 1. On the one hand the grading of a pilot in a class gave information on his qualification. On the other hand, a specific minimum classification, expressed as a class, was required to take specific activities. Whilst a pilot third class could work as commander on "simple aircraft" (AN-2) and as first officer on "medium aircraft" (JAK-40, AN-24), for the commander's position on a "medium aircraft" he required the qualification of pilot second class. The designation required a specific amount of flying experience, greater theoretical and practical training and successful passes in examinations. Except for the fourth class grade, it was not possible to leapfrog any class.

Training in the FSU took place uniformly in all teaching facilities and in all flying operations, based on regulations which were issued by the Ministry for Civil Aviation. The standard operating procedures (SOP) were also issued uniformly by the Ministry for Civil Aviation and combined in the so-called *Technologia*, which was issued for specific aircraft types.

Training in theory was comprehensive. Aeronautical training was very strongly orientated towards procedures. It took place in a type JAK-18 or AN-2 aircraft according to the corresponding *Technologia*.

Assignment to an operational department followed completion of training at the specialist school.

Pilots in the FSU were converted according to uniform syllabuses. A new type rating could be acquired only in the first officer’s position. Only after specified flying experience on the corresponding aircraft type had been acquired (at least 500 flying hours) did conversion to commander take place. On the other hand, conversion to larger aircraft required previous experience as commander on small types. So the typical career of pilots in the FSU alternated between exercising the functions of first officer and commander.

1.5.6.2 Training of the crew of flight CRX 498

1.5.6.2.1 Commander

For the first 20 years of his flying career, the commander of the aircraft involved in the accident was trained exclusively in the system of the FSU. Training as a civil aviation pilot was his only professional training.

On conclusion of his training at the flying school in Krementschug he was assigned as first officer to an AN-2 squadron for crop-dusting. Theory and practical training was continued there according to a plan laid down centrally.

The AN-2 is a single-engined biplane with a two-man crew, which was used for agricultural, freight and passenger flights. It was flown according to visual flight rules.

With conversion to KA-26 the commander of the aircraft involved in the accident was schooled in helicopter flying. Once again, operations were in agriculture according to visual flight rules, with the difference that there was now a one-man crew.

During ten years of activity in crop-dusting, the commander of the aircraft involved in the accident accumulated 4068 flying hours.

Conversion to the AN-24 was a major step in the commander's training. It was here that preparation took place for flying a multi-engined aircraft with turboprop engines and flying according to instrument flight rules. This was his first instrument flight training.

On conclusion of his correspondence course at the flight academy in St. Petersburg he was able to complete his theoretical knowledge and acquired the qualification as pilot-engineer. This also enabled him to be designated a pilot second class.

With these prerequisites, conversion to commander on AN-24 took place.

The commander obtained license No. 025222 from the Ministry for Civil Aviation of the Soviet Union for pilots 2nd class (airline pilot's license), issued on 02.01.1986, with commander's registration for AN-24 and AN-26 and special authorization for flights with a reduced crew.

Some time later the commander of the aircraft involved in the accident underwent a trial to convert from AN-24 (a two-engined turboprop aircraft) to TU-134 (a two-engined jet aircraft) at Aeroflot. He failed in the selection procedure.

In the meantime Moldavian Airlines had acquired a Saab 340B from Crossair. The aircraft was equipped identically to Crossair's other Saab 340B aircraft, i.e. after retrofit it had the same FMS.

After evaluation of his medical and psychological suitability, the commander was employed by Moldavian Airlines and designated for conversion to commander on Saab 340B. Including line introduction, this was completed in four months. In comparison, in the case of the Russian airline Aeroflot, more then twelve months are generally taken to convert to western aircraft types.

His employment with Moldavian Airlines confronted the commander for the first time with western aircraft technology, with western navigation and attitude systems, with western training methods and cockpit philosophy (crew resource management – CRM) and with the western lifestyle.

Further training and checks were carried out both according to the principles of the FSU (line checks, regular examination of theoretical knowledge) and according to the Crossair syllabuses (CAT 2 training, proficiency check, FMS training). No special differential training, which would have had as its subject the differences between east and west, was carried out. Nor did the commander undergo any unusual attitude training.

When the commander of the aircraft involved in the accident was taken on by Moldavian Airlines in 1997, he had a total of 6582 hours flying experience, of which 3085 were flying hours as responsible pilot. The psychological aptitude test was passed with a "recommendation for conversion training within the first group". The medical commission also came to a similar conclusion. The conversion authorization was issued by the Moldavian Civil Aviation Authority (MCAA) on 31.01.1997.

The conversion training took place at Crossair Basle according to the syllabus approved by the Swiss Federal Office for Civil Aviation (FOCA) (*Bundesamt für Zivilluftfahrt* – BAZL) and as per MCAA according to the rules of PPLS GA-92 (training regulations for civil aviation flight crews dated 1992). The theory course took place from 05.02.1997 to 20.02.1997. Training subsequently took place until 20.03.1997 on the simulator and the aircraft. The IFR proficiency check was taken in March 1997.

During the training, 32 flying hours were recorded on the simulator and 1:20 flying hours in the aircraft (17.03.1997).

According to MCAA Instruction No. 17 of 25.03.1997 the Commander received authorization for training flights and line introduction on the Saab 340B. This line introduction then took place on the Moldavian Airlines route network with the following destinations: Kishinev, Budapest, Prague, Verona and Malpensa. Swiss line training commanders, who were provided by Crossair for the period from 31.03.1997 to 21.05.1997, were used on these flights. A line check was also carried out by a Swiss pilot on 21.05.1997.

After the training was concluded, an entry was made on 30.05.1997 in the Soviet license as Saab 340B commander, based on the corresponding MCAA Instruction 41/1 dated 30.05.1997. This license corresponds to the ICAO standard, according to statements from the MCAA. The IFR rating was issued with the addition "Take-offs from 150 m visibility, landings up to 60 m cloud base and 600 m visibility".

The medical examinations were all performed in Moldova in accordance with the Russian regulations in force.

From 03.03.1998 to 04.03.1998 the commander took part in the Crossair FMS UNS-1K theory course on behalf of Moldavian Airlines.

On 13.03.1998 a CAT II Training (simulator course) took place, likewise on behalf of Moldavian Airlines, and again at Crossair. The subsequent license entry in Moldova on the basis of instruction No. 44 dated 24.03.1998 included the addition "Take-offs from 150 m visibility, landings up to 30 m cloud base and 350 m visibility" and was made on 24.03.1998.

The proficiency checks were undertaken on behalf of Moldavian Airlines in the Crossair Saab 340B simulator in Basle with Swiss flying instructors and experts. The checks of 13.03.1998, 09.03.1999 and 12.07.1999 (right hand seat introduction) are documented. From the MCAA side, the respective training and check orders were placed on an MCAA form. The entries in the log book and license were then made accordingly.

On 26.10.1999 Crossair carried out a license proficiency check in Crossair's Saab 340B simulator in Basle. Validation of the license by the Swiss FOCA was applied for with the check form.

The Soviet license at this time had a validity entry until 06.04.2000, based on the validity period of the Moldavian medical examination. The application was accompanied by a confirmation of the Medical Centre of Civil Aviation of (the) Republic of Moldova regarding the validity of the examination until 06.04.2000.

The FOCA requested written confirmation from the MCAA concerning the conformity of the Moldavian license with international standards (fax dated 01.11.1999), which arrived by fax in Berne on 02.11.1999.

Then, on 02.11.1999, the FOCA issued Swiss license CH 42889 for airline pilots, with entry 81-15 "Validation foreign license, according to article 62 of the Swiss Air Navigation Law, the FOCA on basis of the following licences recognises with all rights reserved to revoke without further notice: 15 Civil Aviation Pilot License – Aeroplanes no. 025222 CAA / Republic of Moldova, valid as PIC on the type of aircraft SF 34 within the commercial operations of the company CROSSAIR Ltd., CH-4002 Basle".

No medical examination took place in Switzerland.

A Crossair line introduction over 20 sectors commenced on 09.11.1999 and ended with the line check on 19.11.1999.

Employment with Crossair lasted for three months. Within this period, he completed 139 flying hours. His experience of operation on Zurich airport consisted of four documented departures.

The following could be learned concerning the commander's knowledge of languages:

Mother tongues	Bilingual upbringing: Russian and Moldavian, no accent, fluent in the written and spoken languages
French	Proficiency unknown
English	Basic knowledge from 1990; 29.12.1999 Wall Street Institute entry test: way stage 7 passed (way stage: after Stage 6 students have a functional vocabulary and can speak at the lower-intermediate level and take part in simple conversations), course participation planned from January 2000 with the goal: upper way stage. (Qualification: on completion of stage 9 students can converse in the personal and commercial environment using a functional vocabulary and use the expressions which are employed most commonly in conversation).

1.5.6.2.2 First officer

The first officer of the aircraft involved in the accident underwent his pilot's training after the political collapse of the Eastern block in the late 'eighties. It therefore took place in a hybrid culture, characterised by:

- the strongly regulated environment, with Russian roots and a continuing pronounced Russian influence
- a western orientation with the use of western aircraft types and their philosophy of use.

However, the first officer’s training took place as early as the 'nineties, so he was no longer confronted with Russian instrumentation and Russian SOPs.

His conversion to Saab 340B took place under the aegis of Tatra Air at SAS (the SAS Flight Academy). This conversion constituted a combination of the Tatra Air Syllabus and the SAS simulator program. Flight training, line introduction and deployment took place exclusively at Tatra Air; this was his first experience of a two-man cockpit and commercial civil aviation.

Regular proficiency and line checks were carried out with instructors from Tatra Air.

This first and only commercial experience prior to working for Crossair lasted 1½ years. During conversion to the Saab 340, no formal MCC (multi crew concept) or CRM (crew resource management) training took place. Consequently, his introduction to working in a two-man cockpit took place primarily during simulator training and line introduction with Tatra Air. Repeated instructions to speed up the tempo of work and to prioritize ATC communication are documented from this period.

The first officer held license No. 03940314 for commercial pilots of the Slovakian Republic, issued on 24.10.1994. This document contained the entry as first officer on Saab 340B, a rating for IFR flights and a type entry for L-200. The validity of the license until 20.05.2000 was entered in handwriting and included the added note "spectacles wearer".

In 1997 the first officer was employed by Tatra Air and undertook the conversion to Saab 340B in June and July 1997. At this time he had a total of 295:35 flying hours' experience on engined aircraft. Of this, 54:05 flying hours were on L-200 and 36:40 were instrument flying hours.

The training began with cockpit observation from 02.06.1997 to 09.06.1997. The theory course and simulator training followed at the SAS Flight Academy in Stockholm. The theory course was concluded on 25.06.1997. The subsequent simulator training ended on 06.07.1997 with a total of 15 simulator hours as pilot flying and 5 hours as pilot non flying. Flight training on 09. and 10.07.1997 added up to 3:15 hours and 12 landings.

Line introduction then took place on the Tatra Air route network with the following destinations: Bratislava, Zurich, Kosice, Prague and Malpensa. It was planned over 30 sectors and was concluded on 12.09.1997 after 42 sectors.

After the bankruptcy of Tatra Air, the first officer found a position with Crossair where he underwent training, simulator training, FMS training, line introduction and the proficiency check.

On 02.08.1999 the first officer was taken on by Crossair, with a contract of employment dated 25.08.1999. The beginning of the course for Crossair re-qualification is listed as "(16.08.99) 02.08.1999".

On 24.08.1999 the first officer of the aircraft involved in the accident underwent Crossair's official pilot selection process.

On 02.09.1999 Crossair conducted a license proficiency check in the Crossair Saab 340B simulator in Basle. On 14.09.1999 validation of the license was applied for with the Swiss FOCA.

Swiss license CH 42696 for commercial pilots (CPL), with the entry 81-13 "Validation foreign license, according to article 62 of the Swiss Air Navigation Law, the FOCA on basis of the following licences recognises with all rights reserved to revoke without further notice: 13 CPL – Aeroplanes no. 03940314 CAA / Slovak Republic, valid as COPI on the type of aircraft SF 34 within the commercial operations of the company CROSSAIR Ltd., CH-4002 Basle" was issued on 16.09.1999 by the FOCA.

Line introduction began on 14.09.1999 (CRX 552, 553, 542, 543), two days prior to license validation.

Formal CRM training during the conversion course changing operator with Crossair is not documented.

The FMS theory course was completed on 18.08.1999 and between 14.09. and 24.09.1999 complemented by 14 sectors of line introduction.

No medical examination was carried out in Switzerland.

The line introduction at Crossair ended with the line check on 01.10.1999 after a total of 24 sectors.

The following could be learned concerning the linguistic knowledge of the first officer of the aircraft involved in the accident:

Mother tongues	Slovakian, Czech almost equally good
Russian	Learned during primary school, proficiency unknown
English	Knowledge assessed as good by Crossair colleagues

1.6 Aircraft information

1.6.1 Aircraft HB-AKK

1.6.1.1 General

Aircraft type:	Saab 340B
Manufacturer:	Saab Aircraft AB, Linköping, Sweden
Serial number:	340B-213
LFV type certificate	A1/1984 of 3 July 1989
Year of manufacture:	October 1990
Export airworthiness certificate:	30 October 1990
Registration certificate:	28 December 1998
Airworthiness certificate:	30 May 1995 valid till revoked
Total flying hours:	20589 h
Number of flight cycles:	21676
Engine type:	General Electric CT7-9B propeller turbines
FAA Type Certificate:	E8NE of 16 March 1989

1.6.1.2 Left engine

Serial number:	GE-E-785135
Time since installation in HB-AKK:	1555 h
Flight cycles since installation in HB-AKK:	1450
Time since new:	17856 h
Flight cycles since new:	18869

1.6.1.3 Right engine

Serial number:	GE-E-785245
Time since installation in HB-AKK:	1766 h
Flight cycles since installation in HB-AKK:	1636
Time since new:	17160 h
Flight cycles since new:	18153

1.6.1.4 Left propeller

Propeller type:	Dowty-Rotol R390/4-123-F/27
Serial number:	DRG10172-89
Time since installation in HB-AKK:	395 h
Flight cycles since installation in HB-AKK:	380
Time since new:	19289 h
Flight cycles since new:	19573

1.6.1.5 Right propeller

Propeller type:	Dowty-Rotol R390/4-123-F/27
Serial number:	DRG8096-89
Time since installation in HB-AKK:	4415 h
Flight cycles since installation in HB-AKK:	4201
Time since new:	13442 h
Flight cycles since new:	unknown
Flight cycles since basic overhaul:	5965

1.6.1.6 Navigation

The following systems were available to the pilots for navigation:

- Single FMS (B-RNAV)
- Dual VOR/ILS
- Dual DME
- Dual ADF
- Dual ADS (air data system)

1.6.1.7 Communications

The communications equipment consisted of the following systems:

- Audio integrating system
- Passenger address system
- Cabin interphone system
- Dual VHF com system

A mobile telephone is also carried onboard the Saab 340B aircraft. It is used for communication between the flight crew and ground control. The checklist specifies that the telephone must be switched off prior to engine start-up.

1.6.2 Mass and centre of gravity

As a basis for determining the mass and centre of gravity at the time of the accident, use was made of the entries in the load sheet of the aircraft. These data were confirmed by extensive analysis of findings at the site of the accident.

	Mass (kg)	Index
Dry operating mass	8508	11
Catering	181	6
Passengers	574	2
Baggage	50	3
Zero fuel mass	9313	22
Block fuel	2100	0
Ramp mass	11413	22

The calculated trim index of 22, for a ramp mass of approx. 11400 kg corresponds to a trim setting of 1.4 units ANU. These values are within permitted limits.

1.6.3 Flight controls

1.6.3.1 Control and control forces

1.6.3.1.1 Background information

The Saab 340B has smooth control in all three axes. This is noteworthy in comparison with Russian aircraft types, particularly the AN-24.

1.6.3.1.2 Findings on the aircraft involved in the accident

Only limited statements can be made on the correct functioning of the main controls, because of the scale of destruction of the wreckage which was found. The calculation of the flight path on the basis of the aerodynamic model, however, exhibits consistency with the relevant DFDR recordings of the flight control deflections.

1.6.3.2 Flap system

On the occasion of the C4 check in June 1998 the flaps from HB-AKE were fitted to HB-AKK, after S/B 27-033 had previously been carried out. Subsequently, multiple malfunctions in the flap system occurred with HB-AKK and HB-AKE. During the 18 months between the C4 check (June 1998) and the time of the accident, pilots complained about the flap system a total of twenty-one times:

Occurrence	Date	Ballooning nose down	Time lag, delay	No movement at all	Indication, warning	Remarks
01	03.07.98			X		On final
02	10.08.98	X				Nose down movement during climb out and level off. Most probably right hand flap extended and retracted.
03	15.08.98	X				Small down movement during all flight phases. Right hand flap moved down for approximately 2 seconds, then up again.
04	16.08.98	X				During climb out, nine minutes after take off at 190 KIAS and during descent flaps moved unintentionally down 2 to 3° and up again. Aircraft bumping and descending at 175 KIAS.
05	04.10.98		X			During approach
06	22.12.98		X			
07	07.02.99				X	During approach
08	02.03.99		X			During approach
09	17.03.99		X			Probably during approach
10	29.03.99		X			Probably during approach
11	09.04.99		X			During approach
12	20.04.99		X			During approach
13	15.06.99		X			During approach
14	09.08.99			X		During approach
15	16.08.99		X			During approach
16	21.08.99				X	Probably during approach
17	23.08.99		X			During approach
18	05.12.99	X				At 180 KIAS
19	07.12.99	X				During cruise at 185 KIAS
20	10.12.99	X				During climb out at 180 KIAS
21	22.12.99	X				Between 180 and 185 KIAS

In addition, two cases are known in which asymmetry problems occurred on approach while the flaps were being deployed. After deploying the flaps, the pilot had to perform roll compensation using full aileron deflection. These cases did not concern aircraft HB-AKK.

This type of aircraft has no warning to indicate flap asymmetry. Two flap indicators are present in an instrument in the cockpit. These are virtually ineffectual with regard to asymmetry indication, since the corresponding transmitters are linked to the flap synchronization system, not the flaps themselves. Thus both the cockpit instrument and the DFDR recordings show the position of this synchronization system, not the current position of the flaps.

1.6.3.3 Control blockage

Before the accident flight, a few pilots complained about rudder offset when the gust lock was engaged. This rudder offset of 5° to the right is permitted according to the Saab maintenance manual (27-72-20-4). The pilot training manual also points out that the rudder must be placed approx. 7° right in order to engage the gust lock.

1.6.3.4 Gust lock warning

Before the accident flight, problems occurred with the gust lock warning. This problem could finally be clearly attributed to a switch in the gust lock actuator. After replacement of this switch including the corresponding cable terminals, no more problems occurred. Nor do the analyses of the DFDR data give any indication of a control blockage due to the gust lock.

1.6.3.5 Disconnect handle

The fragments of a disconnect handle (DH) which were found could be identified as DH roll. It is located at the front left of the cockpit on the centre pedestal. The electrical components of the DH roll could not be found.

The investigations of the secured fragments, analysis of the recorded DFDR data for the right-hand aileron and the CVR recordings showed that the DH roll was not activated.

1.6.4 Engines and propellers

1.6.4.1 Left-hand engine

At the time of the accident, the left-hand engine had accumulated 17856 operating hours (time since new – TSN) and 18869 flight cycles (cycles since new – CSN) since manufacture. It was fitted to aircraft HB-AKK in May 1999, after the propeller gear box and the output drive assembly had been replaced. Since installation, it had accumulated 1555 hours and 1450 flight cycles. Since the last overhaul of the cold section in May 1998 the engine had been in operation for 2634 hours and 2490 flight cycles. The last overhaul of the hot section and power turbine took place in March 1997 at 4309 hours and 4205 flight cycles.

The engine was operated by Crossair at reduced power, in accordance with a procedure authorized by GEAE and FAA (GEAE operations engineering bulletin No. 11 dated 29 June 93 derivative engine takeoff rating program).

On impact, the engine was broken into the following three main parts:

- Output drive shaft
- Cold section up to the connecting flange between the axial compressor housing and the radial compressor housing
- Radial compressor and hot section with exhaust

The separation of the engine at the connecting flange between the axial and radial compressor housings occurred as a result of bolts shearing, without major deformation of the flanges. The sheared shanks of the bolts were still mounted in the rivet nuts in the radial compressor housing.

The hot section was ripped open at the connecting flange between the combustion chamber and the gas generator turbine over a sector of approx. 300°. Eighteen connecting bolts were still intact; the remainders were sheared. As a result of the partial destruction of the connecting bolts and the tearing-off of the combustion chamber cover an opening was created.

The traces which were found and the condition of the engine allow the following statements to be made:

- No traces which would indicate a bird strike
- No signs indicating blockage of the air inlet (foreign object)
- No damage due to ice or other foreign objects (foreign object damage – FOD)
- No overheating of the hot section
- No sign of a fire
- No indication of an uncontained failure prior to the crash
- No fractures with indication of a fatigue failure. All fractures in the material are probably the result of excessive force on impact.
- No indications of pre-existing faults or damage

Traces are present which show that the engine rotors (gas generator and power turbine) were rotating at high speed at the time of the impact. When the compressor blades touched the housing, the wear coating (Al/Si) was ground away. Residues of this coating could be found as white deposits in the diffuser of the radial compressor, on the dome of the combustion chamber and on the turbine guide vanes. On this engine, the deposits were less pronounced than on the engine fitted in the right-hand position. However, the traces of friction on the compressor rotor between stage 4-5 and 5 impeller through the guide vanes were more pronounced. The massive destruction of stage 1 of the turbine rotor also indicates high rpm on impact.

1.6.4.2 Right-hand engine

At the time of the accident, the right-hand engine had accumulated 17160 operating hours (time since new – TSN) and 18153 flight cycles (cycles since new – CSN) since manufacture. It was fitted to aircraft HB-AKK in April 1999, after an overhaul of the cold and hot section and the power turbine module had taken place in March 1999. Since installation, it had accumulated 1766 hours and 1636 flight cycles. The engine was broken into the following three main parts on impact:

- Output drive shaft
- Cold section with combustion chamber
- Gas generator turbine, power turbine and exhaust

The engine equipment and the externally fitted transmissions were torn off on impact. The separation of the engine at the connecting flange between the combustion chamber and the gas generator turbine took place as a result of shearing of the connecting bolts, without major deformation of the flanges. The output drive shaft was sheared off.

The traces which were found and the condition of the engine allow the following statements to be made:

- No remains which would indicate a bird strike
- No signs indicating blockage of the air inlet (foreign object)
- No damage due to ice or other foreign objects (foreign object damage – FOD)
- No overheating of the hot section
- No sign of a fire
- No indication of an uncontained failure prior to the crash
- No fractures with indication of a fatigue failure. All fractures in the material are considered to be the result of excessive force on impact.
- No indications of pre-existing faults or damage

Clear traces are also present which show that the engine rotors (gas generator and power turbine) were rotating at high speed at the time of the impact. When the compressor blades touched the housing, the wear coating (Al/Si) was ground away. Residues of this coating could be found as white deposits in the diffuser of the radial compressor, on the dome of the combustion chamber and on the turbine guide vanes.

1.6.4.3 Propellers

Investigation of the propellers produced the following findings:

- Both propellers were functioning normally on impact.
- Both propellers were damaged in a comparable manner. The deformation of the propeller blades showed that the propellers were rotating on impact.
- The pitches of the blades, which could be derived from the traces in the adjustment mechanisms, are consistent with a high power setting.
- All the propeller blades were broken off on impact.

1.6.4.4 Summary

The analysis of the DFDR data allows the following statements to be made:

- Both engines provided the expected power during the accident flight.
- In comparison with previous flights, the data for the accident flight show no deterioration in engine performance.
- The left-hand engine was operated under the derivative engine takeoff rating program (GE bulletin No. 11). The power values corresponded to the values specified in this service bulletin.
- The power settings for the engines were comparable during the accident flight with the power settings for earlier departures from Zurich.
- There were no traces of a compressor stall or flame out as a result of ingress of ice or slush into the engine.
- During the last phase of the flight (descent) the torque of both engines increased as a result of the increasing ram pressure as air speed increased (ram air effect).

The investigation of the engines allows the following statements to be made on the basis of the observed damage:

- No damage to the compressor blades due to ice or bird strike is present.
- No overheating occurred in the hot sections.
- No damage was found which might be attributable to failure of an internal, rotating component.
- Both rotor systems (gas generator and power turbine) were rotating at high speed on impact.

1.6.5 Cockpit configuration

1.6.5.1 General

The Saab 340B is a regional turbo-prop aircraft designed in the 'eighties. The cockpit equipment, as a first-generation glass cockpit, was modern for its time in terms of application for regional aircraft. The Saab 340B was the first aircraft in its class to be certificated for category 2 instrument approaches.

The cockpit size corresponds to the rather small dimensions of the aircraft. The controls are conventional and in the generally customary layout.

On the left of the centre pedestal are the power levers for the engines. They have a rather long regulating travel in comparison with other aircraft. Next to them on the right are the adjusting levers for propeller speed (the condition levers). These are also long and have a relatively long regulating travel.

In the middle, between the pairs of levers, is the gust lock with the corresponding unlocking mechanism. Behind the power levers there is a mechanical blocking device which was retrofitted to prevent inadvertent in-flight reverse. To the right and left of the pairs of levers is a friction lever, by means of which the ease of movement of the levers can be varied.

On the right of the centre pedestal is the lever for the flaps.

All the controls described thus far are positioned approximately at the height of the seated pilot's thigh. The front area of the centre pedestal contains instruments for monitoring the pressurized cabin and the hydraulic system.

The area of the centre pedestal behind the levers for the engines and propellers underwent several modifications and layout changes. It is essentially reserved for the communications radios and part of the navigation radio and also houses the control elements for the autopilot and the weather radar. When the aircraft was retrofitted with FMS (B-RNAV) the control display unit (CDU) was positioned behind the condition levers. In January 2000 this unit (keypad and CRT) was placed in the rear part of the centre pedestal on the entire Crossair fleet. With reference to the seated crew, it was therefore positioned at the height of the upper third of the pilots' thighs.

The engine instruments in the central part of the instrument panel are of the conventional type with additional digital display within the instrument for torque, ITT, engine RPM and propeller RPM. Torque – as a parameter which is influenced by the setting of the power levers – is displayed in the upper row on the left, whilst propeller RPM – as a parameter which is influenced by the setting of the condition levers – is displayed in the central right area.

The multifunctional display is located below the emergency instruments in the lower left part of the central instrument panel.

The control elements for the flight guidance system and part of the navigation radios are located in the central part of the glare shield panel.

The audio selector panels for the individual communications settings are positioned right of the first officer and left of the commander. Here there is also a microphone switch (push to talk switch – PTT) – in addition to the one mounted on the control wheel.

The overhead panel above the pilots' heads comprises the control elements for the aircraft systems (fuel, heating, electrical system, etc.) and is conventionally configured.

1.6.6 Flight guidance systems

1.6.6.1 Electronic flight instrument system (EFIS)

1.6.6.1.1 Electronic instrument displays

With the electronic instrumentation of the Saab 340B (first-generation glass cockpit), some of the conventional electromechanical flight instruments were mapped to cathode ray tubes (CRT). Whilst the fundamental layout of the instruments (basic T) was retained, the artificial horizon (attitude director indicator – ADI) and the horizontal situation indicator (HSI) were displayed on two separate CRTs. These displays were provided with some improvements and enhancements, such as the mode annunciator indication in the EADI or the de-clutter mode of the EADI.

Electronic representation of electromechanical instruments also requires that they take over their peculiarities. In this specific case, this means that a course pointer with deviation bar in the electronic horizontal situation indicator (EHSI) performs the change of a pre-set course faithfully to the electromechanical model. When a new course is applied as an electrical signal, the pointer turns from the original position on the shortest path (angle) to the new position, without taking into account the direction of the course change calculated by the FMS.

1.6.6.1.2 Description of the system

In the Crossair Saab 340B two independent EFIS are installed, complemented by a multifunction display system. Each EFIS consists of a display processor unit (DPU), a display control panel (DCP), an electronic attitude director indicator (EADI) and an electronic horizontal situation indicator (EHSI). The multifunction display system consists of a multifunction processor unit (MPU) and a multifunction display (MFD). This system basically works autonomously, but in the event of failure of a DPU, the MPU can be switched in as a backup. The left-hand DPU receives signals from the left-hand aircraft sensors. The right-hand DPU receives signals from the right-hand aircraft sensors. The MPU, on the other hand, receives signals from both sides. If an attitude heading computer (AHC) fails, it is possible to switch over to the one on the opposite side.

The EFIS contains the following components:

Display processor unit (DPU):

The DPU receives digital and analogue signals from the following aircraft systems: radio altimeter, air data computer, VOR/ILS/MB, DME, ADF, AHC, FCC (FD), weather radar and FMS (LRN). These signals are processed in the DPU and then forwarded for display to the EADI and EHSI.

EADI and EHSI:

These CRT display units receive color signals from the DPU for display.

Multifunction processor unit (MPU):

The MPU basically works identically to the DPU, but the output signals are fed to the MFD. In the event of a failure, the MPU can be used as a DPU backup.

Multifunction display (MFD):

The MFD basically works like an EADI or EHSI. Buttons which are positioned directly on the MFD are used to select the display.

Display control panel (DCP):

Two DCPs, one each on the left-hand and right-hand side, are used to select the information on the EADI and EHSI.

Course heading panel (CHP):

Course and heading are set via the CHP. The selected values are displayed on the EHSI: CRS 1 on the left-hand EHSI and CRS 2 on the right-hand EHSI. The selected heading appears on both EHSIs.

EFIS switches:

In the event of failure of an EADI or EHSI the remaining indicator can be switched over to so-called composite mode, i.e. the remaining CRT displays information from both displays. In the event of a DPU fault, a EADI/EHSI pair can be switched through to the MPU. In the event of an AHC fault, it is possible to switch over to the opposite AHC.

Nav source selection pushbuttons:

Two pushbuttons are mounted on the glareshield panel. These are designated NAVS L and NAVS R. They are used to switch navigation signals from the left-hand or right-hand side to the autopilot or the flight director.

EFIS test panel:

Two switches (EFIS 1 and EFIS 2) are located in the overhead panel. These initiate an EFIS self test, which checks the various EFIS functions:

- Pitch, roll, heading in test position.
- Warning indicators are activated.

1.6.6.1.3 EFIS failure after switching on the logo lights

In October 1996 the following fault occurred on HB-AKK:

Immediately after the logo lights were switched on, all displays on the right-hand EFIS disappeared.

The investigation produced the following explanation for this event:

The two consumers, the R/H EFIS (RH AVION START BUS) and the logo lights (RH MAIN START BUS) are supplied by the same bus (RH BATTERY BUS) via a 25 A circuit breaker (CB 18PP).

Because of a loose cable terminal, this CB heated up, causing it to trip when the logo lights were switched on (increase in load).

The fault was rectified by replacing the cable terminals of the CB 18PP and the cable terminals of the main start bus relay. No subsequent incidents were notified.

1.6.6.2 Automatic flight system (AFS)

1.6.6.2.1 Description of the system

The flight control computer (FCC) constitutes the heart of the automatic flight system. It performs the following functions:

- Autopilot
- Flight director
- Yaw damper
- Rudder autotrim
- Elevator autotrim

The FCC receives signals from various aircraft systems which are required for calculating the control commands.

Flight director commands and mode information are displayed by the FCC on the EADI. Autopilot, yaw damper and trim commands are routed to the corresponding control surfaces.

For operation of the flight director and autopilot, the pilot has the following control elements at his disposal: mode select panels (MSP), altitude preselector alerter (APA), autopilot panel (APP), autopilot disengage buttons, go-around buttons and VERT SYNCH buttons.

The flight director assists in manual guidance of the aircraft. Flight director commands are displayed on the EADI. The flight director also assists in visual monitoring of the autopilot function.

The flight director modes are programmed on the MSP. The following flight director modes are available:

Vertical modes:

- VS (vertical speed)
- IAS (indicated air speed)
- CLIMB
- ALT (altitude hold)
- ALTS (altitude select)

Lateral modes:

- HDG (heading)
- NAV (navigation LRN or VOR)

Combined modes:

- APPR (approach)
- GA (go-around)

The yaw damper is used to stabilize the aircraft around the vertical axis and supports coordinated turns (turn coordinator function).

Rudder and elevator trim functions are used to trim around the corresponding axes.

The auto flight system consists of the following components:
Fight control computer (FCC):

The FCC receives signals from various aircraft systems such as ADC, AHC, RA, VOR/ILS and FMS for processing. It calculates the required control commands in order to fly the aircraft in various lateral and vertical modes. The functions of the FCC are continuously monitored internally.

Mode select panel (MSP):

The MSP is installed in the glare shield panel (GSP). The lateral and vertical flight director modes are selected using pushbuttons on this MSP and indicated by pilot lamps in the pushbuttons. The commanded bank angle can be halved using a further pushbutton (half bank).

Autopilot panel (APP):

The APP is installed on the centre pedestal. Two switches are used to switch the autopilot and yaw damper on and off. The heading can be selected using a turn selector. The pitch wheel is used to set the vertical speed.

NAV source selector:

By means of the NAV source selectors (NAV S L and NAV S R) on the GSP, the navigation sources can be switched to the autopilot/flight director.

Altitude preselector alerter (APA):

An altitude can be pre-selected using the APA. When the aircraft approaches or leaves the pre-selected altitude in a vertical flight mode, a visual and acoustic indication is provided.

Warnings:

Malfunctioning of the flight director is indicated on the EADI. Malfunctioning of the automatic trim is indicated on the central warning panel (CWP).

1.6.6.2.2 Presentation of the flight director

The FD is represented in the EADI as an electronic simulation of the electromechanical FD of older types. Crossair chose the V-bar form of presentation.

Two basic forms of presentation have been developed in the past: the single pointer (V-bar) and the cross pointer (cross bar). In the literature there is no decisive evaluation of the advantages and disadvantages of the two systems. Traditionally, operators of larger aircraft have preferred the cross bar presentations, whilst some pilots have expressed the opinion that the V-bar allows simpler flying and the cross bar more accurate flying.

The cross bar type represents a decoupled presentation of the pitch command and roll command parameters, whereas the V-bar combines both channels.

Given the Russian design of the artificial horizon, also with a decoupled representation of pitch and roll, the cross bar therefore has an apparent advantage in terms of interpretability (cf. 1.16.5.1.1).

The V-bar presentation is limited to a relatively narrow travel of the roll and pitch command, whereas the cross bar representation is subject to a larger excursion.

The FD does not provide any information on the current attitude. It provides control commands to achieve the required angular rates in the pitch and roll axis. The scale of this angular rate is determined by the degree of comfort required.

In a climb, the FD commands changes in attitude with an angular rate of 3°/s.

The pilot monitors attitude and therefore also the functioning of the FD with the aid of the attitude instruments.

1.6.6.2.3 Investigation of the mode select panel

Each key on the mode select panel has pilot lamps which are activated by the flight control computer (FCC) and which indicate the mode in which the flight director is working (active feedback).

The lamps soldered onto the printed circuit were examined. It was ascertained that at the time of impact the NAV and IAS lamps in the left-hand mode select panel were illuminated. The other lamps were not illuminated.

Hence the NAV and IAS modes were activated; this is plausible for a climb.

1.6.6.2.4 Use of the automatic flight system

The autopilot was switched off throughout flight CRX 498 (DFDR data). After taking off from the runway and retraction of the undercarriage, on the commander's instructions the flight director was switched on, the NAV mode was armed and it was confirmed by both pilots that the long range navigation system-1 had captured the course (LRN-1 captured). IAS mode was already activated prior to take-off.

1.6.6.3 Flight management system (FMS)

1.6.6.3.1 Description of the system

At the time of introduction of B-RNAV operation in European airspace, Crossair had its Saab 340B aircraft equipped with a single unit FMS Type UNS-1K from Universal Avionics. This retrofit was certificated as a supplemental type certificate (STC).

The FMS is a fully integrated system which is designed for flight planning, aircraft control and fuel planning.

For calculation of the navigation data, the FMS is equipped with an integrated GPS receiver, as well as aircraft sensors such as DME, ADC and the attitude heading reference system (AHRS). Fuel planning is based on manual input of the fuel on initialization of the flight, updated by the measured fuel consumption and taking the flight plan into account.

The FMS computer uses the GPS position as well as the position determined on the basis of multiple DME stations (scanning DME) and in this way calculates the FMS position (best computed position). In this process, the DME interrogators are controlled automatically by the FMS. The FMS acquires the stations to be selected and their geographical coordinates from the navigation database. The FMS position is continuously monitored, taking other parameters into account (TAS, HDG), and if necessary appropriate warnings are issued. On the basis of the calculated position, the FMS navigates the aircraft along standard instrument departure routes (SID), RNAV routes, airways, holding patterns and standard instrument arrival routes (STAR). In addition to the current position, the FMS also calculates additional navigation data such as course to waypoint, distance to waypoint, wind, ground speed and estimated time of arrival (ETA). These data are displayed to the pilot on the EHSI and on the FMS control display unit (CDU).

Flight planning is carried out by accessing the FMS navigation database. This contains information on waypoints, airways, arrivals, departures, etc. Entire flight routes, known as company routes, are also stored and can be selected by the pilot with little effort. A route selected on initialization can be changed at any time during the flight – e.g. because of ATC instructions. Special mention should be given here to functions such as direct to or holding patterns. The basic data in the navigation database are updated by Jeppesen every 28 days and can be uploaded into the FMC computer via the data transfer unit. The company routes are compiled by the aircraft operator and updated as required. The pilot can in fact modify the sequence of an active company route but not the basic data in the navigation database.

The FMS supplies navigation data such as desired track, lateral deviation, ground speed, distance to waypoint etc. to the two display processor units. If the left-hand NAV source selector is pressed and LRN selected on the left-hand display control panel, the FMS data are activated on the left-hand EHSI. If the 2nd CRS button is now pressed on the right-hand display control panel, the right-hand EHSI additionally displays the FMS desired track. Conversely, if the right-hand NAV source selector is pressed and LRN is selected on the right-hand display control panel, FMS data appear on the right-hand EHSI. The 2nd CRS button on the left-hand DCP activates the FMS desired track on the left-hand EHSI.

The FMS supplies a roll steering command to the flight control computer (FCC). This is processed in the flight director computer of the FCC and then forwarded via the display processor unit to the respective EADI. It is a prerequisite for this that the FCC is working in LRN navigation mode. If one follows the V-shaped flight director (V-bar symbol) on the EADI, one will keep to the pre-set course. At lower altitudes the commanded roll angle is restricted to 27°. Above 15000 ft AMSL the roll angle is successively reduced to 15°. The commanded roll rate is 3° per second. In the event of a fault or at extreme attitudes the V-bar symbol disappears.

If the autopilot is engaged, it holds the aircraft on the calculated course. In this context, signal processing is also carried out by the flight director computer. If necessary, FMS status messages are displayed on the FMS CDU.

The FMS consists of the following components:

Navigation computer unit (NCU):

The NCU is installed in the avionics rack. It contains the FMS central processor, the navigation database, the company routes database and an autonomous GPS processor.

Control display unit (CDU):

The CDU is located in the centre pedestal in the cockpit. It forms the interface between the pilot and the navigation computer. Inputs are entered via the alphanumeric keyboard and special function keys. An LCD screen is available for display.

Configuration module:

On installation, the special features of the Saab 340B configuration are transferred via the CDU into the configuration module and stored.

Data transfer unit (DTU):

The DTU is located in the centre pedestal. It allows data (navigation database, etc.) to be loaded into the NCU using a 3.5" diskette.

Remote annunciators:

Six lamps (remote annunciators) respectively are installed in the pilot's direct field of view; they indicate the system status:

- MSG a new message has been generated
- WPT lateral waypoint alert
- SXTK FMS in selected cross track mode
- FMS HDG FMS in heading mode
- FMS APPR FMS in approach mode
- GPS INTG RAIM not available or a fault is detected. DME may still be ok

1.6.6.3.2 Installation

The Crossair Saab 340B aircraft were delivered without a flight management system (FMS). The single FMS type UNS-1K from Universal Avionics was installed as a retrofit system. The reason for installation was the introduction of the new B-RNAV structure in Europe, which entered into force on 1.1.1998.

The installed FMS is based on the FAA STC No. ST09384 SC, issued on the STC holder New Systems. The STC in turn is based on the detail drawings listed in master drawing 227-00-0001. One of these detail drawings is the GPS top drawing 227-00-0002, which describes the version valid for Crossair (-3) as follows: "UNS-1K FMS/GPS WITH PEDESTAL MOUNTED DTU. SYSTEM INTERFACED WITH 5-TUBE EFIS SYSTEM, AND COLLINS PRO-LINE 2 VOR AND DME". A summary of the applicable drawings is provided from drawing No. 227-00-0000, Saab 340B GPS installation drawing tree. The drawings produced by New Systems correspond to the American industry standard.

For the conversion, work orders (WO) were issued by Crossair in AMOS. These work orders were grouped according to task, zone and skill. The following deficiencies were found:

- WO522208 refers to the GPS top drawing, instead of the corresponding detail drawings (227-91-6000 and 227-91-7000).
- WO522190, reference to drawing 227-91-3000 missing. Reference to STC alone is insufficient.
- WO522186, reference to drawing 227-91-3000 missing. Reference to STC alone is insufficient.
- WO522191, reference to drawing 227-91-4000 missing. Reference to STC alone is insufficient.
- WO522183, reference is incorrect, 227-81-1000 instead of 227-91-1000.
- WO522209, references to the requested functional checks missing.
- WO522193, reference to drawing 227-00-0006 missing. Reference to STC alone is insufficient.
- No WO was issued for the configuration process of the system (227-00-0015).

The modification kits required for installation of the FMS UNS-1K were prepared by the New Systems company and supplied to Crossair.

1.6.6.3.3 Certification

The installed single FMS UNS-1K from Universal Avionics was certificated by STC No. ST09384 SC.

At the FAA the certification process ran under FAA project number ST4900SC-T. The type inspection approval (TIA) was issued on Saab 340B, HB-AKA (conformity inspection record, 8100-1, dated 10-7-97).

With documents 227-00-0017 and 227-00-0018, New Systems provided a statement of conformity of the FMS with FAA and JAA regulations.

In a letter of 8 October 1997 Crossair informed the FOCA of the completed certification in order to obtain validation of the FAA STC. The corresponding documents were appended to the letter.

Since the certification was carried out on one aircraft only (HB-AKA), Crossair Engineering issued an additional test which tests all interfaces of the FMS with other aircraft systems and which was carried out on all aircraft.

A supplement to the FAA approved flight manual was supplied with the FAA STC. This supplement was incorporated in the corresponding Crossair flight operations manuals.

According to information from the system manufacturer Universal Avionics, the FMS UNS-1K meets the following requirements:

- TSO C-129a, Class A1
- TSO C-115b
- DO-178, Level C
- At system level the FMS meets the JAA requirements according to AMJ 20X2 – JAA GUIDANCE MATERIAL ON AIRWORTHINESS APPROVAL AND OPERATIONAL CRITERIA FOR THE USE OF NAVIGATION SYSTEMS IN EUROPEAN AIRSPACE DESIGNATED FOR BASIC RNAV OPERATIONS (Leaflet No. 2 Rev.1).

1.6.6.3.4 Training

No FMS was installed in the simulator, either in Basle or in Arlanda. The computer based training (CBT) for the Saab 340B was not upgraded to the FMS System. A special FMS training unit was available in Basle. Actual use of the FMS was taught and learned on the route.

1.6.6.3.5 Operating experience

The operational behavior of the FMS was checked on the basis of AMOS work orders for the period from 1998 to 1999 and the findings were as follows:

- In 1998 a number of entries were made which concerned the FMS HDG mode (No Heading Input, A/D HEADING FAIL, ANALOG INST FAIL etc.). Software 602.5 was loaded with Universal Avionics service bulletin 34-2616; this remedied the problem.
- In 1998 and 1999 a number of entries were made which concerned the interface between the FMS and FCC. The FMS often displayed the message "STEERING FAIL". The flight director bar was removed, the flight director flag appeared while the autopilot was working normally.

- In 1998 a number of entries were made which concerned the interface between the FMS and EFIS. False displays were observed on the EHSI and/or on the MFD. In 1999 there are no further entries in this respect.

1.6.6.3.6 Maintenance

The FMS was in daily use by the flight crew and was monitored in its functioning (on condition monitoring).

There is a problem with the FMS with remedying faults, in that many faults cannot be duplicated on the ground after the flight. In many cases faults occurred only in specific circumstances or scenarios which cannot be simulated on the ground. As a rule, a self test is then performed, ensuring that there are no hardware or software failures in the FMC. Occasionally a suspect unit is swapped out. Often the fault disappears, even though nothing is done – or the correct thing is not done. A further difficulty is that the indicated faults are reported with very different formulations. There is hardly any uniform terminology.

At Crossair too, FMS trouble shooting took the described form.

1.6.6.3.7 Navigation database

The following navigation database was installed in the FMS at the time of the accident:

- UNS1 database update 1350-D2 (S-1), valid for AFR-EEU-EUR-MES from 30.12.1999 to 27.01.2000.
- UNS1 database update 1350-D2 (E-1), valid for AFR-EEU-EUR-MES from 30.12.1999 to 27.01.2000.
- Crossair Saab 340B UNS-1K flight management system company route database, valid from 30.12.1999 to 26.01.2000.

On the part of the Crossair crews, there were no complaints about standard instrument departure ZUE1Y either before or after the flight which was involved in the accident.

1.6.6.3.8 Misleading navigation

Misleading navigation with warning:

The greatest potential for misleading navigation with warning lies in determining the current position. In the case of the Saab 340B FMS this is determined using GPS and DME. Directly after take-off, there are generally not enough DME stations available. If the GPS constellation (in combination with the attitude) is then unfavourable, determination of position becomes critical. The FMS gives a corresponding warning. Several complaints from crews (AMOS work orders 852773, 920680) might point in this direction.

Misleading navigation without warning:

The greatest potential for misleading navigation without warning lies in the navigation database. As part of the ARINC 424 process waypoints are entered manually and then converted via a compiler into a form compatible with the respective flight management computer. Given a navigation database with millions of data items, the probability of an incorrect input is relatively high, as evidenced time and again in practice. Incorrect entries have a direct effect on navigation. The pilot is the last link in the chain for discovering such errors.

Further potential lies in incorrect programming of the company routes database. AMOS work order 436205 shows such a case, which in that case, however, was noticed by the crew.

Considerably less probable is the potential for misleading navigation without warning which originates from the flight management computer itself. It is specified by the system manufacturer, Universal Avionics, as a probability of 10^{-5} events per hour of flight.

1.6.6.3.9 Use of the FMS

Normal operation consists of the pilot flying (PF) selecting FMS data (LRN) on his EHSI as primary navigation data. For monitoring purposes, the pilot non flying (PNF) chooses VOR 1(2) as primary navigation source and LRN as 2nd course. The reason for this is that the FMS is certificated only as a supplemental means of navigation.

For reasons of space, the FMS-CDU was installed according to STC in an existing gap in the centre pedestal. Crossair took the positioning of the FMS-CDU into account by introducing a procedure for in-flight programming of the FMS which also considered the aspects of the two-man crew and the limited display facilities. Since this procedure was envisaged for use when cruising, the awkwardness in application could be tolerated.

The subsequently introduced use of the FMS for approaches and departures (terminal area), however, led in certain cases, according to statements from crews, to deviations from the published complex programming procedure.

The Universal Avionics UNS-1K FMS has a unique DIR TO (direct to) function, which is not customary on other FMS. With this function the turn direction can be specified. This is entered as LEFT, RIGHT or AUTO. RIGHT and LEFT are self-explanatory. In the AUTO function, the UNS-1K FMS works like other types of FMS by selecting the turn direction which constitutes the smaller angle between the current course and the new course. This angle is less than or equal to 180° in all cases.

If the turn direction is not entered, the FMS selects auto mode. Whilst in the case of explicit entry of left or right a small arrow briefly indicates this information on the display of the FMS CDU even after execution (ENTER), in auto mode the turn direction cannot be ascertained.

Nor is any indication of the turn direction provided on the other displays (EHSI, EADI, MFD).

The correct in-flight programming of a DIR TO (direct to) follows the description in the PIH (procedures, standard FMS procedures, pages 1-6).

Example: Extended Closed Loop

PF	PNF
"Insert direct to ..."	
	Programs the change on the CDU "Direct to ... inserted"
Checks change on CDU "Checked / ENTER"	
	Pushes ENTER on the CDU
Checks change on his EFIS	

For flight CRX 498 the FMS was used as the primary means of navigation. Prior to take-off, the FMS (LRN) had been programmed with standard instrument departure ZUE-1Y. After take-off the LRN was switched to the flight director.

1.6.6.4 Other navigation equipment

1.6.6.4.1 VOR displays

Both radio magnetic indicators (RMI) could be recovered and assigned to the left and right positions. Investigation of the remains produced the following result:

RMI left, serial number 2669:

- Instrument badly deformed, display scale and double pointer present, single pointer missing.
- The last position of the single pointers could not be determined. The position of the double pointer is approx. 059°. Both VOR/ADF selector switches pointed to VOR. The heading display was approx. 119°

RMI right, serial number 1708:

- Reliable analysis was not possible because of the extent of the destruction.

The bearing from the crash position to VOR ZUE approximates fairly closely to the value of 059°. The position of the ADF/VOR selector switch is consistent with a departure from Zurich. This is an indication that the VOR-2 (double pointer) was set to the ZUE frequency and was functioning normally. There is no verbal indication (CVR) of a defect in the VOR systems.

1.6.6.4.2 Air data system

The core of the left-hand air data system is the air data computer (ADC). This is connected to the static pressure system, the pitot pressure system and a temperature sensor for the outside air temperature (OAT). The pneumatic signals are converted to electrical signals in the ADC. These are then processed digitally. The calculated parameters finally are output to the data lines. Data output to the airspeed indicator, servo altimeter, vertical speed indicator, EFIS, FCC, AHC, GPWC, rudder limiter and FDAU is provided via different, independent data lines.

The internal data processing of the air data computer is continuously monitored. In the event of any malfunction, the incorrect output data are identified. This identification is detected as a fault signal by the internal monitoring of the user systems, e.g. airspeed indicator, servo altimeter, etc.

In the airspeed indicator and in the servo altimeter the incoming data are monitored for validity. The internal processing in these devices, as far as the servo circuit, is also monitored. Malfunctions are indicated by warning flags.

Inspection of the work orders of the air data system produced the following findings:

- Some of the work orders were completed inadequately, making traceability difficult.
- The procedure for trouble shooting was in part inappropriate.

1.6.7 Bank angle warning system

All Crossair Saab 340B aircraft were delivered with a ground proximity warning computer (GPWC) mark II. This type does not include a bank angle warning option.

Since the mark II GPWC was no longer in manufacture, new Saab 340B aircraft from serial number 367 onwards were delivered with the mark VII GPWC. This computer additionally includes the bank angle warning as an option.
Saab published SB 340-34-092, which regulates the replacement of the GPWC Mark II by the GPWC Mark VII.

For optional activation of the bank angle warning in the GPWC Mark VII, which requires extensive modifications to the aircraft, no service bulletin existed until March 2001.

To date, no new Saab 340B aircraft with bank angle warning have been certificated (type certificate) and delivered.

JAR OPS 1 subpart K and L do not prescribe a bank angle warning.

In Russia, the bank angle warning is part of the minimum equipment of commercial aircraft. It includes an optical and acoustic warning which trips in at bank angles of over 30°. Unlike western solutions, it distinguishes between the bank angle direction by specific visual indications if the bank angle is exceeded to the left or right (separate lamps). Certain CIS states (e.g. Moldova) accept the Russian certification regulations in accordance with an inter-state agreement.

The Saab 340B (ER-SGA ex HB-AKP) of Moldavian Airlines had no bank angle warning contrary to the information in the MAK (inter-state air travel commission of the CIS) type certificates.

1.6.8 Ground proximity warning system

The ground proximity warning system (GPWS) generates optical and acoustic warnings when the aircraft inadvertently and hazardously approaches the ground.

The ground proximity warning computer (GPWC) monitors and processes specific signals from the aircraft and triggers a warning if the aircraft enters one of the five warning envelopes. The following situations (modes) are monitored by corresponding warning envelopes:

- Mode 1 excessive sink rate
- Mode 2 excessive terrain closure rate
- Mode 3 altitude loss after take-off
- Mode 4 terrain clearance
- Mode 5 inadvertent descent below glide slope
- Mode 6 minimums callout (retrofit by Crossair)

For each mode there are defined acoustic warnings. In the event that multiple warnings were to trip in at the same time, these have different levels of urgency. The stall warning has priority over the GPWS warnings. Modes 1-4 additionally trigger the optical TERRAIN warning, whilst mode 5 additionally triggers the optical warning BELOW G/S. In order to take the different aircraft configurations into account (flaps, gear), the mode 2 and mode 4 warnings are subdivided into submodes.

To determine the warning envelopes the GPWC requires the following signals: radio height, air data (V/S, IAS, altitude), glide slope deviation, flaps position, landing gear position.

In order to avoid a false warning in the event of a deliberate landing with flaps retracted, the current flap position can be overridden with the GWPS FLAP switch (mode 4B, flaps override).

A self test can be carried out using one of the GPWS TEST buttons in the glare shield panel. The TERRAIN and BELOW G/S warning lamps light up and the acoustic warning "WHOOP WHOOP PULL UP" sounds.

In the final phase of flight CRX 498 mode1 and 2 should have responded as expected. Why these did not respond is analyzed in chapter 2.

The GPWC mark II, serial number 8496, was found in the wreckage.

1.6.9 Performance of the aircraft

The engineering data from the DFDR were examined and analyzed together with the aircraft manufacturer. In the process the records of the aircraft involved in the accident were compared with previous flights. Subsequently, an analysis of the DFDR data was performed, by comparing them with a simulation of the performance and mechanical behavior of the aircraft. This engineering analysis provided the following findings:

- The flight simulation of the accident was a very good match with the DFDR data.
- The good match between the DFDR recordings and the simulations permit the conclusion that the aircraft behaved in accordance with the design specifications for type Saab 340B.
- No indications could be found that extraordinary forces acted on the aircraft prior to impact or that any structural part of the aircraft had been substantially deformed or damaged prior to the accident.
- Throughout the accident flight, the aircraft reacted normally to changes in engine power and deflections of the control surfaces.
- The analysis of the acceleration data (g-forces) shows that during the accident flight no substantial turbulence occurred.
- The yaw damper was functioning correctly.
- Since the autopilot was switched off throughout the flight, it must be assumed that all deflections of the control surfaces were caused by the crew.
- There is nothing to indicate effects of ice formation on the aircraft.

1.6.10 Maintenance of the aircraft

1.6.10.1 Maintenance records

According to the documentation received from Crossair the maintenance work specified in the maintenance program was carried out in full. The work done was confirmed on work orders or special signature sheets. The filing is organized according to service bulletins, checks, engines and propellers.

The service history documents, complaints and the list of parts replaced since the last C-check (C4 Check June 1998) were examined in detail. The following findings were made:

- The periodic checks (scheduled maintenance) prescribed by the aircraft manufacturer and the authorities were carried out within the specified intervals.
- The components subject to a periodic overhaul were within the prescribed operating times.
- The maintenance records were on the one hand filed in hand-written form on paper (fingerprints), and on the other hand on the computer using AMOS (Airline Maintenance Operation System).
- The flaps of HB-AKE were fitted on the occasion of the C4 check (28.06.1998) on HB-AKK after S/B 27-033 had first been carried out. The following was ascertained:
  - The transfer of the flaps from HB-AKE to HB-AKK is not recorded in the documents for HB-AKK.

  - The work orders (prepared by Crossair AVOR), which were required for processing the S/B 27-033 in the metalwork shop were incomplete.
- For the double inspections required according to the Crossair maintenance information handbook 2, the signature of the authorized, licensed mechanic was missing on the work orders of the C4 check in the case of the following replaced components:
  - Flight control cables
  - Flaps SB 27-033
  - Flaps installation
- Not all processes were initialed on the work orders by the person doing the work; some were initialed by the supervisor.
- In the work orders for replacement of the flight control cables (during the C4 check) no JAA form one (airworthiness certificate after manufacture or maintenance work in the workshop) or certificate of conformity were found.
- For the right-hand propeller, the JAA form ones were missing in the logbook for the last overhaul/modification as well as for the last two repairs (replacement of de-icing boots). The cause lies in non-compliance by the workshop with the Crossair operating regulations (MME/MOE) for this process. The propeller is not allowed to be installed in an aircraft without the JAA form one.
- In operation, from the C4 check until the accident, i.e. for a period of 18 months, twenty-one complaints were made by pilots about the flap system. The maintenance actions taken did not allow to find the cause of these malfunctions and could therefore not be eliminated. Crossair lacked a procedure which would have made it possible systematically to detect and remedy recurrent faults.
- The modification status of the investigated avionics equipment was monitored and entered in the work orders by manual entries.
- Various cases concerning FMS misleading navigation on SID are known and documented; these are dealt with in the chapter on FMS (1.6.6.3.8).
- Complaints concerning "EFIS black" and "gust lock warning" were rectified.

At the last A9 check on 4.12.1999 all mandatory airworthiness directives and service bulletins were performed.

The following defects not dealt with were noted in the technical logbook (deferred defects list):

- L/H Engine S/N 787135 is derated due to negative margin.
- Whistling noise over seat 6A when 1 or 2 recirc. fans on. Noise disappears when both recirc. fans off.

1.6.10.2 Procedures in the metalwork shop

On the occasion of the investigations of the flap system discrepancies in the processes for repair and modification work by the Crossair metalwork shop were found with reference to correct administration.

The necessary documentation (work orders and working documentation) for correct execution of the repair to the flaps was not available. The reason for this lay in the lack of process instructions for production engineering (AVOR).

1.6.11 Examination of the fuel used

A fuel sample from the tanker which supplied HB-AKK immediately before the accident flight was subjected to analysis at the Federal Materials Testing and Research Institute (*Eidgenössischer Materialprüfungs- und Forschungsanstalt* – EMPA) which produced the following result:

Fuel type: JET A-1, appearance: water white, clear, no solids and water.

Characteristics (test methods):

Total acidity (ASTM D 3242), Aromatics (ASTM D 1319), Olefins (ASTM D 1319), Sulfur total (ASTM D 4294), Doctor test (ASTM 4952), Distillation (ASTM D 86), Flash point (IP 170), Density at 15°C (ASTM D 4052), Freezing point (ASTM D 5901), Viscosity at –20°C (ASTM D 445), Specific energy net (ASTM 3338), Smoke point (ASTM D 1322), Naphtalenes (ASTM D 1840), Thermal stability (ASTM D 3241), Corrosion cooper class (ASTM D 130, Existent gum (ASTM D 381), Electrical conductivity (ASTM D 2624), Water (ASTM D 1744).

All these characteristics of the fuel were within the prescribed tolerances.

Two other parameters were measured outside the tolerances:

Interface rating (ASTM D 1094): measured value 2; tolerance 1
MSEP (ASTM D 3948): measured value 50; tolerance min. 70

The EMPA commented on this result as follows:

Quote:

„Das interface rating, geprüft gemäss der ASTM D 1094, beschreibt die Tendenz einer Mischung von Wasser und Flugpetrol (Jet A-1), einen Zwischenschichtfilm oder -ausfällungen zu zeigen. Der Test reagiert auf Verunreinigungen durch Tenside (surfactants) sehr empfindlich. Das Vorhandensein von solchen Tensiden kann die Wirkung von Filterseparatoren zur Wasserabscheidung beeinträchtigen.

Genau diese Wasserabtrennungsfähigkeit beschreibt der MSEP-Wert, geprüft gemäss ASTM D 3948. Ein MSEP Wert von 50 bedeutet, dass dieses Flugpetrol tensidisch wirkende Verunreinigungen enthält, welche die Wasserabscheidung beeinträchtigen. Ein Milligramm eines Tensides in einem Liter Flugpetrol genügt bereits, um die in diesem Untersuchungsbericht gefundenen off-spec Werte zu erhalten. Da alle andern Eigenschaften inkl. Wassergehalt in Ordnung sind, ist es nicht auszuschliessen, dass bei der Probenahme kleine Spuren von Tensiden in diese Flugpetrolprobe hineingekommen sind.“

End quote.

1.7 Meteorological information

1.7.1 General weather situation

A weak cold front which had reached Switzerland on the preceding day lies above the north side of the Alps and is coming under the increasing influence of high pressure.

On the ground the central area of an extended high pressure region extends from the near Atlantic over central and eastern Europe. Switzerland is at the southern edge of the central area.

At altitude there is a virtually stationary but much weakened trough over Switzerland. This is being further broken up by a strengthening ridge of high pressure.

An extended and substantially compact cloud cover lies over the flat country on the north side of the Alps. In places, slight drizzle is falling, but this is hardly picked up by the precipitation radar or the rain measurement stations. The contrasts in pressure on the north side of the Alps are minor. A corresponding weak wind from the north-west to north is blowing over the midlands.

1.7.2 Weather at Zurich airport

As a result of the cold front from the previous day, low cloud cover lies over the airport at Zurich (stratocumulus), generally in several strata, with a cloud base between 500 and 800 ft AGL. Up to the time of the accident, it was producing weak rainfall or a slight drizzle. Over the day, visibility fluctuated between 4 and 8 km. The temperature in the aerodrome area, measured at 2 m AGL, was between 2 and 3 °C throughout the day. The wind, measured at 10 m AGL, reached mean speeds of 2 to 4 knots and was blowing from 290 to 360°.

At the time of the accident, the following METAR reports for Zurich airport were applicable:

101620Z 31003KT 6000 BKN005 02/01 Q1032 TEMPO 5000
101650Z 29003KT 6000 –DZ BKN005 02/01 Q1032 TEMPO 5000
101720Z 29003KT 5000 –DZ BKN005 02/01 Q1032 NOSIG

At the time of the accident, the following ATIS report was broadcast:

INFO LIMA
QAM LSZH 1650Z 10.01.2000
290 DEG 2 KT
VIS 6 KM
LIGHT DRIZZLE
BKN 500 FT
+02/+01
QNH 1032 THREE TWO
QFE THR 14 981
QFE THR 16 981
QFE THR 28 980
TEMPO VIS 5000 M
SPEED LIMITATION
NOSIG

The aerodrome weather forecasts were:

TAF 09 HR: 101601 33003KT 8000 SCT007 BKN010 TEMPO 1601 3000 DZRA OVC005

TAF 18 HR: 100018 33003KT 6000 FEW005 BKN015 TEMPO 0006 3000 -RASN OVC005 BECMG 0609 04005KT

For FIR SWITZERLAND neither a SIGMET nor an AIRMET were active.

1.7.3 Weather in the region of the accident

Since the site of the accident was only about 4 km from the aerodrome and the weather conditions above the central and eastern sectors of central Switzerland were very homogeneous, it can be assumed that the weather in the accident region corresponded to that at Zurich airport. The accident site also lay in the area of the detailed meteorological measurement network of the airport, and this also supports the above assumption.

1.7.4 Pilots' reports

Statements are available from 13 crews who landed or took off at Zurich at the time of the accident or 30 minutes either side of it. The statements are based exclusively on memory and not on the analysis of the flight data.

1.7.4.1 Wind

Almost all crews reported calm, practically calm or a light breeze (approx. 050/04 KT). Only one report mentioned a north-westerly wind of 30 kt at 2500 ft AMSL.

1.7.4.2 Visibility

Visibility under the cloud base was predominantly described as good (approximately 5000 m). The report which is closest to the time of the accident mentioned diffuse visibility (approximately 2000 m).

1.7.4.3 Cloud

Several strata of cloud were reported with a low and distinct base between 400 and 1100 ft AGL. The cloud top varied between 5000 and 8000 ft AMSL.

1.7.4.4 Precipitation

Several reports mentioned very slight or slight drizzle; other crews stated that there was no precipitation.

1.7.4.5 Temperature on the ground

The statements provided mentioned 2 to 3 °C.

1.7.4.6 Observations on icing

The crew which had taken off shortly before the accident flight (16:52 UTC), spoke of very light icing during the climb-out.

A crew which took off about half an hour after the accident at 17:30 UTC reported light frost.

Other crews who had taken off from Zurich between 16:20 UTC and 17:30 UTC did not detect any icing. No aircraft taking off in the period under investigation carried out de-icing on the ground but used the anti-icing system (engine anti-ice on).

Several of the approaching crews mentioned icing. One crew reported light icing on the wings (light wing icing). The altitude range was specified as flight level 50 to 70.

The reports on the occurrence of icing on approach (ILS) were contradictory. In the case of two incoming MD11 aircraft, the severe ice detection warning responded in each case. However, a visual examination by the crew did not take place in either case.

1.7.5 Icing

On the basis of the available vertical profiles of the atmosphere, it is apparent that the aircraft involved in the accident was climbing from approximately 2000 ft AMSL in cloud in a temperature range from 0 to -3 °C, a temperature range which is critical for icing.

The following meteorological factors are critical for icing:

- Air temperature
- Atmospheric humidity
- Liquid water content of cloud
- Drop size distribution
- Upwind speed

1.7.5.1 Air temperature

Ice formation is possible between 0 and -40 °C, with decreasing probability and intensity towards lower temperatures. In the 0 to -4 °C range the probability of icing increases greatly. The greatest probability of icing, according to various investigations, lies in the range from -4 to -8 °C.

1.7.5.2 Atmospheric humidity

In mixed cloud, the ice particles grow to the detriment of the water particles and therefore reduce the relative atmospheric humidity, reducing the intensity of icing. Since the difference in dew point (spread) in the cloud layer which was present was small and since it can therefore be assumed that the cloud was a pure water cloud, in the case in question there was a high probability of icing.

1.7.5.3 Liquid water content of the cloud

In stratus cloud, as in the present case, the liquid water content is relatively lower than in convective clouds and the maximum values are in the strata near the cloud top. The liquid water content increases in an approximately linear fashion from 0 g/m^3 just below the cloud limit, within the first 700 to 1000 ft above the cloud base.

The liquid water content of this stratum of cloud would probably have been 0.75 g/m^3 max. This value is still in the range for moderate icing.

1.7.5.4 Drop size distribution

The mean drop diameter in stratocumulus/stratus cloud is 8 to 13 µm. With such drop sizes icing is restricted to the front of highly curved surfaces and may extend further but does not yet reach protected surfaces not subject to airflow.

In the case of freezing drizzle, drop diameters of 100 to 1000 µm are to be expected. The associated icing extends over protected surfaces and exhibits growth in the air current.

1.7.5.5 Upwind speed

The greater the upwind speed in a cloud, the faster the growth of drops and the higher the probability of icing.

In the present case, the following reasons argue in favor of low upwind speeds:

- observed cloud type (stratocumulus/stratus are layered clouds)
- vertical temperature layering
- observations of other crews: no turbulence, calm approach

Thus the upwind speed factor would probably not have been favorable for icing.

1.7.5.6 Icing in clouds with precipitation

The probability of icing in clouds with or without precipitation is of approximately the same magnitude, because stratus cloud from which rain has been falling for some time can have only a low water content and will tend to consist predominantly of ice crystals.

1.7.6 Turbulence

The engineering data from the DFDR were examined and analyzed in collaboration with the aircraft manufacturer. This engineering analysis of the acceleration data (g-forces) shows that no substantial turbulence occurred during the accident flight.

1.8 Aids to navigation

1.8.1 Relevant navigation systems

VOR/DME Kloten (KLO) and VOR/DME Zurich East (ZUE) are omnidirectional radio range beacons which function according to the Doppler principle. Both are equipped with distance measuring equipment (DME).

DVOR/DME KLO	
Geographical position	47 27 25.73 N, 008 32 44.14 E.
Elevation	1414 ft AMSL
Coverage range (DOC)	50 NM/25000 ft
Frequency	DVOR 114.85 MHz, DME channel 95 Y

DVOR/DME ZUE	
Geographical position	47 35 31.82 N, 008 49 03.55 E.
Elevation	1730 ft AMSL
Coverage range (DOC)	80 NM/50000 ft
Frequency	DVOR 110.05 MHz, DME channel 37 Y

On 10.1.2000 the DVOR/DME KLO and DVOR/DME ZUE equipment was fully operational in the period from 16:45 to 17:00 UTC and was available without any complaints.

1.8.2 Constellation of the GPS satellites

To determine the geographical position, the flight management system type UNS-1K installed in the Crossair Saab 340B requires external signals. In addition to the conventional VOR/DME signals, signals from the global positioning system (GPS) are also received and included in the calculation. Reception of the GPS signals is of particular importance for initialising the FMS on the ground, since the VOR/DME signals are generally insufficient.

In order to be able to determine the geographical position, the GPS processor in the FMS must receive signals from four satellites. Five satellites are necessary for continuous monitoring of position (RAIM).

A study of the satellite constellation on 10 January 2000 at 16:50 UTC was carried out by the Institute for Geodesy and Photogrammetry of the ETH Zurich. On the basis of this study, at that time six satellites were available at stand F 74. From this it can be concluded that a sufficient number of satellites were available for FMS initialization. It can be assumed that six minutes later sufficient satellites were available to determine the position during the climb.

1.8.3 Radar equipment and radar displays

The air traffic controllers had at their disposal a flight position display based on multi radar tracking (MRT). In the case of the present accident only the data from the Lägern (primary/secondary) and Holberg (analogue primary/secondary only) radar equipment could be processed, since the aircraft was at a very low altitude (cf. Annex 2).

In departure control (DEP), the Holberg radar data are displayed as a priority. In the tower (TWR) a distance-limited bright display is provided.

1.9 Communications

1.9.1 ATC involved

Clearance delivery	(CLD)	Frequency 121.80 MHz
Aerodrome control – tower	(TWR)	Frequency 118.10 MHz
Departure control	(DEP)	Frequency 125.95 MHZ

1.9.2 Recordings of conversations

The following data in TWR and DEP are permanently recorded by a digital storage system and saved to digital audio tape (DAT):

- All VHF radio channels in use. In addition, DEP and TWR are each equipped with a recorder for short-time recordings.
- All wired connections between workstations (intercom).
- All telephone conversations at the workstations (intercom).

The conversations in the radar room and at the tower were not recorded by an area microphone.

1.9.3 Communications equipment

The TWR and DEP operations records and the system management (SYMA) log book show no failures or faults in the communications equipment of the air navigation services. The same applies to all internal ATC calls (intercom, telephone).

1.10 Aerodrome information

1.10.1 General

UNIQUE Zurich Airport has three runways:

- Runway 16/34, dimensions 3700 x 60 m, elevation of runway thresholds 1390 ft/1386 ft AMSL
- Runway 14/32, dimensions 3300 x 60 m, elevation of runway thresholds 1402 ft/1402 ft AMSL
- Runway 10/28, dimensions 2500 x 60 m, elevation of runway thresholds 1391 ft/1416 ft AMSL

The reference elevation of the airport is 1416 ft AMSL and the reference temperature is 24.0 °C.

1.10.2 Runway equipment

Runways 14 and 16 are authorized for precision approaches CAT III B.

No other runways are equipped for precision approaches.

1.10.3 Rescue and fire-fighting services

The airport fire fighting service fulfils Category 9.

1.11 Flight recorders

1.11.1 Digital flight data recorder (DFDR)

1.11.1.1 Technical description

The flight recorder system consists of a flight data acquisition unit (FDAU), a digital flight recorder (DFDR), a flight data entry panel (FDEP) and a tri-axial accelerometer. In addition there are a large number of sensors e.g. potentiometers; attitude heading computer – AHC; switches).

The FDAU is installed in the avionics rack. It interrogates the various analogue and digital sensors according to a pre-set program. The interrogation rate depends on the rate at which the individual parameters are changing. All the data which are read in are converted into a uniform format (Harvard bi-phase) and then saved in a predetermined sequence. The data are stored in the DFDR in this form. For analysis, the data must be converted by ground-based software into so-called engineering units (e.g. heading in degrees, altitude in feet etc.).

The DFDR is installed in the equipment rack in the tail of the aircraft. It stores the data processed by the FDAU in a solid-state-memory which is housed in an impact-resistant and fireproof cassette. A locating transmitter is installed on the DFDR which facilitates detection of the recorder under water. The DFDR can record 64 parameters over a period of approximately 50 flying hours. When the memory is full, the oldest data are overwritten automatically.

The FDEP is installed in the cockpit in the left-hand console and is used to enter flight-relevant data. By means of a special event button a special event can be marked in order to make it easier to locate subsequently. Two warning lamps (FDAU and DFDR) indicate when the internal monitoring registers an error.

The triaxial accelerometer is located in the centre of the aircraft. It registers body acceleration (g-forces) along the three axes of the aircraft.

The sensors for the flight recorder system are distributed over the entire aircraft and supply the data for recording.

The flight recorder system begins to work as soon as one engine is running and one generator is in operation. However, before any data are recorded, the FDAU runs an initialization program which checks the system functions.

1.11.1.2 Specific parameters

Since the aircraft reached unusual attitudes during the accident flight, it was important to clarify whether any limits with regard to pitch and roll parameters exist. In the process, the following points were established:

The pitch and roll attitudes are calculated in the AHC. The AHC contains rate gyros, which detect the angular rates around the three axes pitch, roll (bank) and yaw. On initialization on the ground, a virtual platform is set up and calibrated in the AHC. With the aid of the rate gyro signals this virtual platform can be continuously updated by the computer in flight.

At the output from the AHC, the following signals are available in digital form:

- Euler angles (pitch, roll, yaw)
- Body angular rates
- Body linear acceleration (g-forces)
- Local level acceleration (g-forces)
- Heading

The range of the signal output from the AHC is as follows:

- Pitch +/- 90°
- Roll +/- 180°
- Heading +/- 180°
- Body angular rates +/- 128°/s
- Acceleration +/- 5g

In the list of parameters of the DFDR, the ranges are specified for pitch as +/- 90° and for roll as +/- 180°. The DFDR accordingly records the full range of the AHC. During the accident flight, the DFDR recorded max. -62.8° pitch and 137.5° roll. The data for pitch and roll were consequently not limited.

1.11.1.3 Maintenance and monitoring

The flight data recorders have an integrated monitoring system which monitors the function of the DFDR both during initialization and during operation.

In order to check the functionality of the sensors, during the C check the DFDR data are also written to a PCMCI card and analyzed in the laboratory.

1.11.1.4 Position recording of the right-hand aileron

The DFDR data for the right-hand aileron show extreme deflections of the right-hand aileron throughout the accident flight. Sometimes the recorded values reached the extreme positions of the right-hand aileron and for the most part did not correlate with the left-hand aileron. In addition, the recording showed stochastic values.

This discrepancy of the recording can be explained as follows:

During the accident flight, the changes in attitude around the longitudinal axis corresponded to the deflections of the left-hand aileron and the right-hand aileron synthetically correlated with it.

The data recorded for the right-hand aileron during the accident flight were not correct. The flights directly before the accident flight also showed the same type of recording. The same error was also found on another Crossair Saab 340B.

The source of the error was unambiguously identified as the transmitter (potentiometer) of the aileron. This transmitter is used in several locations on the Saab 340B. It is known that the failure rate of this component is high.

1.11.2 Cockpit voice recorder (CVR)

1.11.2.1 Technical description

The voice recording system consists of a cockpit voice recorder (CVR), an acceleration switch, a control panel and an area microphone (cockpit area microphone – CAM). The CVR is installed in the tail of the aircraft. The control panel is installed in the cockpit in the right-hand side panel, whilst the CAM is installed in the overhead panel.

The installed recorder was an analogue CVR, Fairchild (Loral) type A100A. This unit contains a magnetic tape loop with a playback time of 30 minutes. The tape is split into four tracks (channels): P1 (commander), P2 (first officer), PA and CAM. The magnetic tape is housed in an impact-proof and fire-proof cassette. A location transmitter is installed on the CVR to facilitate detection of the recorder under water.

Channels P1 and P2 record conversations of the commander and first officer respectively; these are recorded acoustically via their boom microphones. The CAM channel records conversations and noises in the cockpit. The PA channel is used to record conversations between cockpit and cabin and announcements made over the public address system.

1.11.2.2 Maintenance

According to the manufacturer's maintenance instructions, checks are scheduled after 4000 and 9000 flying hours. The check after 4000 flying hours is carried out at the aircraft. The check after 9000 hours takes place in the workshop and corresponds to an overhaul.

The CVR recording for flight CRX 498, in the phase before engine start-up, contains voices and noises which obviously do not originate from the accident flight. In the phase referred to, the pilots were not yet wearing the boomsets, so the investigation was dependent on the recording via the CAM. On this channel, however, the volumes of conversations from earlier recordings and the current recording were approximately equally low. Intelligibility was clearly better, however, when the first officer used the hand microphone for radio communications.

After engine start-up, comprehensibility of the commander and first officer channels was better, since they were now wearing their boomsets. They now spoke directly into the boom microphone and the effective level was substantially higher. The engine noise now became audible on the CAM channel, so only relatively loud voices e.g. cabin attendant calls into the cockpit) and noises were perceptible. The superimposition of a 400 Hz tone, especially on the CAM channel, was also conspicuous.

It could be established that erasure of the previous flights on the CVR of HB-AKK was not complete. The reason for this are deposits of tape material which were able to accumulate on the erase head because of excessively long prescribed maintenance intervals.

1.11.3 Reading the flight data recorders

The DFDR and the CVR were found on Wednesday, 12 January 2000, at a depth of approximately 2 m in a damaged but interpretable state. After they were salvaged, the CVR was read in the presence of the Swiss Aircraft Accident Investigation Bureau (*Büro für Flugunfalluntersuchungen* – BFU), the Swedish *Statens haverikommission*, Saab Aircraft AB and the CVR manufacturer, by the engineering branch of the Transportation Safety Board of Canada (TSBC). The recording was then analyzed by AAIB employees; a transcript was made and synchronized with the radio communications recording.

The DFDR was also read by the TSBC. Like the CVR transcript, these data also had to be synchronized with the official UTC times of the ATC transcript. Thus all relevant data, including the ATC radar plot, are available on a uniform time base.

1.11.4 CVR communication

Conversations between the aircraft and ATC are available both on the CVR and on the ATC recordings. Internal conversations in the cockpit are available only on the CVR.

1.12 Wreckage and impact information

1.12.1 Impact

Shortly before impact, the aircraft was in a spiral dive to the right. The heading at the start of the spiral dive was north and on impact was approximately 120°.

The last recordings of the DFDR, approximately 2 seconds before impact, showed the following parameters concerning the movement of the aircraft:

Rate of descent:	27461 ft/min, corresponding to 459 ft/sec, increasing.
Indicated airspeed:	285 KIAS (interpolated at impact: 310 kt).
Heading:	080° (interpolated at impact: 120°).
Pitch:	62° AND (interpolated on impact: 63° AND).

1.12.2 Initial findings at the site of the accident

The following points could be established immediately after the accident:

- No survivors
- A crater at the point of impact (soil thrown up)
- Large concentration of aircraft wreckage at the point of impact
- Small items of debris spread over a wide area
- A fire in the crater

1.12.3 Debris field

The debris field was characterised by a crater at the aircraft's point of impact. As a result of the high impact speed and the steep angle of impact, the degree of destruction of the aircraft was extraordinarily high. A large proportion of the wreckage, mainly from the cockpit and fuselage, bored into the soft ground.

About 20% of the debris (predominantly the rear of the fuselage and parts of the wing structure) were spread over an extended ground area in the direction of the final flight path.

The extent of the destruction and the position of the debris is consistent with the recorded DFDR data immediately before the crash.

1.12.4 Salvage operations

Before commencement of the salvage work, the parts lying on the surface of the ground were labeled, numbered, measured and recorded on a plan. Salvage was then carried out by continuously removing soil and sorting the items of wreckage (detailed plan: cf Annex 3).

1.13 Medical and pathological information

1.13.1 Commander

1.13.1.1 History and medical findings

During his training and during his activity as a pilot, the commander was regularly examined, medically and psychologically. The flying-related medical examinations took place according to the system of the former Soviet Union (FSU), which provided for extensive clinical examinations, after which the pilots were also regularly psychologically examined. The regular checks were carried out twice a year in a flight medical centre and lasted about a week in each case. In addition, prior to assignment in the flying service, a brief medical examination took place; as a rule it was limited to a brief consultation and measurement of blood pressure.

The regular checks were documented in hand-writing in a medical booklet, which is available in full and in part in translation. The complementary interview with the management of the flight medical institute in Kishinev completed the gaps in the information due to illegible handwriting. The available records extend over the period from 1979 to the last examination on 30 September 1999.

Decisions on fitness to fly were therefore taken on the basis of the regular examinations by the flight medical commission of experts (VLEK) and on the other hand a brief medical assessment was made before every flight. The clinical examinations were in each case complemented by medical/technical examinations (audiometry, electrocardiography, laboratory and x-ray examinations, plus electroencephalogram and tests in the vacuum chamber). The regular dental examinations are also documented.

The commander never underwent a flight medical examination in Switzerland. There is also no indication that he consulted a doctor or dentist privately during this time.

The medical findings can be summarized as follows:

- The records do not allow any inference of any health defect existing prior to or to the time of the accident. In particular, the functions of the sensory organs (vision, hearing) were always normal and in no way adversely affected. The commander, 166 cm tall and weighing between 64.0 and 66.0 kg, was of rather small stature and of normal weight.
- Previous medical history and findings of examinations, as well as various interviews with family members and acquaintances, give no indications of abuse of alcohol, medicines or drugs. All sources describe the commander as a non-smoker who consumed alcoholic drinks rarely and in small amounts.
- The examination of the contents of the commander's crew bag found in the wreckage revealed an opened pack of the Russian tranquillizer Phenazepam. According to information from his partner, she had obtained the prescription medicine for the commander, since he had told her his sleep was disturbed.
- An investigation of abdominal complaints carried out in 1999, with a suspected diagnosis of gallstones, produced no positive evidence of the presumed complaint or of any other disease which may have been able to explain the complaint.

1.13.1.2 Medical forensic findings

As a result of the very high impact energy, all occupants of the aircraft suffered very serious injuries to all vital organs. All occupants, including the commander, were identified by haematogenetic investigations. This was possible without any doubt. Because of the massive destruction, however, neither the circulatory organs nor the central nervous system (CNS) of the commander could be morphologically examined. Consequently, pathological-anatomical diagnosis of any pre-existing disease was not possible.

The chemical-toxicological analyses showed between 0.00 and 0.35 g ‰ (average values) of ethyl alcohol in the commander's muscular tissue. In addition, the Russian medicine Phenazepam was found in the commander's muscle tissue in a concentration of 7 to 8 ng/g (nanograms per gram).

Phenazepam is a medicine from the group of benzodiazepines, which according to current knowledge of the investigation team is produced only in Russia and the countries of the FSU.

The following information on the medicine is provided by the complementary chemical-toxicological report of the *Institut für Rechtsmedizin* (IRM) of the University of Zurich

quote:

„Wirkstoff:

Fenazepam ist in Russland unter dem Namen „Phenazepam“ im Handel, chemische Formel siehe Abb.1, ABDATA-Nr.: 3003155, CAS-Nr.: 51753-57-2, Synonyma: 7-Brom-5-(2-chlorphenyl)-1H-1,4-benzodiazepin-2(3H)-on (IUPAC) und 7-Brom-5-(2-chlorphenyl)-1,3-dihydro-2H-1,4-benzodiazepin-2-on [2].

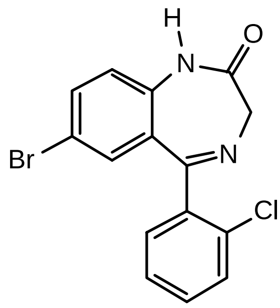


Figure 1: Chemical formula of Phenazepam, $C_{15}H_{10}BrClN_2O$, MG = 349,62 [2].

Tablettenformen:

Es gibt Phenazepam-Tabletten zu 0.5 mg und 1.0 mg; die Packung enthält 50 Tabletten [2][3][4].

Wirkungen:

Phenazepam ist ein Psychopharmakon und gehört zur grossen Gruppe der Benzodiazepine. Es entfaltet beruhigende (Tranquilizer), dämpfende, schlafinduzierende, krampflösende, muskelrelaxierende (muskelentspannende), angstlösende und antiepileptische Wirkungen [3][4]. Phenazepam hat eine ähnliche Wirkung und Wirkungsstärke wie Lorazepam (Temesta ®) [5], ist aber ein stärkerer Tranquilizer als Chlordiazepoxid (Librium ®) oder Diazepam (Valium ®) [5].

Nebenwirkungen:

Koordinationsstörungen, Schläfrigkeit, Schwindel; nicht während der Arbeitszeit von Chauffeuren und anderen Personen einnehmen, deren Beruf rasche psychische und motorische Reaktionen erfordert [3]. Schläfrigkeit, Muskelschwäche, Schwindel, Übelkeit, Ataxie [4].
Indikationen:

Bei neurotischen, psychopathischen Zuständen, bei Angst, Angespanntheit, Reizbarkeit und emotionaler Unausgeglichenheit; bei vegetativer Dysfunktion, Schlafstörungen, Kupiren von Alkoholabstinenz, bei verschiedenen Aetiologien, zur Behandlung von Muskelanspannungen, Hyperkinesie und Epilepsie [4].

Kontraindikationen:

Myasthenia gravis, Leber- und Nierenstörungen, Schwangerschaft, Kombination mit anderen Tranquilizern, Neuroleptica, Schlafmitteln, Narcotica und Alkoholabusus [4].

Vorsicht:

Während der Behandlung mit dem Präparat wird nicht empfohlen, Tätigkeiten auszuüben, welche rasche psychische und physische Reaktion erfordern [4].

Dosierung:

0.25 bis 0.5 mg 2 bis 3 mal täglich; bei Verwendung als Schlafmittel 0.25 bis 1 mg 20 bis 30 Minuten vor dem Schlafengehen; maximale Dosis bis 10 mg pro 24 Stunden [3]. 0.5 bis 1 mg 2 bis 3 mal täglich; Dosiserhöhung bis 2 bis 5 mg, stationär bis 10 mg pro Tag [4]. 0.5 bis 1 mg, 2 bis 3 mal täglich, Maximaldosis 10 mg pro Tag [5]. Therapeutische Tagesdosen 2 bis 4 mg [6].

Pharmakokinetik/Blutspiegel:

Peakplasmakonzentrationen werden etwa 3 bis 4 Stunden nach oraler Einnahme erreicht; nach Einnahme von 2 mg werden maximale Blutkonzentrationen von 8 bis 15 ng/ml erreicht, der Steadystate-Zustand (Fliessgleichgewichtszustand im Blut) wird nach etwa 10 bis 14 Tagen erreicht. Nach Einnahme von 2 mg Phenazepam wurden folgende Blutspiegel beobachtet: nach 4 h 9,2 ng/ml, nach 6 h 8,2 ng/ml, nach 24 h 5,7 ng/ml, nach 48 h 5,6 ng/ml, nach 96 h 3,9 ng/ml. Nach Langzeiteinnahme von täglich 1 mg Phenazepam werden minimale Steadystate-Blutkonzentrationen von 8 bis 9 ng/ml nach 2 Wochen erreicht; bei täglich 1,5 mg Phenazepam ca. 13 ng/ml nach etwa 34 bis 46 Tagen. Bei solchen Langzeitbehandlungen wurden keine oder nur sehr schwache sedative, schlafinduzierende Nebenwirkungen beobachtet. Hingegen wurden bei Langzeiteinnahmen von Dosen von 3 bis 4,5 mg pro Tag schlafinduzierende Wirkungen festgestellt; die Steadystate-Blutkonzentrationen betrugen bei solchen Tagesdosen 40 bis 100 ng/ml oder mehr [6]. Bei Verwendung als Tranquilizer bei Neurosen gelten therapeutische Fenster von 30 bis 70 ng/ml Blut. Nebenwirkungen (Dämpfung, Sedierung) werden gelegentlich schon bei 5 ng/ml (im Steadystate-Zustand) beobachtet, in andern Fällen beobachtet man selbst bei Blutkonzentrationen von 130 ng/ml keine Nebenwirkungen. Die Eliminationshalbwertszeit (= Zeitspanne innerhalb der der Blutspiegel jeweilen auf die Hälfte absinkt) aus dem Blut nach einer 2-mg-Dosis beträgt etwa 48 bis 75 Stunden, in Extremfällen 26 bis 133 Stunden [6].

Hersteller:

Hersteller in Russland, Tabletten zu 0.5; 1 und 2.5 mg; Ampullen zu 1 ml mit Konzentrationen von 1 bzw. 3 mg/ml [5]. Moskau Fax Nr. (095) 912-71-61 [3]. Moschimfarmpreparati, SU [2].“

End quote IRM, bibliography in the original report

1.13.2 First officer

As part of his aptitude tests, training and employment as a pilot, the first officer was regularly examined, medically and psychologically. The first examinations took place in Prague. The documents with the results of the examination are no longer to be found. After the division of Czechoslovakia they should have been sent from the competent office in Prague to the military hospital of Košice, which was competent for the Slovakian Republic. However, they never arrived there.

Therefore the only documented examinations were those carried out in the military hospital of Košice. Pilots' medical examinations, according to the employees of the institute interviewed, each last about 5 to 6 hours and each time they also include a psychological examination. Every 5 years an extended examination takes place, which last 2 days. Additional medical-technical investigations (laboratory, x-rays, ECG. etc.) are carried out at least to the same extent as those laid down in Switzerland (according to JAR-FCL).

The medical dossier was inspected at the military hospital of Košice and the important parts were photocopied. The findings were explained and commented on by the competent employees of the institute. An additional translation was produced in Switzerland.

In the available documents for the examinations from 1994-1999 the only relevant medical finding is slight short-sightedness of –2 dioptres, which was corrected satisfactorily with spectacles.

The first officer was never medically examined in Switzerland.

1.14 Fire

1.14.1 Investigation of traces of fire among the aircraft wreckage

The traces of fire on the aircraft wreck, particularly in the area of the right-hand wing and engine pod structure, were investigated to establish their origins.

The fire evidence at the various parts of the structure are isolated, i.e. they occurred only after the disintegration of the aircraft. In particular, no traces of fire with aerodynamic progression such as would occur if a fire had broken out in flight were to be found.

1.14.2 Results of interrogation of eye witnesses

The questioning of the eye witnesses about any perceptions provides no demonstrable indications that the aircraft was affected by fire prior to impact.

1.15 Survival aspects

The accident was not survivable.

1.16 Tests and research

1.16.1 Investigations related to electromagnetic interference (EMI)

The British civil aviation authority (CAA) has carried out field strength tests with mobile telephones on two older types of aircraft and came to the following conclusion quote:

"Measurements made on two types of civil transport aircraft confirm that transmissions made in the cabin from portable telephones can produce interference levels that exceed demonstrated susceptibility levels for aircraft equipment approved against earlier standards"

end quote

Since the aircraft type Saab 340B was certificated before December 1989, it had to be assumed that some of its equipment may fall within the above-mentioned category. Therefore, an electromagnetic interference (EMI) test was carried out on a Saab 340B under the following conditions:

- Aircraft Saab 340B, HB-AKM
- Location: in the hangar and in the silencer, Basle airport
- Installed CVR: Fairchild P/N 93-A100-83, S/N 52765
- Installed DFDR: Allied Signal P/N 980-4700-003, S/N 0781
- Mobile telephone 1: 900 MHz, special version with a constant transmitting power of 2 watts
- Mobile telephone 2: 1800 MHz special version with a constant transmitting power of 1 watt
- Special equipment for recording and monitoring the CVR (rear tape monitoring)

The test on the HB-AKM permits the conclusion to be drawn that the processor-controlled systems of the Saab 340B are insensitive to interference signals from mobile telephones. Slight interference with the audio systems was, however, detected.

The aircraft manufacturer had carried out an HIRF test on the type Saab 340B. There are no indications of interference due to EMI.

1.16.2 Investigation of the flaps

In the event of certain malfunctions in the flap system, e.g. minor leaks in one of the two flap actuators, so-called flap ballooning may occur in flight (autonomous partial deployment and then retraction).

Detailed tests and measurements were carried out on a Saab 340B of identical construction.

The investigation showed that hysteresis of the flap position selector system in the FLAPS UP position is less than 2°. The flaps therefore move downwards in the event of ballooning by less than 20 mm (measured between the trailing edge of the flaps and the engine cowling).

1.16.3 Comparison flights

Several comparison flights were carried out on a Saab 340B from Zurich. One of these comparison flights corresponded in its geometry to the accident flight; the right turn was flown with a maximum bank angle of 20°.

The DFDR data recorded on these flights did not deviate markedly from the data for the accident flight in all flight phases.

1.16.4 Ergonomics and crew workload

The cockpit procedures of an aircraft are affected by the ergonomics of the cockpit and by particular features of the design.

For the Saab 340B, the take-off and initial climb phase of the flight are work-intensive. One excellent example of a procedure requiring effort and concentration is the operation of the CTOT/APR system. This is used to limit engine power on take-off as a function of external conditions (runway length, aircraft mass, temperature) and therefore to reduce engine wear. After take-off, at the commencement of the initial climb, this limitation must be switched off again. The procedure requires great concentration, especially on the part of the first officer.

Controls and the corresponding displays are not necessarily positioned at the same viewing angle. Flying instruments, controls and displays for the aircraft systems are arranged in a distributed fashion.

The retrofitting of the Saab 340B with an FMS took place in this context. For the FMS, an interface with the existing avionics had to be provided, without having to resort to costly modifications. Not all functions of the FMS can therefore be represented in their full complexity. The alphanumeric display on the CDU of the FMS is therefore the primary display for the operator.

In this context, it is worth mentioning as an example the complex DIR TO function of the FMS (1.6.6.3.9).

For a three-dimensional representation of the cockpit situation cf. Annex 5. This shows the field of view available to the first officer whilst performing the power settings.

1.16.5 Intercultural aspects

The investigating team dealt intensively with the social and flying background of the commander in the FSU.

In the following areas, significant differences were established from the conditions known in Switzerland:

- Aircraft instrumentation
- Cockpit procedures
- Crew resource management (CRM)
- Languages

1.16.5.1 Aircraft instrumentation

Various differences were found in the instrumentation on aircraft of Russian manufacture compared with western types. In what follows, only the specifics of the type AN-2 and in particular the type AN-24, on which the commander served, are described.

1.16.5.1.1 Artificial horizon

The Russian attitude indicators (artificial horizon) are based on a different construction principle from the western variants. Whereas in the west a so-called inside-out representation was chosen, the Russian instruments follows the outside-in principle in their representation (cf. Annex 6).

In the case of the inside-out representation, the artificial horizon represents the situation which the pilot would see when looking out of the window with a view of the natural horizon. A symbol in the centre keeps its position stable in relation to that of the aircraft, whilst a mask in the background changes its position. A dividing line between the blue (the sky) and the brown (the ground) part represents the actual horizon. In the event of a change in pitch, the visible part of the blue and brown areas shift. In a climb (pitch ANU) the visible brown part (the lower half of the display) diminishes and the blue part (the upper half of the display) increases. The symbol in the centre of the instrument therefore appears in front of the blue background. A scale with subdivisions indicates the angle of climb or descent.

With regard to pitch, the display of the Russian horizon behaves identically.

The roll of the aircraft is represented on the western type horizon by the slope of the horizon line. The horizon line moves in the opposite direction of the actual roll of the aircraft. The bank angle is indicated by a sky pointer, which travels over a scale in the upper part of the instrument.

In contrast, in the Russian horizon, an aircraft symbol (model) indicates the attitude of the aircraft in front of the horizontal blue-brown dividing line which remains stable. The aircraft symbol is inclined to the side on which the aircraft is inclined. The angle can be read off at the tip of the lower wing on a scale with graduations on the outer ring of the instrument housing.

In addition to the inverse representation of roll, mention should also be made of the decoupled representation of roll and pitch in the Russian instrument compared with the combined representation in the western type.

In Russia, the risk of confusion when interpreting the artificial horizon display and when reading off the roll angle is well known since the introduction of the western type horizon on a number of aircraft types (TU-154, all western types). Several accidents have been caused by this.

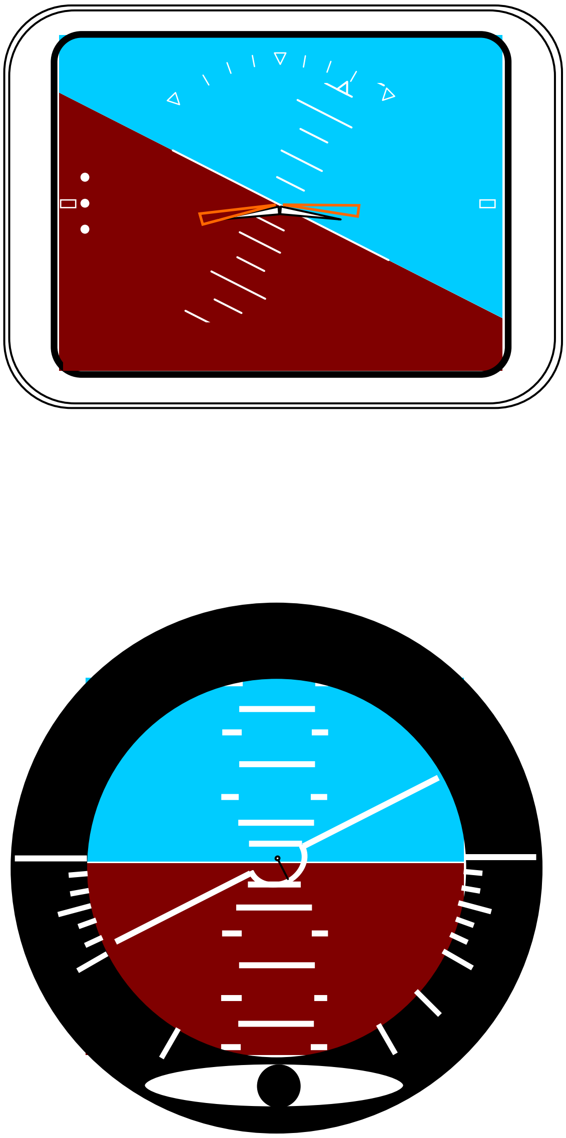


Illustration: comparison of western and Russian horizon, left bank angle 27°, pitch 1° ANU

1.16.5.1.2 Compass

A further distinct difference lies in the design of the gyro compass (cf. Annex 6). In a compass of western design, a circular compass card, with gradation of the full circle on its periphery, is retained in such a way that it can rotate around its centre. A mark on the top edge of the instrument (the lubber line) then stands above the actual heading on the scale. When the heading changes, the compass scale rotates below this mark in the direction of rotation opposite to the direction of rotation of the aircraft. In the case of a left turn, therefore, the card rotates clockwise.

A heading bug can be set at the edge of the scale and turns with the latter. It shows the desired heading and generally controls the flight director and autopilot in heading mode.

Externally, a compass of Russian design looks very similar to the western design. Here, though, the compass card is arranged so that the desired heading is positioned under the mark at the top edge of the instrument. The card does not rotate when the aircraft changes heading. Rather, the current heading is indicated by a pointer which rotates around the card, with its tip pointing toward the current heading on the scale of the compass card. The pointer rotates in the same direction as the change in heading of the aircraft. In the case of a left turn, the pointer therefore rotates counter-clockwise.

1.16.5.1.3 Bank angle warning

In the broader sense, the bank (roll) angle warning installed since the 'seventies on all commercial aircraft of the FSU may be regarded as part of the instrumentation. It actuates an acoustic (horn) and a visual (lamp) signal if the operational bank angle limits of 30^{o} are exceeded. Unlike the seldom implemented western solutions, it discriminates between the direction of roll by specific visual indications of the bank angle being exceeded to the right or left (separate lamps).

1.16.5.2 Cockpit procedures

Cockpit procedures in the FSU and the current CIS states are compiled in the so-called *Technologia*, which is prescribed for all operators for a specific aircraft type. Especially with aircraft types with crews of four, five or even six members, the distribution of work is much more pronounced than in a two-man cockpit. Thus, for example, a flight engineer is responsible for operating the engines, whilst the pilots simply order the power parameters which are to be set.

Navigation is carried out by the navigator, who in critical flight phases (e.g. an instrument approach) indicates values for heading and rate of descent to the pilots; the latter can restrict themselves to actually piloting the aircraft.

In all, a low degree of cockpit automation is offset by the number of personnel and division of tasks. Use of the autopilot was generally limited to cruising and was often interpreted as a sign of weakness.

In addition, the *Technologia* is much more restrictive than western standard operation procedures (SOP). Actions of crew members are defined as a function of sequenced procedures, aircraft position (distance from airport, altitude) and flight parameters (speed in particular). These parameters are – regardless of broader physical limitations – specified to close tolerances. Gear and flaps operating speeds are defined in kilometers per hour with tolerances of +/- 10 km/h. Exceeding these operational limits in either direction is detected by reading the flight data recorder after every flight and is presumed to be an infringement of regulations.

The crews of the aircraft are permanently allocated, so the individual members can work very well together as a team. The commander of a crew is acknowledged as the uncontested authority and also as a trainer – especially of the first officer.

The *Technologia* is drawn up by the competent ministries for civil aviation. It is consistent, not only for the individual cockpits but also for air navigation services coordination. Air traffic controllers are very accurately informed of procedures in the cockpit. Therefore, procedures such as high speed approaches or visual separation are incompatible with the *Technologia*.

1.16.5.3 Crew resource management (CRM)

In general, it must be stated that until the beginning of his career with Moldavian Airlines the training of the commander of the aircraft involved in the accident was based on an understanding of crew interactions and crew communication which differed from current practice in the west. Pilot's views of themselves and their assessment were generally founded on the quality of their mastery of the aircraft and accuracy of flying. Rules on cooperation in the cockpit were strictly and comprehensively regulated and a pronounced difference in authority between commander and first officer and the other crew members corresponded to the generally accepted standard. The commander of a crew was seen as a role model and teacher, as a superior with an influence on the selection of crew members and their evaluation and career opportunities.

In emergencies, the commander was as a rule expected to control the aircraft, while the other crew members had to work through the checklists. In the self-image of FSU pilots, strength, decisiveness, calm and composure were highly valued, whilst communication in the western sense was not so highly valued.

Generally, a pattern of behavior with corresponding communication rules was available for exceptional situations. This was also the case for intervention by a PNF if the roll limits were exceeded. Training for this was provided in the simulator.

Example of exceeding roll to left:

PF	PNF
	"left roll"
"understood, correcting right "	
if no reaction:	" left roll"
if no reaction:	"taking over control, correcting right"

1.16.5.4 Languages

In the FSU all aspects of flying were dealt with in Russian. This applied to documentation as well as to communication in the cockpit and radiocommunications.

For flights abroad, additional training stages were and are completed, including language training in English. No knowledge of English was required of average pilots flying domestic flights.

1.17 Organizational and management information

1.17.1 Operator

1.17.1.1 General

At the time of the accident, the Crossair company was one of the airlines in the SAirGroup and was under the operational management of its founder and CEO. A phase of intensive growth over several years under great cost pressure had characterised the industry world-wide. Within the Swiss air travel industry, this led, among other things to a pronounced shortage of pilots and – notwithstanding the scarcity in the labor market – to relatively low salaries for Crossair pilots in comparison with other airlines in Switzerland. A dispute was in progress with the pilots' association (Crossair Cockpit Personnel – CCP) and was affecting the working climate for many pilots who were involved, as well as for the management of the company.

1.17.1.2 Structure

At the time of the accident, Crossair had a management structure in conformity with JAR-OPS 1. This meant that on the flight operations side the positions of accountable manager, postholder flight operations, postholder training, postholder ground operations and postholder maintenance were designated and filled. In addition, a quality management system was in existence.

In view of the extent of flight operations and the relatively wide variety of aircraft types, however, there was further sub-division in a number of areas. This was then reflected above all in the aircraft fleets, in which the chief pilots (fleet managers), chief flight instructors and technical pilots enjoyed a high degree of autonomy.

In the case of the Saab 340 fleet, because of the planned cessation of operations, there was still a certain additional shortage of resources. Thus after the departure of the fleet manager of the Saab 340 operation the chief flight instructor was simultaneously designated chief pilot. So in addition to great responsibility for operational matters (procedures, checklists, etc.), the latter also had a large say in the selection of pilots. In the case of direct entry commanders induction was almost exclusively according to selection by the fleet manager. In the case of the Saab 340 fleet, supervision during training and checking was performed by this same person.

Monitoring across all the fleets was performed by the accountable manager and postholder flight operations. Furthermore, the function of a flight safety officer across all the fleets had been filled.

1.17.1.3 Pilot selection

1.17.1.3.1 Selection procedure for direct entry commanders

For pilots taken on directly as commanders (direct entry commanders), Crossair did not provide any special assessment analogous to that for first officers. The key factor for appointment was the information which was relevant to suitability derived from the license and the check flights. The appointment decision was generally taken by the fleet manager and was influenced by the demand for direct entry commanders.

1.17.1.3.2 Selection procedure for first officers

The selection procedure for first officers was carried out by an assessment team and consisted of:

- Individual assessment (presentation)
- Group assessment (moon landing, and the like)
- Psychological tests (Wartegg, PF-16 or Rey Figure, parts of the Salzburg procedure, graphological report)
- Technical test (ATPL material)

In addition there were one and a half hours on the flight simulator and an interview, at which two senior management executives from Crossair were present. A selection board met about every 10 days to take decisions, though no record was kept of the meetings. It was simply a matter of marking go or no go and three to four signatures were appended. The board met in various configurations. Each candidate was discussed for approximately 15 minutes.

In principle, any application for selection from the assessment team, or the board itself, could be overruled by the management.

In qualitative borderline cases (e.g. a candidate with good human aptitude but poor training), a deferral for a certain period could be decided upon.

In this context, there were so-called yellow files: pilots who received a training and employment contract subject to conditions and who remained under observation by the fleet manager.

After selection, each case was completed for the assessment team. The dossier was closed and transferred to pilot administration. There was no possibility of feedback from operational planning to the selection department.

1.17.1.3.3 Monitoring of pilots during the period of employment

Personnel and qualification dossiers were kept during pilots’ employment by the respective fleet manager. Above all, these dossiers contained check forms and other technical qualifications, but also documentation on personnel matters.

No flying or disciplinary incidents are documented regarding the pilots of the aircraft involved in the accident.

1.17.1.4 Terms of employment

The commander of the accident flight had been employed since 1997 with Moldavian Airlines in Kishinev, Republic of Moldova. In financial terms the family in Moldova was better off than the local standard, since the commander earned 900 lei (150 USD) per month basic salary plus 350 to 500 USD expenses.

The leasing by Crossair of two commanders from Moldavian Airlines was agreed in the summer in correspondence by fax.

In accordance with this correspondence the Moldavian Airlines leasing pilots continued to receive their basic salary of 900 lei (150 USD) in Kishinev, plus an additional monthly 1000 USD and 3 CHF per duty hour, with payment to Moldavian Airlines of 3000 USD per month (fax of 29.9.1999).

A formal leasing contract specifying the financial remuneration does not exist.

This is the relevant statement from the CEO of Moldavian Airlines: "The total contract called for the payment of USD 5000 to the company with USD 2000 going to the pilot and USD 3000 to the company. He also kept his basic salary of USD 150 (…) For the Crossair lease the apartment and travel and expenses of CHF 3 per hour were paid."

According to information from the commander's partner, he received 900 lei and 2000 USD, of which he sent home 1000 USD. On this basis, the financial resources left for the commander’s living expenses are at the existence minimum for Switzerland.

The first officer was working under the terms of a standard Crossair employment contract for pilots

1.17.1.5 Working climate

The following circumstances applied at the time of the accident and had their effects on the working climate which existed:

- The company had been through a long phase of rapid expansion. In addition, there was high employee turnover. This made it difficult to maintain and integrate the culture of a "big family company" which existed at the time the company was founded.
- The rapid growth of the industry as a whole led to a general shortage in the labor market of cockpit personnel. The pilot corps of the company therefore included a relatively large proportion of foreign employees from many different nations with correspondingly varied flying origins and basic training. Many crew members thus had relatively short-lived experience in various flying cultures.
- The company operated a bonus system for all its personnel. The apportionment of bonus payments took place at the end of every year according to the operating profit.
- In the labor conflict with the pilots' association, the major issue was the salary structure, or rather the relatively low salaries of cockpit personnel in terms of a national comparison.
- Since its foundation, Crossair was in distinct competition with Swissair. However, in many areas it was simultaneously a contractor and – since the purchase of the majority of shares by the SAirGroup – actually one of its subsidiary companies.

The statements of the witnesses questioned about the working climate differed greatly.

The management described the firm as a big family, in which each member could turn to his or her superior in the event of a problem, at any time and in full confidentiality. This presumed great loyalty by employees with regard to the management, and disloyal behavior was perceived as the major threat.

According to information from some of the employees questioned, the company management’s way of dealing with criticism was such that many found it ill-advised to express criticism openly. This also applied to opinions which concerned flight operations.

1.17.1.6 Rolls Royce Germany audit

After the accident, among other things an audit of Crossair's maintenance organization was carried out by Rolls Royce Germany. The corresponding report states, among other things, that:

- The delegation of tasks and competencies to middle management level is handled without apportioning responsibility.
- Company manuals not based on ISO 9000 or, in terms of aviation technology, EN 9100 and AS 9100 respectively, and without a process-orientated layout.
- Closer control is needed within AVOR, trouble-shooting and engineering.
- The structural and procedural organization of Crossair’s technical department has to be fundamentally reconsidered.

1.17.1.7 Maintenance quality system

The following Crossair documents form the basis of the quality management systems in the areas of technology and maintenance:

- Maintenance management exposition (MME)
- Maintenance organization exposition (MOE)
- Maintenance information handbook 1 and 2 (MIH)
- Crossair reliability program (RELPRO)
- Crossair quality manual
- Crossair aircraft maintenance program

All documents were submitted to the FOCA and – if legally required – approved or recognized.

1.17.1.8 Reporting system

The investigation showed that Crossair's reporting system consisted of the following elements:

1.17.1.8.1 AMOS

Crossair applied AMOS (airline maintenance organization system). The system allows all technical activities relating to an aircraft to be recorded:

- Every technical complaint opened a work order report.
- Rectification of the reported malfunction closed the work order report.
- The work order report was numbered and contained the aircraft registration, ATA number, date, the mechanic performing the work, status, etc.
- Work order reports could be retrieved according to the above criteria.
- The work order report also included data on replacement of components.

1.17.1.8.2 Occurrence report

This report could be used for a more precise description of a technical malfunction, for a particular observation of the operating behavior of a system or for reporting an occurrence.

- Occurrence reports were managed in a separate access database.
- If it was linked to a work order report, the occurrence report bore the number of the work order.
- Reports went to the operations department for recording and distribution to: flight operations (OCX), quality management (QM) or technique (TEC).
- Recipients, e.g. the technical pilot, could add to the distribution list according to the content.
- The forwarding office had to insist on a feed-back, which was then entered in the database.

1.17.1.8.3 Reliability reporting

Reliability reporting allows an evaluation of the operating behavior of the aircraft systems and engines, as well as the quality of aircraft maintenance and shop maintenance. It consists of the following elements:

- Technical dispatch reliability
- Top-ten trouble items (basis: AMOS)
- Component reliability data (MTBUR), engine reliability data (IFSD/SVR)
- Pilot complaint rate (basis: AMOS)

1.17.1.8.4 Special reporting

A special form is produced for special reporting on a case to case bases. One example is the FMS event reporting form. After installation of the Universal FMS this form was used relatively often in order to record any software bugs. The recipient for special technical reporting forms is the technical pilot. Since the introduction of FMS Software 602.5 the FMS event reporting form is used only sporadically.

1.17.2 Regulatory authority

1.17.2.1 General

As in most states, aviation regulation in Switzerland is based on the recommendations of the ICAO Convention (1944 et seq.) and its appendices. Switzerland has noted various exceptions to these standards, which are not relevant in connection with the accident.

Swiss legislation includes various decrees on aviation. For commercial aviation operators, the regulations of the European Joint Aviation Authorities (JAA) also apply. These have been recognized in Swiss legislation.

The Swiss federal authorities delegate supervision of civil aviation to the Federal Office for Civil Aviation (FOCA) - *Bundesamt für Zivilluftfahrt* (BAZL).

1.17.2.2 Structure

At the time of the accident, the FOCA had approximately 150 employees working in various sections.

The following sections of the FOCA are of significance in connection with this accident (status: January 2000):

- Flight operations section (OP)
- Licences for aviation personnel section (LP)
- Flight training section (FA)

1.17.2.3 Re-organization

As a result of the introduction of JAR-OPS and JAR-FCL in the years preceding the accident, the FOCA experienced major changes. The entire federal administration was under political pressure to reduce personnel costs.
At the same time there was a phase of headlong growth in the aviation industry. In conjunction with the management of the Department of the Environment, Transport, Energy and Communications (DETEC), the FOCA decided to create the necessary capacity to handle the increase in supervisory activity by outsourcing existing tasks and taking on a small number of new employees.

The following points are particularly worthy of note:

- The FOCA has regularly requested additional posts and has also received them (1999: 3 posts, 2000: 2 posts, 2001: 2 posts).
- It was difficult to recruit qualified personnel for the supervisory authority on the saturated job market.
- Within the department there was a great need for training.

- There were major fluctuations in personnel in the Flight Operations section.
- In accordance with the quality strategies of JAR-OPS, the supervision of airlines was conducted with more emphasis on the companies' internal control mechanisms; these in turn were subject to great pressure in terms of costs and competition.

1.17.3 Crossair's relations with the regulatory authority

Crossair's relations with the FOCA were of different kinds and were conducted at several levels. In each case, individual FOCA employees confronted the large Crossair operation. The manager of the flight operations section referred to this problem in internal reports and to the problem of major employee turnover.

The flight operations section in Zurich dealt with operational questions, whilst the section for licensing aviation personnel in Berne was responsible for licensing questions. In the case of training-related questions, the aspects related to licensing (e.g. type rating course) were clarified in Berne, whilst operations-related points (e.g. operator proficiency check) were dealt with in Zurich.

Documentation on formal inspections of Crossair by the competent FOCA sections (OP, LP and FA) is not available. On the other hand, audits were carried out in the area of maintenance. In view of the shortage of personnel, operational supervision concentrated on various forms of continuous supervision (e.g. daily operation reports, half-yearly coordination meetings, approval of changes to the Operations Manuals, etc.).

1.18 Additional information

1.18.1 Training equipment

1.18.1.1 Overview

Crossair was in possession of the following training equipment for the Saab 340B:

- One flight simulator
- Two FMS trainers

1.18.1.2 Flight simulator

- The flight simulator was built by Flight Safety International (USA) for the Crossair Saab 340B and installed in Basle in 1991.
- The simulator was last certificated to JAR STD 1A, Level CG.
- No FMS was installed in the simulator.
- The simulator was sold in 2000 as the Saab 340B fleet was being taken out of service.
- Subsequently, training was carried out on external simulators

1.18.1.2.1 Certification

- The flight simulator was certificated by the FOCA for the first time on 19.8.1991 in accordance with FAA AC 120-40A, Phase II.
- The re-certifications were carried out regularly by the FOCA in accordance with the FAA/JAR requirements.
- Deviations were eliminated by Crossair in each respective case.
- The last re-certification was carried out on 31.8.1999 in accordance with JAR-STD 1A, Level CG.
- There is no indication that the flight simulator did not fulfill its requirements during its use at Crossair.

1.18.1.2.2 Installation of the FMS

At the end of 1997 Crossair's Saab 340 fleet was equipped with FMS. At that time, the sale of the aircraft was foreseeable. In view of the high costs caused by the installation of the FMS in the flight simulator, its integration was rejected. The flight simulator was sold in 2000 because of the decommissioning of the Saab 340B fleet.

1.18.1.3 FMS trainer

In order to train crews on the FMS, Crossair acquired two training systems. One was based on a PC with FMS simulation software. The other FMS trainer consisted of an equipment set-up with an FMS CDU, of the type also used in the aircraft.

Both units are functionally practically identical which makes it possible to simulate all essential functions of the real FMS. Both trainers were not formally certificated as training equipment.

1.18.2 Artificial horizons in the former eastern block

Through contact with the Russian investigating authorities, the following facts were established:

In the 'fifties, the horizon with a moving silhouette became customary in the former Soviet Union (cf. 1.16.5.1.1). It was introduced on the basis of psychological, psycho-physiological and ergonomic investigations according to a "concept of the flight image": It is argued that the pilot spends a large part of his life on the ground and unconsciously chooses this as his system of reference. So the outside-in representation is supposed to be more natural.

At the end of the 'sixties, with the new commercial aircraft, a transition to the horizon with the western form of representation (inside-out) gradually took place, in order to increase opportunities for export. Since then, 18 spiral dives have occurred (as of spring 2000). Fifteen of these flight conditions led to an accident. All these aircraft were equipped with western style display instruments and were operated by crews who had been trained with the eastern horizon. In three cases it was possible to end the dive without causing an accident. In these cases the aircraft were equipped with eastern attitude indicators.

A study registered the time needed by pilots trained on eastern horizons to detect an attitude with certainty. (cf. Annex 7). One series of measurements were taken using eastern instruments and another using instruments of the western type.

After one second, 98% of pilots can interpret the attitude, if it is represented with eastern horizons. But only 32% of the same pilots can reliably determine attitude after one second on western instruments.

These findings affected conversion programs to aircraft with western instrumentation (including the Russian types TU-154, TU-204, IL-86, etc.). In particular, the psychological supervision of pilots is provided with the aim of verifying their ability to adapt to the new instrumentation. In addition, in the FSU every conversion to a new aircraft type takes place only in the co-pilot position. Subsequent promotion to commander requires a minimum experience of 500 flying hours on the new aircraft type. The Russian airline Aeroflot has set up a further training program for Russian pilots who have to fly western-type aircraft.

1.18.2.1 Program for retraining pilots for deployment on international routes with western aircraft

In view of the experience of previous years, in the late 'nineties Aeroflot International Airlines developed a program for retraining its pilots on western types of aircraft. Its completion requires a period of more than 12 months and it therefore exceeds by far the training effort implemented in the FSU. It consists of the following elements:

- Restrictive selection of crews from the Russian pilot corps, in rare cases directly from a school (objective: young pilots, good knowledge of English, medical and psychological requirements fulfilled). Aeroflot trains pilots today in its own schools, i.e. they no longer pass through the state aviation schools (Ulyanovsk, Kirovograd). These Aeroflot schools use the Lufthansa system.
- Selection with the career objective of being taken on as a commander on international flights
- Preparation for working as a two-man crew: CRM training, comprehensive introduction to philosophy and working techniques, communication
- Language course, with the objective of being able to read and use American manuals
- Training for international flights (air law, meteorology, imperial system of measurement, routing, etc.)
- Once this section of the training is completed, a further (psychological) test is carried out, with selection
- Type rating course (theory, simulator) with proficiency check
- Line introduction preferably with western companies, e.g. in Germany or in Canada
- Line introduction with Aeroflot; certain airports with a high degree of difficulty, such as Zurich, require an additional introduction
- Line check
- Working as first officer

All sections of the training are accompanied by intensive observation and regular checking. Everyone who completes the course is first employed as a first officer and only later, given sufficient practical experience, is he promoted to commander.

1.19 New investigation techniques

After the accident, contact was made with the avionics manufacturers Rockwell Collins and Universal Avionics in order to find out whether a non-volatile memory (NVM) is installed in one of their products. Collins informed the Swiss AAIB that this is the case with the display control panel (DCP). The two DCPs were found and opened. First indications were that the NVM in the right-hand DCP was totally destroyed. The NVM in the left-hand DCP seemed to present an opportunity of reading it. The following were available for this:

- Display control panel (DCP-85) P/N 622-6320-002, S/N 662 (captain side)
- Printed circuit board A1 P/N 647-6838-xxx
- Non-volatile memory chip U17 (identified as type ER2055)

A further enquiry to Rockwell Collins indicated that the NVM stores data relevant to the investigation, such as NAV source selection, selected heading etc..

A specialist company was found in Canada which has experience of reinstating and reading memory chips. A preliminary study confirmed the feasibility of the read procedure, so the necessary extensive work appeared to be justified.

On the basis of the preliminary study it was intended to reinstate the NVM chip U17 so that it would subsequently be able to be read by Collins on a standard reader. On further clarification this method proved to be too risky.

One now concentrated on a second method in which a very thin layer of liquid crystals are applied over the memory cells and the content of the cells is rendered visible by polarization with the light from a special source. This method had to be abandoned, since the charge in the cells was too low to affect the liquid crystal sufficiently.

A third method was then examined in which the chip would be read by accessing cell circuits directly. It was established that neither a laser nor a focused ion beam (FIB) are needed, since the passivation layer can be penetrated directly by the measurement probe. However, this method required a very expensive test cable with very low electrical capacitance.

This option was simulated on a test memory chip. It turned out that measurement with several probes was practically impossible.

Then a printed circuit was developed which makes it possible to wire conventionally the connections which were still intact on the chip from the aircraft involved in the accident. The aim was to reduce the number of measurement probes. In addition, a test memory was prepared so that it could take over missing control functions of the defective chip from CRX 498.

Two outside companies were commissioned to make the necessary connections (micro wire bonding and FIB bonding) on the test set-up.

After further trials reading test memories, permission was then given to read the chip from the accident flight. The first set of four bits (Bits 4-7) could be read without any problems. Then a number of connections had to be changed; in the process, unfortunately, other connections were broken, and this made further reading impossible.

The four bits per byte which were read allow no concrete conclusions to be drawn concerning the stored data. The test must therefore be considered as failed.

2 Analysis

The investigation of the accident to flight CRX 498 on 10 January 2000 was orientated essentially around the following questions:

- Was the aircraft in an airworthy condition when it was taken over by the crew involved in the accident and did anything change with regard to this condition during the flight?
- At the start of the accident flight, was the crew of the aircraft fit to fly and was there any change in this condition during the flight?
- Did operational procedures have an influence on the accident?
- Did external influences have a causative effect on the accident flight

2.1 Technical aspects

2.1.1 Flight guidance system

2.1.1.1 Electronic flight instrument system (EFIS)

2.1.1.1.1 Reliability

The mean time between unscheduled removal (MTBUR) of the main EFIS components was verified. The MTBUR values were in the expected range of a few thousand flying hours and corresponded to the industry standard.

The analysis of the AMOS work orders produced no significant results with regard to the operating behavior of the electronic flight instrument systems.

In the EFIS, the following monitoring functions are installed, which generate a warning if a fault occurs:

- The DPU monitors the presence of the roll/pitch input signal (digital bus activity monitor). In the event of a failure, the ATT flag appears on the EADI and the horizon display disappears.
- Left and right DPUs compare the roll/pitch signals. If there is a difference of more than 4°, "ROLL" or "PITCH" is displayed on the EADI and the master caution is triggered.
- The functions of the DPU are monitored by hardware and software monitors. The processors inside the DPUs monitor each other. In addition, one DPU monitors the other. Depending on the failure mode, "DPU FAIL" is displayed on the EADI or the corresponding EADI goes dark.
- The heading signal is monitored in a similar fashion.

On the basis of the installed software and hardware monitors, the probability of an incorrect display (e.g. a frozen attitude reference) without a warning is very low.

2.1.1.1.2 Availability during flight CRX 498

- On the crew side, there is no indication (CVR) of any problems of any kind with the EFIS.
- The CVR recordings give no indication that one of the EFIS changeover switches (DRIVE XFR, XSIDE DATA, ADI REV or HSI REV) were in any position other than in "NORM".
- According to the CVR/DFDR data, it can be assumed that the aircraft was being flown manually and with the flight director.
- The DFDR and the left-hand DPU obtain attitude and heading data from the left-hand AHC. From the reconstruction of the flight with the help of the engineering model these parameters appear plausible up to the end of the DFDR recordings. Given the internal monitoring

circuits in the DPU, there is a very low probability that attitude- and heading data were in fact correctly generated by the AHC, but were incorrectly displayed by the EFIS without an error warning.

- The two remarks at 16:56:12 UTC and 16:56:24 UTC were in all probability made by the first officer on the basis of the turn direction realized (heading rate) and the attitude respectively. It can therefore be assumed that these parameters were displayed correctly on the multifunction display and on the right-hand EADI respectively.
- The fact that the commander in all probability flew the beginning of the standard instrument departure Zurich East 1Y (SID ZUE1Y) and then the beginning of the direct to Zurich East (DIR TO ZUE) to the right with the flight director, allows to conclude that the flight director display on the left-hand EADI was in working order in that phase of the flight.
- The radio altitude is supplied in analogue form by the radio altimeter (RA) to the left-hand DPU and displayed on the left-hand EADI. In addition, the radio altitude is forwarded as a digital signal from the DPU to the FDAU. Analysis of the DFDR data showed that the RA signal was plausible up to the end of the recording. The DPU was accordingly always able to forward a valid RA signal to the FDAU.

On the basis of the above points, a technical fault in the EFIS which might have adversely affected the attitude display in the critical phase of the flight can with great probability be excluded. The occurrence of such a fault without a corresponding warning in the cockpit can be excluded with a probability which approaches certainty.

2.1.1.2 Auto flight system (AFS)

2.1.1.2.1 Reliability

The MTBURs of the main AFS components were checked. The MTBUR values for the FCC and the APP are at the lower limit. The other values correspond to the industry standard.

The analysis of the AMOS work orders produced no significant results with regard to the operating behavior of the auto flight systems.

2.1.1.2.2 Availability during flight CRX 498

- According to the CVR/DFDR data it can be assumed that the aircraft was being flown manually and with the flight director.
- There are no indications from the crew (CVR) about any problems of any kind with the flight director.
- The fact that the commander in all probability flew the beginning of the SID ZUE1Y, and then the beginning of the DIR TO ZUE to the right, with the flight director allows to conclude that the flight director display on the left-hand EADI was in working order in that phase of the flight.
- The fact that the NAV and IAS lamps on both mode select panels were lit on impact allows to conclude that at that time the flight control computer was active and the selected mode was still being displayed.
- After switching on the yaw dampers (16:55:51 UTC) the rudder deflected to the right (turn coordinator). In the reconstruction of the flights with the help of the engineering model this deflection was assigned to the prevailing attitude.

On the basis of the above indications, a technical fault in the auto flight system during the critical phase of the flight can be excluded with a probability approaching certainty.

2.1.1.3 Flight management system (FMS)

2.1.1.3.1 Reliability

FMS equipment failures on the Crossair Saab 340B fleet were relatively rare. With the exception of the problems with the interface between FMS and FCC the FMS exhibited good reliability during the period under examination.

The Universal Avionics FMS UNS-1K has an integrated monitoring system (continuous bite). Malfunctions which are detected by one of the monitors are indicated by a corresponding message on the CDU. An "MSG" lamp in the pilots' field of vision draws their attention to such messages.

In 1998 a number of entries were made in the technical log concerning the interface between the FMS and EFIS. There have been no further entries since 1999. Most of these complaints were not accompanied by an FMS message but were detectable by the flight crews. The absence of an FMS message points to a problem in the EFIS with reading the FMS data correctly.

2.1.1.3.2 Availability during flight CRX 498

After take off and gear retraction, on the commander's instruction the flight director (FD) was switched on, the NAV-mode armed and it was confirmed by both pilots that the long range navigation system 1 was following the heading ("LRN1 captured").

> Comment
>
> Prior to take-off, the standard instrument departure SID ZUE 1Y had been entered in the FMS. The statement "LRN1 captured" allows the conclusion to be drawn that a valid roll steering signal was provided at this time to the FCC by the FMS.

At 16:55:39 UTC the command was given to fly left, directly to the omnidirectional radio beacon Zurich East (VOR ZUE). At the same moment the aircraft reached waypoint 2.1 DME KLO, the point in the ZUE1Y standard instrument departure at which a left turn is initiated in order to fly radial 255°, starting from VOR KLO.

> Comment
>
> The data recorded by the DFDR confirm that the aircraft did actually turn for a few seconds to the left, before it went into a right turn. The roll behavior (roll rate) indicates flying with the flight director.

At 16:55:47 UTC the first officer informed the commander, who was flying manually, that the LRN system was programmed from the current position to Zurich East ("From present, LRN is to Zurich East, yeah"), which the commander acknowledged. The left turn direction mentioned by departure control was not mentioned.

> Comment
>
> Since the bank angle to the left attained a maximum of 16.9° at 16:55:45 UTC, then reduced until at 16:55:52 UTC when it changed to a bank angle to the right, it can be assumed that the change in direction was caused by a "direct to" input (DTO) into the FMS (LRN). The current heading at 16:55:45 UTC was approximately 270°. If a "direct to" entry is made in this situation, without defining the turn direction, the flight director commands a right turn.
>
> The communication which took place internally in this phase of the flight gives no indication of any technical difficulties.

Between 16:55:47 UTC and 16:55:55 UTC the attitude of the aircraft changed at a rate of approximately 3°/s to the right, whilst the pitch remained constant between 13 and 14° ANU.

> Comment
>
> This corresponds to the situation when the right turn commanded by the FMS with the flight director (DTO ZUE) is flown precisely. The right bank angle had now reached 8.4°.
>
> On the basis of the progress of the flight it can be assumed that by 16:55:55 UTC a valid roll steering signal was forwarded by the FMS to the flight director and was also being displayed in the EADI.

At 16:56:14.6 UTC, at a right bank angle of 65.8°, the commander murmured "oh-na-na". This utterance took place at a bank attitude at which, in the electronic attitude director indicator (EADI), all data except the attitude reference are masked out (declutter mode).

In declutter mode, the flight director bar also disappears from the EADI. In view of the high reliability of the system, it can be excluded with a probability approaching certainty that the system ceased supplying a valid roll steering signal to the FCC between 16:55:55 UTC and 16:56:14.6 UTC.

2.1.2 Other avionics equipment

2.1.2.1 Air data system

2.1.2.1.1 Reliability

Technical reliability (MTBUR) was within the expected limits and corresponded to the industry standard. The examination of the operating reliability produced no significant results with regard to the operating behavior of the left-hand air data system.

2.1.2.1.2 Availability during flight CRX 498

- There were no indications from the crew (CVR) of any problems of any kind with the air data system.
- Two seconds before the crash, the DFDR was recording plausible data (baro altitude, airspeed, OAT) from the air data computer.
- On impact, the left-hand altimeter (servo altimeter) was indicating a plausible value which also correlates with the recorded data.
- The left-hand airspeed indicator (ASI) was so badly damaged that it could not be evaluated.
- The speed flown until 16:56:04 UTC corresponds to normal values and shows that the speed reference was available in the flight director and/or in the airspeed indicator.
- Until 16:56:22 UTC the ATC transponder (mode C) was transmitting the correct altitude (pressure altitude). This signal was sent from the air data computer via the servo altimeter to the ATC transponder and was recorded by ATC radar.

On the basis of the above indications it can be assumed with a probability approaching certainty that the air data parameters were available to the commander throughout the flight.

2.1.2.2 Ground proximity warning system (GPWS)

In the final phase of flight CRX 498, the warning mode 1 "excessive sink rate" and mode 2A "excessive closure rate" should have responded as expected, when the aircraft fell below 2450 ft AGL radio altitude.

In order to determine the warning envelopes of mode 1 and 2A the ground proximity warning computer (GPWC) requires signals from the radio altimeter and the air data computer.

The antennas of the radio altimeter are located on the underside of the aircraft fuselage. They have a beam angle of approximately +/- 45°. Because these antennas were pointing away from the ground as a result of the roll attitude of the aircraft when HB-AKK dropped below 2450 ft AGL, the radio altitude remained at a value which is slightly above 2450 ft. This corresponds to the maximum altitude output from the radio altimeter, as it is normally generated, during cruise.

The warning envelopes for mode 1 and 2A are limited upwards by 2450 ft radio altitude. Since the radio altitude remained somewhat over 2450 ft, the corresponding warnings were suppressed.

2.1.3 Flight controls

2.1.3.1 Flaps system

During the 18 months between the C-check (June 1998) and the time of the accident, 21 malfunctions in the flap system were reported by pilots. These were of two types:

- Delayed deployment prior to landing.
- So-called flap ballooning (uncommanded deployment and then retraction).

Delayed deployment of the flaps prior to landing is not relevant to the accident flight.

Flap ballooning in the critical phase of the accident flight was initially taken into consideration as a factor affecting flying behavior. Pilots who had complained about flap ballooning on HB-AKK were therefore questioned.

The result of the questioning showed that the occurrence of flap ballooning in a climb at a speed below 150 KIAS was never established. However, even if this malfunction had occurred, this would not have affected flying behavior significantly.

During the accident flight, with a probability approaching certainty, no problems occurred with flap asymmetry. The previously known cases occurred on aircraft other than HB-AKK and on approach with flaps fully deployed.

According to the investigations with the aid of the engineering model all attitude changes in the climb and the subsequent accident phase resulted solely from crew control commands to the control surfaces.

2.1.4 Engines and propellers

- All damage found was assessed as a result of the impact of the engines.
- The traces left by the rotors indicate that the impact of the engines occurred at high speeds.
- No pre-existing damage was found on the engines which might have caused a loss of power.
- No indications were found of a compressor stall or a flameout in the engines as a result of ice or slush.
- The residues in the compressors were examined visually and no indications of a bird strike could be found.
- None of the engine pods exhibits damage which might have been caused by the fracture of an internal rotating component.
- On the hot parts of the engine (combustion chamber, turbine parts) molten Al/Si material is present. This proves that at the time of impact the compressor rotor was abrading material at high speed (blades touching on the housing) and the hot section components were at a high temperature.

- On both engines the bolts which connect the gas generator turbine to the gas generator compressor had been sheared off. This also indicates that the gas generator rotor was rotating at high speed at the time of the crash.
- Both propellers were in an operable condition up to the impact.

2.1.5 Maintenance

The deficiencies ascertained within the framework of the investigation concerning maintenance records, procedures and the quality of maintenance had no influence on the HB-AKK accident.

2.1.6 Electromagnetic interference (EMI)

There are no concrete indications that in the critical phase of flight CRX 498 a mobile telephone was in operation onboard HB-AKK. On the basis of the testes carried out it can be assumed that even a transmitting telephone would not have been able to have any adverse effects on the systems which are important for the control of the aircraft or on the representation of their parameters.

2.1.7 Airworthiness

The aircraft HB-AKK was handed over to the crew of flight CRX 498 in an airworthy condition. There are no indications that any change occurred in this condition up to the crash.

The investigation has found that the accident was not influenced by technical deficiencies.

2.2 Human and organizational aspects

2.2.1 Flight crew

2.2.1.1 Commander

2.2.1.1.1 Career

The commander was deeply rooted in the culture of the FSU and the independent Republic of Moldova and until he was taken on by Crossair had few references to western culture.

2.2.1.1.2 Pilot training and training specific to his profession

The pilot training took place via education at a technical college. This met the requirements for a career which could have led him to the position of first officer on an AN-24; a technological university education, on the other hand, would have opened up the entire range of piloting possibilities from the beginning.

He compensated for the initially absent prerequisites for a further career with promotion to commander on medium-sized aircraft or first officer on heavy aircraft by means of a correspondence course at the Civil Aviation Academy in Leningrad.

According to information from his professional environment at that time, the commander was able to compensate for shortcomings in the flying and operational area by hard work and dedication.

2.2.1.1.3 Training

The commander's conversion to western systems took place on behalf of Moldavian Airlines at Crossair in Basle and was, in comparison with the customary effort in the FSU, completed by a procedure which was not tailored to the individual requirements of the commander. The instrumentation differences were not known at that time to Crossair and it was not possible, within the short time available, to give it adequate attention.

It must nevertheless be noted that these differences are essentially unknown in broad circles of western civil aviation.

During the introduction to the procedures specific to Crossair (changing operator course) on the occasion of commencement of activity as a leasing pilot, the fact that the commander had more than 1600 hours on the Saab 340B was considered as sufficient evidence of qualification. The fact that he had acquired this experience in a different operational environment was not taken into consideration.

2.2.1.1.4 Language knowledge

The commander had sufficient knowledge of English for routine operations in the cockpit, including standard radiocommunications. However, it was probably only just adequate for extraordinary operational situations and for personal conversations. In addition, it is questionable whether the commander was able, given these linguistic circumstances, to communicate adequately within the framework of day-to-day operations in the multilingual environment which was typical of the Crossair operation.

Additional language training at the Wall Street Institute was arranged and planned but had not yet begun.

In the entire documented sequence of cooperation between commander and first officer during the accident flight, with one exception, only the absolute minimum of communication is apparent. This circumstance leaves some doubt as to linguistic competence for communication in non-standard or emergency situations.

2.2.1.1.5 Social background

The social background of the commander was characterised by separation from his family which was limited in duration and by modest financial circumstances. His network of social relationships was restricted to daily telephone calls to his family and friendship with other Moldavian Airlines leasing pilots.

The absence of a formal leasing contract citing financial remuneration for the commander's activity with Crossair indicates that the leasing agreement was a kind of "gentleman's agreement" between the two companies. During the investigation, discrepancies were found concerning the compensation paid, on the basis of various witnesses' statements and correspondence. In brief, the range of compensation payments can be limited to 4000 to 5000 USD, of which 3000 USD accrued in each case to Moldavian Airlines. The commander consequently received an income of 1000 to 2000 USD, plus expenses amounting to 3 CHF per flying hour and 900 lej (150 USD) basic salary in Moldova. According its own indications, Crossair covered the costs of accommodation.

The switch to Crossair brought him a monthly salary of between USD 1000 and 2000, which was high in Moldavian terms. However, this only allowed him a very modest life in Switzerland – especially after the commander sent USD 1000 home every month.

2.2.1.1.6 Psychological aspects

At the time of the accident, there were no indications of the existence of chronic mental disturbance or illness. The possibility of an acute psychotic illness with hallucinations is in principle always present. Neither the life history nor the detailed psychological reports during his career as a pilot, indicate a disposition to psychotic decompensation in the sense of increased vulnerability, which makes the onset of such an occurrence during the accident flight highly improbable.

It can be assumed that all cognitive faculties – the functions of orientation, concentration, attention, memory and intellect – were not adversely affected during the accident flight in the sense of an acute diminution in competence. With regard to possible adverse effects due to medication, refer to chapter 2.2.1.1.7.

The tests carried out on the occasion of the routine detailed medical/psychological examinations in Moldavia confirmed that the commander had a stable basic personality and adequate capability to fulfill the requirements of a commercial pilot. It is not excluded, but extremely improbable that anything had changed in these circumstances at the time of the accident flight. In any event, analysis of the 72 hours before the accident gave no indications which would justify such an assumption.

After 16:56:00 UTC the commander did not speak further, with the exception of the indistinctly mumbled "oh, na, na" recorded in the transcript at 16:56:14 UTC. Although the control movement recorded in the DFDR do not make it possible to assign the control column to the commander, the commander was, with a probability approaching certainty, not adversely affected in his psycho-physical capabilities in this brief final phase of the flight.

Nor could any substantive significance be attached to the expression "oh, na, na" after consulting the commander’s former professional colleagues and his partner. On the basis of the analysis of all facts present, he is expressing becoming aware of something unexpected (declutter mode) rather than being physically unwell.

The situation of the commander with the geographical separation from his family because of his changed employment situation may be seen as an obvious emotional stress factor. The commander had been for some months in a foreign country with a foreign language and culture. According to unanimous opinion, he was a very social person, who had strong emotional ties to his partner and his children. Daily telephone contact was the rule. The family’s move to Switzerland was being considered with his partner. The resulting emotional burden resulting from this situation should not remain without mention.

In summary, on the basis of the available findings it can be assumed that flying capability was present, according to currently valid criteria used in psychological reports. The cited pre-existing destabilizing factors and stress factors were subliminal. However, these would not necessarily have had a negative effect on performance.

2.2.1.1.7 Medical aspects

According to all the documents available, the commander was healthy at the time of the accident. Neither the medical history not the risk profile make it possible to assume an increased risk of an acute adverse disturbance of flying capability (sudden incapacitation) occurring. From the recorded flight data too (CVR, DFDR), there is no positive clue to such a disturbance. However, since on the other hand it cannot be completely excluded, the degree of probability of an acute adverse effect on flying capability, e.g. due to an acute illness of the heart, circulatory or central nervous system must still be considered:

- The commander was a slim, 40 year-old non-smoker, who indulged moderately in sports and whose regular basic medical statements in the history indicate no increased risks of any kind in the areas of fat and sugar metabolism or cardiac function. He therefore presented an optimal risk profile with regard to illnesses of the cardiovascular system and their consequences. In itself, such a profile does not exclude an acute illness; it merely makes it highly improbable.
- It is moreover to be assumed that an acute illness or even unease of a crew member will be reported without delay to the crew partner. It can therefore be assumed to be highly improbable that such a notification would not have been made by the commander.
- Finally, it can be assumed that any obvious disturbance (e.g. loss of consciousness, great pain, etc.) to a crew member would very probably be noticed quickly by his crew colleagues, leading to an immediate hand-over of control. In view of the fact that the commander’s instruction to "set climb power" at 16:56:00 UTC was given in a normal, clearly understandable tone, the first officer had no cause to make such an assumption.

The combination of the three above-mentioned considerations which were described as extremely improbable events makes is possible to exclude, almost with certainty, an obvious sudden incapacitation of the commander before the accident.

The possibility remains of merely slight incapacitation of the commander in terms of difficulty with perceiving and processing information (subtle incapacitation). This may, for example occur in the event of minor functional disturbances of the central nervous system, the heart and circulatory system or the metabolism. A general lack of oxygen might lead to such incapacitation. However, there is no positive indication of any of the cited disturbances.

The possibility of subtle incapacitation as the result of a health problem can also be assumed to be highly improbable.

The evidence of the Phenazepam medication in the mortal remains of the commander, on the other hand, makes it possible to conclude that the cited medicine had been taken at an unknown time prior to the flight. From the witness statements it is not clear whether the commander took the medication regularly or even if there could have been dependence. From the proven presence of the substance in the commander’s organism, it is quite possible to assume an effect, as per the quotation below from the IRM report.

Toxicological assessment of the concentration of Phenazepam in muscle tissue (quotation from the IRM report):

„Für die toxikologische Beurteilung werden üblicherweise die Blutkonzentrationen (Blutspiegel) verwendet. Im vorliegenden Fall stand uns wegen der vollständigen Traumatisierung des Körpers von (Name des Kommandanten) jedoch kein Blut, sondern lediglich Muskulatur in kleinen Stücken zur Verfügung. Die Identität der Muskelproben wurde vor den chemischen Analysen mittels DNA-Vergleichsuntersuchungen abgeklärt, vgl. separates Gutachten.

*Bei der Interpretation der ermittelten **Phenazepam-Muskelkonzentration von ca. 7 – 8 ng/g** muss zuerst das Verhältnis der Muskel-Konzentration zur Blut-Konzentration abgeschätzt werden; denn entsprechende Angaben über Phenazepam-Muskelkonzentrationen konnten wir in der Literatur keine finden. Aus einer eigenen Arbeit [..] wissen wir, dass die Benzodiazepin-Konzentrationen im Blut in einer ähnlichen Grössenordnung liegen, wie jene in der Muskulatur. Im Falle von Bromazepam (Wirkstoff z.B. von Lexotanil®) und teilweise auch bei Nordazepam (Wirkstoff z.B. von Vegesan®) findet man in der Muskulatur etwa die doppelte Benzodiazepin-Konzentration, wie im Blut, bei Oxazepam (Wirkstoff z.B. von Seresta®) etwa die gleiche und bei Diazepam (Wirkstoff z.B. von Valium®) etwa 40 % weniger, als im Blut.*

Bei der Interpretation der Muskelgehalte im vorliegenden Fall dürfen wir somit mit gutem Grund schliessen, dass bei einer Phenazepam-Muskelkonzentration von ca. 7 – 8 ng/g eine ähnliche Konzentration im Blut vorgelegen hat. In Analogie zu den vorerwähnten Muskel-Blut-Verhältnissen lässt sich für den Zeitpunkt des Ereignisses für (Name des Kommandanten) eine ***Phenazepam-Blutkonzentration von ca. 4 – 12 ng/ml abschätzen.***

Vergleicht man diesen Blutkonzentrationsbereich mit den Daten in Abschnitt 4.1 (Pharmakokinetik/Blutspiegel), so stellt man fest, dass er keinesfalls mit der aktuellen Einnahme einer hohen Einzeldosis oder mit der Langzeiteinnahme von Tagesdosen von 3 bis 4,5 mg (welche zu einem Blutspiegelbereich von 40 – 100 ng/ml führen würden) oder mit der Behandlung einer Neurose (welche in einem therapeutischen Bereich von 30 – 70 ng/ml erfolgen würde) übereinstimmt. Hingegen liegt der abgeschätzte Blutkonzentrationsbereich im niedrigen therapeutischen Bereich. In Frage käme somit die Einnahme einer Einzeldosis von etwa 1 mg, oder je nach Einnahmezeit vor dem Ereignis eine höhere oder eine niedrigere Einzeldosis. Die effektive Einnahmezeit ist unseres Wissens unbekannt. Sie lässt sich auch nicht anhand pharmakokinetischer Überlegungen oder Interpretationen ermitteln.

Die hier vorliegende Blutspiegel-Situation kann grundsätzlich durch vier unterschiedliche Einnahmeszenarien interpretiert werden:

Bei Szenario 1 *wäre die einmalige Einnahme einer relativ niedrigen Phenazepam-Dosis (z.B. etwa 0,5 – 2 mg) im Zeitbereich von einigen Stunden vor dem Ereignis denkbar.*

Bei Szenario 1 wäre mit einer beruhigenden, sedierenden Wirkung zu rechnen, welche mit einer gewissen Verlangsamung, Dämpfung, Müdigkeit und Schläfrigkeit verbunden wäre. Aufgrund der Verlangsamung wäre auch von einer verminderten Reaktionsschnelligkeit und evtl. von einer verlangsamten oder nicht mehr adäquaten Verarbeitung von äusseren Reizen und Wahrnehmungen auszugehen. Die Stärke der Beeinflussung hängt von der Gewöhnung an dieses Präparat ab.

Bei Szenario 2 *wäre die einmalige Einnahme einer relativ niedrigen Phenazepam-Dosis (z.B. etwa 0,5 – 2 mg) im Zeitbereich von sehr vielen Stunden oder mehr als 1 Tag (einziger Unterschied zu Szenario 1) vor dem Ereignis möglich. Szenario 2 entspräche beispielsweise der Situation, wenn (Name des Kommandanten) in der Nacht auf den Ereignistag eine Tablette Phenazepam als Schlafmittel eingenommen hätte. Wegen der sehr langsamen Elimination von Phenazepam sinken die Blut- und Muskel-Spiegel ausserordentlich langsam. Wie bei anderen Benzodiazepinen ist auch bei Phenazepam davon auszugehen, dass nach einigen Stunden (wahrscheinlich etwa 6 bis 8 Stunden [7]) die Wirkungen und die Nebenwirkungen abgeklungen sind, obwohl dann immer noch Phenazepam in einer niedrigen therapeutischen Konzentration im Blut (und auch im Muskel) nachgewiesen werden kann. Wie oben beschrieben, werden nach Einnahme von 2 mg Phenazepam nur sehr langsam absinkende Blutspiegel beobachtet, nämlich nach 4 h 9,2 ng/ml, nach 6 h 8,2 ng/ml, nach 24 h 5,7 ng/ml, nach 48 h 5,6 ng/ml, nach 96 h 3,9 ng/ml.*

Bei Szenario 2 ist in dieser Spätphase nicht mehr von einer dämpfenden, verlangsamenden, schlafinduzierenden Wirkung auszugehen. Vigilanz, Reaktionsfähigkeit und geistige Präsenz sind in dieser Phase wieder intakt, denn die sedierenden, müde machenden, reaktionsvermindernden Wirkungskomponenten dürften nach einigen Stunden (etwa nach 6 bis 8 Stunden) abgeklungen sein.

Bei Szenario 3 *wäre die einmalige Einnahme einer relativ hohen Phenazepam-Dosis (mehr als 2 mg) im Zeitbereich von einem oder mehreren Tagen vor dem Ereignis zu diskutieren. Bei diesem Szenario wäre Phenazepam wegen der sehr langsamen Ausscheidung aus dem Blut (Eliminationshalbwertszeit etwa 48 bis 75 Stunden, in Extremfällen 26 bis 133 Stunden) im Blut zwar* *noch in niedrigen Konzentrationen (z.B. wie hier abgeschätzt von ca. 4 – 12 ng/ml) nachweisbar.*

Bei Szenario 3 wäre nach so langer Zeit nach der Einnahme (trotz positivem Blut- bzw. Muskelbefund!) keine Wirkung mehr zu erwarten.

***Bei Szenario 4** steht die regelmässige, wiederholte Einnahme einer relativ niedrigen Phenazepam-Dosis (z.B. etwa 1 mg) während einigen Tagen oder Wochen vor dem Ereignis zur Diskussion. Nach Langzeiteinnahme von täglich 1 mg Phenazepam werden minimale Steadystate-Blutkonzentrationen von 8 – 9 ng/ml nach 2 Wochen erreicht; bei täglich 1,5 mg Phenazepam ca. 13 ng/ml nach etwa 34 bis 46 Tagen.*

Bei Szenario 4 wäre mit keinen oder nur mit sehr schwachen sedierenden, schlafinduzierenden Nebenwirkungen zu rechnen.

Die hier dargestellten pharmakokinetischen und pharmakodynamischen Interpretationen der Phenazepam-Muskelkonzentration können keine Entscheidungskriterien zur Frage anbieten, welches der vier diskutierten Szenarien (oder Mischformen davon) im vorliegenden Fall zutrifft oder am Wahrscheinlichsten zutrifft. Möglicherweise ergeben sich aus den übrigen Unfallabklärungen Hinweise auf die Phenazepam-Einnahmegewohnheiten von (Name des Kommandanten) bzw. auf die eingenommene(n) Dosis (bzw. Dosen) und die Einnahmezeit(en).

Schlussfolgerungen/Befund

Im Muskelgewebe von (Name des Kommandanten) konnten Spuren des Benzodiazepins Phenazepam (Psychopharmakon, Tranquilizer) in einer niedrigen Konzentration von ca. 7 bis 8 ng/g nachgewiesen werden.

Ob der (Name des Kommandanten) im Zeitpunkt des Ereignisses unter einer leichten Phenazepam-Wirkung im Sinne einer leichten Dämpfung, einer leichten motorischen und geistigen Verlangsamung und einer leichten Sedierung stand, kann weder nachgewiesen noch ausgeschlossen werden.“

End of IRM quote, bibliography in the original report.

2.2.1.2 First officer

2.2.1.2.1 Pilot training and training specific to his profession

The initial education path of the first officer did not lead directly to his later profession of line pilot

During and after his pilot’s training, the first officer worked in various professions, including meteorologist and, with Czech Airlines as a station manager, supervisor and sales representative.

Despite an externally good starting point for a career as a pilot – his father was a pilot – the first officer did not succeed straight away.

He was first confronted with the rules of commercial aviation during transition training with the Saab 340B and line introduction with Tatra Air in 1997. With this company, until its bankruptcy in 1999, he acquired his first, rather brief professional experience (just 1000 flying hours). The line introduction lasted for 42 sectors instead of the planned 30.

Shortly after the Tatra Air bankruptcy, he was taken on by Crossair, after an introduction with simulator training, FMS training, line introduction and a proficiency check.

With regard to recruitment and induction with Crossair it is striking that the formal sequence which was otherwise customary in Crossair – selection – employment – training – assignment to routes – was not followed. Thus selection took place after recruitment. Recruitment took place only after the commencement of the course. Finally, organizational inadequacies were such that the co-pilot was being used on commercial flights two days before the commencement of validity of his license.

2.2.1.2.2 Social background

The first officer's origins from a pilot's family may have been a factor in his own choice of profession.

The first officer's distinct bond with his family led him to spend as many of his off days as possible with this wife and child in the Slovakian republic.

His financial status corresponded to that of a Crossair pilot. His salary should have been sufficient to maintain his family in the Slovakian republic in view of the cost of living there.

2.2.1.2.3 Psychological aspects

The first officer showed no indications of the existence of chronic mental illness. The possibility of the first officer having an acute psychotic illness with hallucinations can be excluded, because on the basis of the recordings it can be assumed that he perceived the dangerous situation, and because he expressed himself quite comprehensibly and adequately on the situation shortly before the crash. Accordingly, it is highly probable that his cognitive capabilities were unaffected during the accident flight.

The detailed psychological tests carried out on the occasion of the routine medical/psychological examinations in the Slovakian republic confirmed that the first officer tended towards a mildly unstable basic personality with adequate capability to become used to the requirements of a commercial pilot.

At the time of the accident, the first officer had already reacted to the obviously present emotional stresses (geographical separation from his family, changed working situation, N.B. in a foreign country with a foreign language and culture) by giving notice of termination of his employment contract as of the end of the year 2000.

Notwithstanding an existing residents' permit for his wife and child, the first officer had not moved his family. The emotional burden persisted, despite his giving notice to quit. It may have become even heavier, since he was facing a further change in his place of work and the associated circumstances.

In his life history and in the detailed psychological reports during his career as a pilot (among other things in the assessment by Crossair in August 1999) there were references to a somewhat reduced resistance to stress (higher emotional excitation).

In the Crossair assessment the first officer exhibited a tendency to integrate and intervene in team situations only with a delay. These proven criteria, however, were not so pronounced that they disqualified him from a position with either Tatra Air or Crossair.

In standard operations, such tendencies to weakness do not have an effect as a rule; it is, so to speak, the privilege of a first officer still to be rather uncertain. With regard to situations outside routine operations, however, such personality traits do include a degree of risk, which cannot be quantified. Depending on the composition of the crew, this risk may be increased or reduced. Weaknesses in communication and decision-making may accumulate if both parties involved exhibit the same pattern of behavior.

With reference to the specific flight situation, the above findings had the following influence: the first officer's reaction to recognition of an incorrect turn direction with a weak intervention (16:56:12 UTC, "turning left to Zurich east, we should left"), was logically correct subject to the assumption that he had recognized the turn direction only, but not the bank attitude.

From this moment up to the time at which recovery was no longer possible (approximately 16:56:19/20 UTC), the first officer still had about seven seconds to make an appropriate intervention. In empirical-psychological terms, five seconds constitute the minimum time required to react appropriately to a new, unknown and unexpected situation. A complicating factor is that in a dynamic system the parameters change quickly and continuously.

Although the remaining time of seven seconds appears to be theoretically sufficient, the following aggravating factors must be taken into account:

- Realization of the navigational problem took place in a period in which the first officer was absorbed in the performance of a complex procedure (power setting).
- An appropriate reaction would have required the immediate setting of new priorities.
- The merely partial recognition (direction of turn but not bank attitude) of the hazardous situation prevented giving an adequate alarm and the massive intervention which would logically be expected.
- Because of the absence of communication by the commander, external warning signals were not available to the first officer at this time. Also, acceleration (g-forces) in all axes were below the threshold of perception.
- Although the intervention by ATC (16:56:17 UTC: "Crossair 498 confirm you are turning left") may have interrupted the first officer in analyzing the situation, it simultaneously constituted an essential warning. Consistent with this pattern of behavior, the first officer gave the greatest attention to the ATC communication before turning again to solving the problem.

It is apparent from the documentation of the training with Tatra Air and Crossair that the first officer exhibited a latent weakness in decision-making and establishing priorities throughout his flying career. In the qualification issued during his training with Tatra Air he was, moreover, required several times to give priority to ATC communication.

The fact that the first officer perceived the last ATC query at all allows us to conclude that he was not yet aware of the full extent of the danger.

In summary, the psychophysical state of the first officer cannot be judged to be pathological in the narrower sense, in the present context. In all, it can be assumed that flying capability was present, according to currently valid criteria used in psychological reports. The cited pre-existing stress factors and minor limitations in the area of stress resistance and decision-making capability were subliminal. However, these would not necessarily have had a negative effect on performance.

The forceful intervention by the first officer (16:56:24 UTC: "turning left, left, left, left .... **left**!") came only at a time at which successful recovery was no longer possible. Simultaneous intervention by the first officer in control seems probable after analyzing all the data but cannot be proved.

2.2.1.2.4 Medical aspects

According to all the documents available, at the time of the accident the first officer was suffering no kind of adverse health. Neither the medical history nor the risk profile make it possible to assume an increased risk of an acute adverse disturbance of flying capability (sudden incapacitation). Nor do the recorded flight data (CVR, DFDR) give any hint of such an incapacitation. The first officer's statements recorded on the CVR sound calm and concise until shortly before the impact of the aircraft.

As to the probability of the occurrence of a health problem adversely affecting flying capability in an acute manner, the same considerations apply as for the commander. The medical risk profile of the first officer may even be considered as more favorable, given that he was younger.

The chemical-toxicological evidence of a low concentration of alcohol in the examined muscle tissue is assessed as follows in the IRM toxicological report:

Quote:

„Im Zeitpunkt des Flugzeugabsturzes befand sich somit mit an Sicherheit grenzender Wahrscheinlichkeit kein Ethylalkohol (Trinkalkohol) im Körper von (Name des Copiloten)".

End quote.

2.2.2 The flight crew environment

2.2.2.1 Social environment

Both pilots had been living in Switzerland for only a few months and were working for Crossair under different conditions. Assimilation to the conditions of the country had hardly occurred for both of them. The necessary knowledge of a Swiss national language was substantially absent in both cases. In both cases, the closest family members continued to live in the respective country of origin. Both were living under the modest financial conditions of an emigrant maintaining his family at home with his income. The countries of origin of both pilots are characterised by a culture which is very different from that in Switzerland.

There were no indications that the two pilots had got to know each other before the current sequence of duty (rotation). However, this situation often occurs in the Swiss aviation environment.

2.2.2.2 General pilots' environment

2.2.2.2.1 Procedures

At the time of the accident, the procedures were substantially in conformity with JAR-OPS 1 and published accordingly.

2.2.2.2.2 Times of flying duty

The limitations on flying time were complied with.

2.2.2.2.3 Language and communication

Communication was regulated and published; English was the prescribed language for communication within the framework of checklists and procedures. Both pilots complied with this regulation throughout the entire progress of the flight.

It can be assumed that in the present case the absence of a common mother tongue on the one hand, and the limited knowledge of English on the other, made verbal communication difficult in an unforeseen or extreme situation.

2.2.3 The Crossair airline

2.2.3.1 General

Crossair was moulded and led by its founder. In principle, the final decision-making power in management lay with this person. "Loyalty" was one of the most important basic attitudes expected of employees. This aspect had an effect on the culture of criticism and conflict within the company.

The cultural separation from Swissair led, among other things, to fundamental differences in the areas of operation and safety management. For example, even for aircraft types where monitoring of the pilots was technically possible by means of an auxiliary data acquisition system (ADAS), this was not adopted. The justification given was that such monitoring would be equivalent to spying on the pilots.

Major pressure on costs in the industry as a whole led in Crossair’s case to low salaries for cockpit personnel, in a national comparison. This had an effect on recruitment and was one of the reasons for the labor conflict with the pilots’ association, the CCP, already mentioned.

In the years before the accident, in Switzerland as in the European environment as a whole, the employment market for flight crews had been mined to exhaustion. Consequently many pilots from different countries and cultures, and with different forms of training and experience, were taken on.

2.2.3.2 Structure

The imminent fleet conversion with replacement of the Saab 340B led to a concentration of tasks in the fleet management sector onto individual persons.

The chief flight instructor for the Saab 340B was simultaneously employed as the fleet manager for this fleet. Personnel decisions, such as employing direct entry commanders, were thus taken, to a large extent, by one single individual.

2.2.3.3 Selection procedure for leased direct entry commanders

Renouncing formal assessment for direct entry commanders hired according to the leasing procedure led to a lack of information on the aspects of personality and cultural background. The selection procedure therefore rested substantially on flying qualifications. In the knowledge of the importance of the above-mentioned factors for satisfactorily functioning CRM, this procedure included a degree of risk.

2.2.3.4 Selection procedure for first officers

The above-mentioned components of the selection procedure for first officers were assessed as appropriate and adequate for the purpose. However, there were indications that the motions of the selection board were occasionally overruled by the management.

2.2.3.5 Working climate

The labor conflict with the pilots’ association was also argued out in public with some pronounced emotional components on both sides. The conflict was certainly not favorable to a constructive working climate.

A labor conflict must be assessed as so-called company stress. Like any form of stress with rather negative symptoms, such company stress leads to those affected experiencing a potential adverse effect on concentration and therefore on safety at work. This applies especially to activities with complex working processes.

However, one limiting factor in this respect is that both pilots of the accident flight – as already mentioned – had been working for the company for only a very short time and hence it is possible that they were as yet little affected by the labor conflict.

2.2.4 Regulatory authority

Over the years, a certain relationship of trust was established on the part of the supervisory authority with regard to companies such as Swissair and Crossair, not least because such companies had established their own positive instruments for quality control. The fact that formal inspection in the areas of operations and training was not carried out over a period of years remains unsatisfactory.

2.3 Operational aspects

2.3.1 History and analysis of the flight

The aircraft, HB-AKK, had landed on 10 January 2000 as Crossair flight CRX 842 from Guernsey (EGJB) and reached stand F74, which is close to the end of runway 28, at 16:00 UTC. The aircraft was then prepared for the next flight. No de-icing took place.

According to statements from the crew of this flight preceding the accident flight, there were no technical defects on the aircraft and no other abnormalities were to be found. On hand-over of the aircraft, there was a brief conversation with the new crew, during which no peculiarities were commented on.

A ground personnel employee (red cap) also had contact with the crew and noted no irregularities.

At 16:39:14 UTC flight CRX 498 to Dresden (EDDC) received from clearance delivery (DEL) the clearance: "runway two-eight, Dresden, Zurich East One Yankee departure, squawk three-zero-zero-four" and was at the same time instructed to changed to the apron (APR) frequency. Permission to start engines was given at 16:45:00 UTC. At 16:49:22 UTC the first officer informed APR that the aircraft was ready to taxi. This information could be taken both from the CVR recordings and from those of the DEL and APR. At this time, both pilots were carrying out their work without wearing their headsets. The conversations could therefore only be recorded via the CAM (cockpit area microphone). From the recordings it is clear that engine start-up was carried out with the aid of the corresponding checklists and in accordance with Crossair procedures.

There was a concentrated work atmosphere in the cockpit. No private conversations were being conducted.

A brief interruption by the cabin attendant (CA) at the beginning of the start up procedure involved a minor difficulty in communication between the flight crew and the CA, but this was able to be sorted out after a short time.

There was a relaxed atmosphere between the flight crew and the cabin crew.

While the crew waited for clearance, a number of points on the taxi checklist were dealt with. This took place at the instigation of the first officer and must be assessed as an appropriate crew measure. However, the aircraft was in a parking position which allowed a very short route to the threshold of the runway. By using the waiting time to deal with a few checks, the crew were able to get an advance in the handling of the prescribed procedures.

At 16:50:30 UTC, APR gave flight CRX 498 clearance to follow a Swissair A 320 (SWR 014) to the holding point of runway 28. This clearance interrupted the crew in speaking about standard instrument departure SID ZUE 1Y. The interruption took place in the first officer's sentence: "departure: we have Zurich East ...". In retrospect it cannot be established whether a previous discussion had taken place before the beginning of the CVR recording. In the further phases of the operation, no further mental revision of the instrument departure took place.

In accordance with the taxi clearance, CRX 498 begun to move and the crew carried out the outstanding items on the checklist. The checklist item "departure" was again cited by the first officer and answered by the pilot with "yeah", on which the first officer continued: "transponder, FMS checked". This was once more commented on by the commander with "yeah". The next checkpoint addressed was "take-off briefing, speed bug". The commander's response cannot be clearly determined from the CVR recording. However, it is clear that no further detailed take-off briefing took place and that the position of the speed bug was checked. It can be assumed with a high degree of certainty that a regular take-off briefing had already taken place (no corresponding recording exists on the CVR) and that the crew considered this an appropriate situation. From the overall behavior of the first officer it can also be assumed that if the take-off briefing had not taken place he would have requested one at this point. Despite two radio interruptions the taxi checklist was completed and this completion was confirmed by the first officer at 16:52:14 UTC: "taxi check is completed", after the commander had already expressed this confirmation at 16:52:10, rather prematurely and not entirely in accordance with the procedure.

During processing of the taxi checklist, the first officer contacted the tower (TWR) at APR's request, and this may have made the commander unsure of the status of processing of the checklist. However, the aircraft was taxiing in the dark, so he had to concentrate his attention on matters outside the aircraft. At this moment, the first officer was giving great priority to radiocommunications, whilst maintaining an overview of the outstanding checklist items in the given situation.

At 16:52:36, TWR gave clearance to turn onto runway 28. At 16:52:41 UTC, the commander then initiated the line-up checklist. This was dealt with quickly up to the point take-off clearance, which was reached at 16:53:10 UTC: First officer: "... next take-off clearance", commander: "to go .."

Once the aircraft was aligned on the runway axis there was a lengthy delay due to the traffic situation. The commander was following radiocommunications with other aircraft and also commented on it in one case. This indicates that he was attentive and that there was no lapse in this attention. After half a minute's silence, the first officer tried to make a personal comment: "in Slovakia only two runway ... runways have centre line ...". This comment went unanswered by the commander and 14 seconds later take-off clearance was given by the TWR.

Take-off clearance was given at 16:54:00, with wind information 300°/3 knots. According to ATIS, the following meteorological conditions existed at 16:50 UTC: wind 290° at 2 knots, visibility 6 km in drizzle, cloud base at 500 feet above ground, temperature 2 °C, dew point 1 °C, QNH 1032 hPa. The aircraft began its take-off roll at 16:54:10 UTC in darkness, with the landing lights switched on and flaps at zero degrees (normal position). Before this the commander had asked: "are you ready", at which point the first officer addressed the final point of the line-up checklist: "take-off clearance" this was confirmed by the commander with "received". The first officer then reported "line-up checklist completed, ready".

Take-off roll and take-off took place without incident. The gear was retracted by the crew very early and at minimum ground clearance, but in the correct sequence according to procedure.

After take-off and gear retraction, on the commander's instruction the flight director (FD) was switched on, the NAV-mode armed and it was confirmed by both pilots that the long range navigation system 1 was following the course (LRN1 captured). This procedure corresponded to practices for the Crossair Saab 340B fleet. The installed FMS provided navigation on RNAV departures. To this end, the FMS was switched through to the instruments of the flying pilot

(PF). In the present case, in which the commander was acting as PF, the FMS as LRN 1 was used as the primary navigation system.

After the flight director was switched on, it was displayed on the EADI of both pilots. At 16:54:45 UTC the commander instructed: "flight director on", and the first officer acknowledged at 16:54:47 UTC: "flight director on". The FD display is provided in V-bar mode on the Saab 340B. The FD was initially in heading (lateral) and speed (vertical) mode.

After the commander had ordered "arm NAV" at 16:54:48 UTC, the first officer switched the FD to LRN-mode and confirmed this at 16:54:49 UTC: "LRN 1 is captured". This procedure replaced the lateral preset of the heading bug with the more complex output of the FMS. After the switch-over process had been completed, the top left corner of the EADI showed the caption "LRN 1" and confirmed that the FD was processing the steering commands from the FMS. Checking this display, the commander confirmed at 16:54:52 UTC: "LRN 1 ... captured".

The commander (PF) was controlling the aircraft in a stable climb at a pitch of 15° attitude nose up (ANU) and a speed of 136 KIAS. For the entire subsequent phase of the flight, the flight data recording confirms that the autopilot was never engaged. According to the CVR recordings, throughout the remaining phase of the flight the first officer remained in the role of pilot non flying (PNF). Since the cloud base had been indicated as 500 ft AGL, it must be assumed that above approximately 1900 ft AMSL the aircraft reached instrument meteorological conditions (IMC).

Comment: division of labor between commander and first officer

There is a high probability that the use of the autopilot would have been able to prevent the accident, since in the subsequent phase of the flight no extreme attitudes would have occurred. The assistance tasks of the first officer were demanding and required great concentration. The instruments and controls which the first officer had to operate in this context were not in the same field of view as the flight attitude instruments. The division of labor in the take-off phase was always the same at Crossair. In particular, take-off was always undertaken by the commander. Therefore, the first officer had little experience of controlling the aircraft in this take-off phase and of any possible difficulties which might arise in the process. It is conceivable that the first officer of the aircraft involved in the accident was paying little attention to the flight path being flown by the commander and to the attitude.

The commander now executed a so-called vertical synch in the vertical control channel of the FD. Because of the low flying weight and the low outside temperature, the flight speed of 126 KIAS which was set and which had been ascertained prior to take-off led to an excessive pitch of the aircraft. This is limited to 15° ANU. This value now resulted in a speed of 137 KIAS, which was accepted as the new setpoint for the FD by pressing the vertical synch button on the control wheel. This value was displayed in the top right-hand corner of the EADI.

The initial heading of 276° followed the extension of the runway until 16:55:05 UTC, when CRX 498 changed to the DEP frequency. Then the radar track showed a change in course of 5 degrees south, which corresponds with the recorded heading of 271°. This slight heading deviation was reduced before reaching DME 2.1 KLO by initiating a right turn.

Comment:

The investigation has not been able to find any full explanation for the southward drift. The drift was never more than 100 meters from the envisaged flight path and was therefore within the tolerance range for lateral navigation. On the other hand it was established that in comparison with approximately 350 type Saab 340B aircraft departures in January 2000 from runway 28 (under various meteorological conditions) the departure of the accident flight had the most southerly of the recorded flight paths.

The transfer to the departure ATC (DEP) was implemented by the TWR ATC: "Crossair four nine eight, contact departure, adé”. The First officer responded: "departure, Crossair four nine eight, bye", switched the radio to the frequency which had already been pre-selected and commented, inside the cockpit: "calling".

The DEP call took place at 16:55:09 UTC: "Grüezi departure, Crossair four niner eight, crossing two thousand eight hundred now". The ATC’s answer came only 5 seconds later, at 16:55:15 UTC, with clearance to climb to flight level 110. At the same time the commander requested: "aaah ... CTOT/APR off".

This command corresponded to the logical sequence of after take-off procedures. It must have escaped the commander’s attention that at this time ATC had not yet responded to the first officer’s call. So this was the first time on this flight that there was an overlap of tasks which had been induced by the crew.

The first officer now had the task of conducting radiocommunications with DEP and implementing the resulting clearance to climb. He gave this process priority over the task set by the commander of switching off the CTOT/APR, which constituted a relatively complex procedure.

The commander’s modulation when issuing the instruction was also a subject of investigation. From time to time, a sing-song diction accompanied his commands; this was particularly clear in the case of "aaah ... CTOT/APR off" and sounded somewhat strange. Various witnesses stated that the unusual intonation corresponded to the commander’s habits and does not represent any indication of emotional or mental distress. However, after the toxicological findings of the investigation proved that there was a blood level of the drug Phenazepam and therefore, possibly, a general adverse effect, it cannot be excluded that a medication effect might have contributed to the striking intonation.

After reading back the clearance, the first officer set the altitude preselector alerter (APA) to flight level 110 and at 16:55:21 UTC requested: "one one zero, confirm". The commander answered one second later: "checked". This completed this procedure quickly and in full.

At 16:55:22 UTC the commander again requested: "CTOT/APR off". The first officer answered – inside the cockpit and very quietly – "coming", at which point he began the operations.

At virtually the same time this procedure was completed, DEP issued the instruction, at 16:55:39 UTC, to fly left, direct to VOR Zurich East (ZUE): "four nine eight, turn left to Zurich East". Once again, the first officer gave priority to radiocommunications over his other tasks and read back the instruction correctly over the radio at 16:55:41 UTC: "turning left to Zurich East, Crossair four niner eight".

Immediately after reception and confirmation of the turn clearance, the first officer began to reprogram the FMS. This process took place between 16:55:41 UTC and 16:55:45 UTC. It ended with activation of the new routing at 16:55:45 UTC.

At the same moment as the DEP instruction to turn left was received, the aircraft reached waypoint DME 2.1 KLO, the point in standard instrument departure SID ZUE 1Y at which a left turn is made to attain radial 255°, outgoing from VOR KLO. The data recorded by the DFDR confirm that the aircraft did actually turn left for a few seconds, before going over to a right turn.

Analysis of the DFDR data shows that the initiation of the left turn took place with a roll rate of 3°/s. This implies that this maneuver was flown following the FD command, with the latter processing the FMS output parameters corresponding to the original programming of ZUE 1 Y. The left bank began at 16:55:41 UTC and attained a maximum value of 16.9° to the left at 16:55:45 UTC. Then the reprogramming of the FMS became effective.

The programming process took place with a deviation from the Crossair-SOP, which describes a clear assignment of roles. As a result, the command "direct to (DTO) – left – ZUE" was programmed only as "direct to – ZUE".

Comment:

The programming option of the turn direction for a "direct to" instruction is a special feature of the UNS-1K which was installed in the aircraft involved in the accident. In principle, an FMS will take the current position with reference to the next waypoint and the current course as a basis for calculation of the change in direction. Whereas while cruising this change requires only a few degrees to a few tens of degrees, greater angles may be necessary for a change in direction in the aerodrome area during approach and departure. If this change in direction exceeds 180°, the FMS will choose the shorter turn angle to the other side. This is where the "left" or "right" option of the FMS UNS-1K comes into play; it allows a conscious choice of the turn direction and therefore a change in direction of up to 359°.

If this choice is not made (a conscious choice of automatic mode or omission), the system reverts to automatic mode and selects the shortest turn direction.

Comment: use of the flight management system (FMS)

Use of the FMS was inappropriate and took place at a tactically unfavourable moment. When programming the FMS the commander probably did not realize that the "direct to" (DTO) entry had been made without entering the left turn direction. Both pilots were possibly aware that the FMS chooses the shortest path in the case of the non-specific input DTO – ENTER. At this time, however, they were hardly aware that the smaller turn angle from the present position, given the current heading, was to the right.

The programming was performed by the first officer alone, without the prescribed monitoring and checking by the PF. The latter was absorbed in manually flying the aircraft. There is proof that no entry of a "left" instruction was made, so the heading of 271° and a position line to ZUE of 068° resulted in a right turn. The first officer also performed activation of the FMS programming (ENTER), taking the possibility of reading the turn direction to ZUE using the display on the CDU of the FMS.

This first deviation from standard procedures broke the closed loop of instruction – execution – verification. So the error – which did not necessarily have to lead to a dangerous attitude but only to a navigation error – was not able to be detected.

At 16:55:47 UTC the first officer informed the commander, who was flying manually with FD that the LRN 1 system was programmed from the current position to ZUE: "from present, LRN is to Zurich East, yeah", which the commander acknowledged with "checked". The left turn direction instructed by departure control was not mentioned.

Comment:

Since the bank angle to the left reached a maximum value of 16.9° at 16:55:45 UTC and subsequently diminished, changing to a bank angle to the right at 16:55:52 UTC, it may be assumed that the change in direction was caused by a "direct-to"(DTO) entry into the FMS (LRN1). On the basis of the distribution of labor it can be assumed that the first officer activated the programming (ENTER), before he informed the commander of this at 16:55:47 UTC. One peculiarity of the UNS-1K is that it no longer shows the turn direction after this activation.

At this time the aircraft was in a left turn, which the commander was able to confirm from the displays of the attitude instruments. He heard both the ATC and the first officer command and confirm via radio respectively the left turn to ZUE. And on his EHSI he saw the display for the FMS course (magenta-colored navigation needle) turn visibly for about 3 seconds from the current display of 225° counter-clockwise – i.e. to the left – to the new display of 068°. This was possible since the needle was already pointing to the new course of 225°, which was the interception course on the radial KLO 255°. Regardless of the calculations of the FMS relating to a turn direction to the right, the EHSI was receiving only the electrical signal for the new course. From this the resulting turn direction of the needle was across the smaller angle, i.e. counter-clockwise.

Several impressions therefore confirmed the commander in his assumption that the flight would actually continue to follow a left turn. This one-sided perception may have been favored by a reduction in the commander’s capabilities of analysis and critical situational awareness as a result of the previously mentioned effect of the medication.

The right turn resulting from the FMS programming was again commanded by the FD with a moderate roll rate of 3°/s, causing wings level to occur at 16:55:52 UTC. The left-right command change was in no way sudden. It is therefore conceivable that the commander perceived the control deflections to the right as stabilization of the left turn.

Comment:

The spiral stability of this aircraft makes it necessary to stabilize a bank attitude by contrary control deflections, since it would magnify itself if the ailerons were neutral.

At this time the first officer was once more preoccupied in executing the instructions routinely given by the commander (yaw damper on, bleed air on) and in maintaining contact with ground control. All relevant flight parameters in this phase indicate a stable climb, with logical deflections of the controls. The communication which was being conducted internally did not give any indication of difficulties. On the contrary: neither of the two pilots noticed the reversal of the original left turn.

Between 16:55:47 UTC and 16:55:55 UTC the bank angle of the aircraft changed at approximately 3°/s to the right, whilst the pitch remained constant between 13 and 14° ANU. This corresponds to the situation when the right turn commanded by the FD (DTO ZUE) is being flown precisely, as could be verified by several comparison flights. The right bank angle had reached a value of 8.4° at 16:55:55 UTC.

From 16:55:55 UTC to 16:56:00 UTC the angular rate of the bank attitude increased and the nose of the aircraft dropped from 14.2° to 10.8° ANU. The right bank angle had now reached 31.0°. At this point the commander gave the command: "set climb power".

Comment:

The FD issues roll commands up to a bank angle of 27°. When this limit is approached or exceeded, the FD generates an opposite roll command. At 16:56:00 UTC the latter therefore indicated a left roll command and a climb command.

By means of corresponding control deflections, the right bank angle was finally stabilized for seven seconds (16:56:03 UTC to 16:56:10 UTC) in the range between 39 and 42°. The pitch, however, continued to reduce, since no corresponding elevator deflections were made to compensate for the loss of lift due to the high bank angle. It stabilized briefly at 16:56:06 UTC by means of corresponding elevator deflections and for four seconds remained at approximately 1° ANU. As a result, the aircraft reached the maximum altitude attained by the accident flight of 4720 ft AMSL. The air speed had increased from 139 KIAS to 158 KIAS. According to a statement from the crew of the preceding flight SR014, the cloud top at this time was approximately 5000 ft AMSL.

At this point too, there was no communication inside the cockpit which would indicate in any way that one of the two pilots had identified the flight path or attitude as incorrect. For the first officer too, no apparent suspicion of a subtle incapacitation in the commander’s flying capability was manifest. Rather, by his routine command to "set climb power”, the commander seemed to indicate that the flight was progressing normally. The instruction was in turn confirmed by the first officer with "coming". Setting climb power directed the first officer’s attention to the central area of the cockpit with the levers on the centre pedestal and the engine displays in the centre instrument panel. His visual focus was therefore relatively far away from the attitude instruments, which he could, however, have seen in the corner of his eye. The display on the MFD was easier to see (cf. Annex 5).

The interval of nine seconds between 16:56:10 UTC and 16:56:19 UTC was characterised by a further attitude destabilisation attributable to uncoordinated left/right aileron deflections. The aircraft behaved aerodynamically in accordance with the deflections of the controls. The rightward deflections were predominant and as a result the bank angle to the right increased from 42 to 80°. Since the elevator was practically in the neutral position during this time frame, as a result of the large bank angle the pitch increased to 25° AND. The aircraft quickly lost altitude and the speed increased to 207 KIAS.

Now the indications of the attitude displays changed clearly. The FD showed a climb command in the upper limit stop (6° above the aircraft symbol) and a roll command in the left limit stop (15° inclination to the left), whilst the horizon line (dividing line between brown and blue) was positioned inclined in the top left third of the EADI. At the same time, the compass card on the EHSI and MFD was turning with an average of 5°/s counter-clockwise. On the EHSI the heading bug set to 276° turned with the compass card.

Comment: interpretation of the displays

The instrumentation of the aircraft involved in the accident did indeed correspond to the western standard and was widespread. Nonetheless, it must be noted that the attitude and navigation instruments were not ideally suited to interpreting extraordinary attitudes and provided little help in the early detection and prevention of an unfavourable development. Nor were any hints of a solution provided by the system.

The EADI display was now already difficult to interpret. The combined representation of two parameters (bank attitude and pitch) made it essential to perform mental extrication. This applies especially in comparison with the Russian-type horizon with a decoupled representation where attitude and pitch can always be read independently of each other. The bank angle was shown in the angle of the horizon line (blue-brown dividing line) of the EADI compared with the instrument case. With the dominant display of the brown element and the slipping of the horizon line to the top left corner, this became increasingly difficult. The sky pointer had exceeded the scaling limit at 60^{o} bank angle. The pitch display was now no longer represented as the position of the horizon line in vertical reference to the neutral line of the instrument. With vertical bank, for instance, a change in pitch caused a lateral movement of the horizon line.

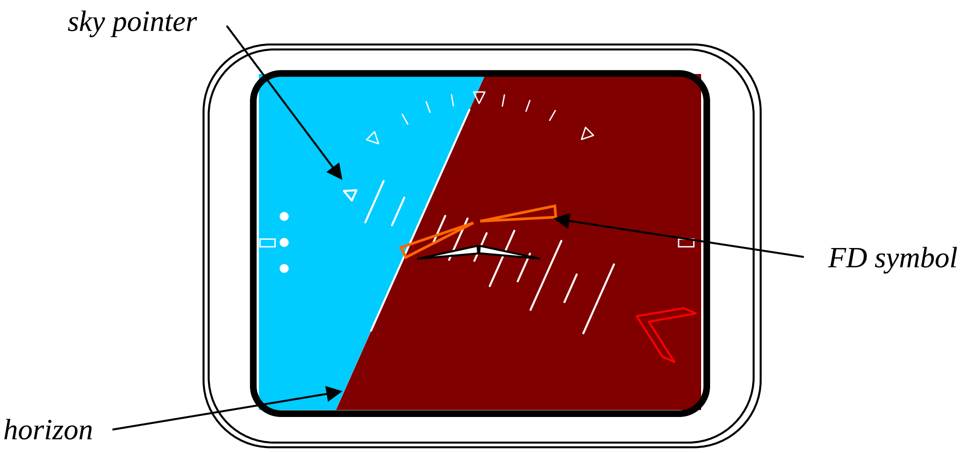


Illustration: representation of the EADI with FD symbol for a right bank angle of 65° and a pitch of 15° AND

It is conceivable that in this period the commander's confusion about the current attitude dominated his perceptions and that he was having trouble interpreting the EADI display at all and reconciling it with his mental picture of flight path and attitude. Once again, an enhanced effect due to the medication cannot be excluded.

Comment: resorting to models learned earlier (heuristics)

The commander's growing confusion led him to resort to problem-solving models learned at an earlier time. The confusion over attitude and the corrections to be applied was reinforced by the fact that the commander had been trained on Russian instruments and that as a result he may have retrieved and applied a reaction pattern from that period. It must be added that he had had no opportunity to be trained in any other pattern of behavior.

This mental recourse to problem-solving models learned previously (heuristics) offered the commander the following interpretations in this situation:

- The dominant brown coloration of the EADI display gave him a clear indication of an attitude nose down (AND) pitch. However, at this time, because of the increasing fixation on the bank attitude problem, he was probably no longer able to perceive this.
- The bank angle is judged on Russian-type horizons with the aid of the position of the aircraft symbol (model) and read off at the tip of the lower, inner wing on a scale with a gradation on the outer ring of the instrument housing. Here, two possible displays offered themselves: on the one hand the magenta-colored FD symbol, which was shown on the display with a 15o bank to the left, and on the other hand the horizon, also with a visually dominant and increasing slope to the left.
- In addition, the heading bug in the EHSI was moving counter-clockwise at about 5°/s, which seems to admit the possibility of confusion with the heading indicator in a Russian compass. The latter would also indicate a left turn by a counter-clockwise rotation.

This might explain the continuing mental confirmation of the assumption of a continuing left turn.

At the beginning of this interval, 16:56:11.7 UTC, the first officer made the commander aware that he should turn left to ZUE: "left, we should left". This intervention corresponded to his perception of the right-turning aircraft, provided by the MFD which was within his field of view. At this time this represented a compass rose, which was turning counter-clockwise. With this perception, the first officer did in fact have the possibility of noticing the incorrect turn direction, but not its cause in the incorrect programming of the FMS. Likewise, he had no direct indication of the extreme attitude and no reason to make such an assumption. Nor did the commander give any indication of the cumulative difficulties, and acceleration (g-forces) in all three axes remained below the threshold of perception.

At 16:56:14.6 UTC, at a right bank angle of 65.8°, the commander mumbled to himself: "Oh... na, na". This expression occurred at a bank attitude at which all data in the EADI, except the attitude reference, were retracted from view (declutter mode). This changed the EADI display in a clearly visible fashion, and probably into a form which neither the commander nor the first officer had ever seen before.

This provided a trigger for both pilots, but particularly for the first officer, to perceive the unusual attitude.

Three seconds later, i.e. in a phase of perception and interpretation by the first officer, DEP wanted confirmation that the aircraft was turning left. The first officer again gave first priority to radiocommunications and answered: "moment please, standby", at which point DEP instructed the crew at 16:56:21 UTC to continue the right turn. The composure of the first officer's response, however, did not necessarily correspond to his emotional state. He was already in a stress situation, had been entrusted with various tasks (setting climb power, radiocommunications, navigation problems) and was confronted with the extreme display on the attitude instruments. The task here was also extraordinarily difficult for the first officer, since this situation found him unprepared. It was also contrary to the calm cockpit atmosphere which was characterised by routine work. The first officer's audibly heavy breathing in this phase is a further indication of the stress situation described.

Comment: Reaction time

Reaction to a completely unexpected change in the situation, or to a development which is diametrically opposed to expectations is complex and requires considerably more time than a simple, reflex-type reaction. The type of reaction is additionally highly dependent on factors such as personality, upbringing, climate in the vicinity of the event, etc. The first officer began to breathe more deeply and more quickly 5 seconds after perceiving and expressing the incorrect turn direction; this indicates he was getting to grips with solving the problem and possibly points to an anxiety reaction. Only after an interruption by communication, normally prioritized by him, with ATC was he able - 12 seconds after the realization – to deal with the problem once more. His reaction followed his temperament and his personality structure, initially verbally, and then possibly also physically. The last possibility of saving the aircraft, however, had already passed by this time.

In the final phase of the accident flight, which lasted only 8 seconds longer, the aircraft went into a steep spiral dive. As a result of massive aileron deflections, the aircraft reached a maximum bank angle of 137° and, at the end of the data recording, still had a bank angle of 76° to the right. The engines were still supplying high power. The nose of the aircraft was dropping until the end of the recording (16:56:25 UTC), to 63° AND, at an airspeed of 285 KIAS. At 250 KIAS the over speed warning horn sounded. At 16:56:23.8 the first officer very forcibly again informed that commander that he should turn left ("turning left, left, left, left **... left**").

Comment: Communication

Crew communication was restricted to a minimum throughout the entire observable phase. This fact, together with the information from the biography of the pilots, make it possible to conclude that there was an atmosphere in which little spontaneous communication was possible. The two pilots were able to converse only in a foreign language, English, and in addition this language was full of the highly standardized expressions of technical aviation. It must remain open whether this circumstance left any space at all for spontaneous communication. It must be stated that under such conditions a spontaneous reaction to an unexpected perception, such as an exclamation or an expletive, would tend to remain suppressed. A common linguistic pattern appropriate to this abnormal attitude – such as that for the communication of technical failures, for example – was obviously not available to the crew.

At this time, the first officer had probably understood the situation and correctly interpreted the attitude, whilst the commander was in fact causing erratic aileron deflections but no longer had the attitude under control. It must be assumed that his confusion about the actual flight situation continued up to impact. From 16:56:20 UTC it was too late for any successful intervention by the first officer, since recovery was no longer possible because of the low altitude (engineering analysis).

At 16:56:27.2 UTC the aircraft crashed in an open field near Au, Nassenwil, ZH (coordinates: 677 850 / 258 200).

2.3.2 Division of tasks

An overview was produced to visualize the working sequences and communication cycles (cf. Annex 1). The objective was to establish the phases of absorption of the pilots' attention and furthermore to find out the extent to which the procedures for two-man operation and the closed loop procedures in the cockpit were able to be complied with, i.e. the extent to which the sequences of action in the cockpit were synchronous and undisturbed.

This sequence of events shows that in the critical phase of the flight (from 16:55:39 UTC) the commander was exclusively occupied with flying the aircraft manually and with the instructions according to SOP. The first officer was more than fully occupied with the effort of implementing these instructions and with radiocommunications.

2.3.3 Analysis of actions

The analysis of the chronological sequences showed that the main burden of work during the brief flight phase was on the first officer. This is illustrated by the fact that throughout the duration of the flight (take-off to impact) of 1 minute and 54 seconds the first officer was able to concentrate on monitoring the attitude only for a total of 10 seconds, at the beginning of the climb. Throughout the remainder of the flight he was constantly occupied with manipulations or with radiocommunications.

The first officer was noted for the exaggerated precision in his piloting behavior, which often reduced his speed (a video recording from the time of conversion additionally documents this behavior). He attempted to compensate for this circumstance by reacting promptly to instructions and commands. The in some cases extremely short reaction time of the first officer is surprising and allows the assumption that he was often ready to implement the instruction by anticipating it. This also includes a certain physical readiness: in each case he seemed to have his hand at the location of the next action. In communications, the first officer was precise and in conformity with procedures.

His rapid reaction to instructions and commands becomes particularly visible in his swift responses to radiocommunications. In this context, it is possible to recognize the stamp of his earlier employment with Tatra Air. Documents are available from that time which address this problem during training (initial line introduction). The first officer was explicitly requested several times in the debriefings to answer all radio messages immediately and carry out ATC instructions straight away. He was repeatedly required to work more quickly.

This prioritization of radiocommunications is apparent several times and may be described as typical of him. Prioritization of radio communications above all other activities by the first officer had consequences on two critical occasions:

At 16:55:39 UTC, practically simultaneously with the conclusion of the CTOT/APR off procedure, DEP gave clearance to turn to the left for VOR ZUE. Instead of giving the completion message (CTOT/APR off) to the commander, thereby establishing the closed loop, the first officer interrupted the almost complete sequence of actions to acknowledge the ATC request. As a consequence he assumed a new task (programming the FMS), on his own initiative and as a deviation from the standard procedure, which he again carried out in a great hurry. The CVR shows that the FMS programming by the first officer took place without a request from the commander and was already activated when the commander was informed of this by the first officer. This took place with a lack of precision: "from present, LRN is to Zurich East, yeah”, and this was acknowledged by the commander with "checked”. Thus this important error (incorrect programming of the FMS) made by the pilot during the flight remained undetected.

The first officer gave priority to radio communications a second time at 16:56:17 UTC when DEP queried:" .. confirm you are turning left". After the first officer had already tried, at 16:56:11 UTC, to exercise a correcting influence ("turning left to Zurich east, we should left") and was aware that the flight path at least, and at worst the attitude, were not correct, he interrupted his attempt at analysis and correction to carry out radio communications.

Throughout the duration of the flight the commander was occupied exclusively with manually controlling the aircraft and issuing instructions to the first officer. From this it can be assumed that the issue of commands was complemented to a certain extent by monitoring, especially when the first officer reported completion of an operation. At approximately 16:55:00 UTC – during a period of low workload – the commander could have switched on the fully functional autopilot. The fact that under the difficult operational conditions (night-time, low cloud, risk of icing, etc.) he chose manual flying made his task even more difficult. One limiting factor in this context is that at the time of the accident there were no mandatory regulations and that the use of the autopilot was considered as a piloting weakness in the commander’s previous environment.

The analysis of the CVR recordings gives the impression that the after take-off procedures were carried out by the crew with a high degree of routine. However, there also seems to have been a definite lack of critical attention (complacency). A degree of haste is peculiar to the sequences of actions, and this is expressed in clear form in the gear up procedure. The gear was retracted immediately after rotation and only a few feet above the runway. At this time, therefore, there was already a not insignificant danger to the flight, which was, remarkably, carried out as a formally exactly applied two-man procedure. The first officer’s report "positive rate, gear in transit" therefore performed the function of an alibi, since at this time neither the radio altimeter nor the variometer could have indicated a climb.

2.3.4 Error management

One essential goal of two-man operation applying CRM principles is appropriate error management. This includes vigilance, the detection and analysis of errors and appropriate correction.

The work of the two pilots of the accident flight is characterised by certain contrasts. Segments of great vigilance and attentiveness are to be found, in which the first officer in particular stands out. One example would be his behavior after engine start-up.

On the other hand, it is possible to discern segments during which the possibility of the pilots’ own errors is not taken into consideration. An example of this is the programming of the FMS.

Although for the major part of the operation formally correct communication, i.e. in conformity with procedures, was conducted, this broke down in the case of error management.

The commander was not able to express his uncertainty about the flight path and attitude. What this circumstance is attributable to must remain an open question. However, it can be stated that the commander did not possess pronounced communication abilities. In his attitude towards his job he was strongly influenced by his professional career in the FSU, which had assured him a great difference in authority between commander and other crew members. This fact probably made it difficult for him to admit to uncertainty or mistakes.

At the same time it is known that the commander was restricted in his powers of expression. English alone was available to the two pilots as a common language. The first officer’s knowledge was superior to that of the commander, though not perfect. The commander was sufficiently fluent in aviation English to meet the requirements of normal operation. However, differentiated communication with subliminal content was hardly possible for him. This is shown, for example, by the fact that for the entire duration of the CVR recording all the crew’s utterances were limited strictly to the professional environment.

The pilots had some 20 seconds to detect the error. During this phase the first officer managed to recognize that the turn direction was incorrect. The extreme attitude was recognized only at the end.

Practically no attempt at error correction was made within the framework of coordinated two-man operation. The commander remained firm in his error analysis and attempted to reach a result empirically. The first officer too had made insufficient progress in his analysis. He had only the two following means to make a correction:

- The verbal intervention had no result, since it referred only to one part of the problem (incorrect turn direction) and on the other hand triggered no reaction from the commander, for reasons which are not known.
- Initially, there was apparently no cause for manual intervention by taking over the controls on the part of the first officer. At a later point (after 16:56:22 UTC) there may have been a manual intervention, but without any effect on the further progression of the accident flight.
- At 16:56:17 UTC, a massive intervention by the co-pilot, accompanied by taking over control, would have been the last opportunity in the sequence of events to make a successful recovery.

2.3.5 Crew resource management (CRM)

It must first be noted that neither the commander nor the first officer had undergone extensive training in crew resource management (CRM). At the time they were taken on by Crossair such training according to JAR-OPS 1 would have consisted of a multi crew concept (MCC) course and an initial CRM course.

Conversion to JAR-OPS 1 and JAR-FCL 1 was accompanied by the formal application of CRM training requirements. The transition period, however, permitted the recognition of experience already acquired in multi crew cockpits as a substitute for MCC training.

- In both sections of the training the pilots would have become acquainted with sources of errors and error scenarios and with techniques for prevention, detection and correction. In addition, they would have been able to firm up these techniques in practical (simulator) exercises.

The standard conversion programs at Crossair included integrated CRM elements, for which a basic knowledge on the part of the pilot candidates was a prerequisite. In the case of the pilots of the accident flight it was unfortunate that they had already acquired the patterns of their individual CRM behavior before their employment with Crossair, and that it particularly in the case of the commander this was not congruent with western principles of CRM. It is to be assumed that the nature and scope of these pre-existing patterns was not known to Crossair.

During the accident flight, both pilots tried to apply the CRM elements conveyed by Crossair. This was expressed essentially by the fact that the crew complied more than precisely with some of the communication rules and the prescribed cockpit procedures, and this gave the impression of a sterile cockpit atmosphere.

The most serious departure from procedures, which mutual monitoring and subsequent detection of any errors are intended to prevent, took place in the case of the programming of the FMS. The first officer made entries into the FMS without involving the commander.

The commander did not intervene, nor did he try afterwards to critically assess and complete the first officer's FMS programming.

The crew were not under any time pressure to change the FMS programming as a result of the shortening of the flight path. The ATC's communication was relaxed and in no way indicated any need for urgency. The clearance to continue the right turn given shortly before the crash, moreover, indicates the flexibility with which the ATC was able to handle flight CRX 498.

The FMS programming was considered implicitly by both pilots as having been completed (first officer: "from present LRN is to ZUE, yeah.." commander: "checked"). The first officer continued to assume that he had programmed the FMS correctly. By perceiving the turn direction on the course indicator in the EHSI, the commander might simultaneously have got the impression that the FMS had been programmed for the instructed flight path.

In the subsequent phase of the commander's uncertainty about flight path and attitude, two-man operation broke down. Whilst outwardly a normal flight sequence with application of the after take-off procedures was being implemented, both communication and reciprocal monitoring were lacking. The elements which were striking even during normal operation, namely superficial communication with learned commands and the great haste to implement procedures, make the pilots' work appear formally correct and controlled, whilst at the same time the attitude was becoming increasingly out of control.

2.3.6 Cockpit configuration

2.3.6.1 Ergonomics

It was established which attitude instruments were located in the first officer's central field of vision while he was performing specific operations (cf. Annex 5). This investigation was motivated by the question of why the first officer, at 16:56:11.7 UTC made a statement about the flight path ("left, we should left"), even though the extreme bank attitude and pitch would in fact have required an intervention referring to the attitude.

As a result of this investigation, statements by several pilots were confirmed, to the effect that especially during operations on the engines (power setting, CTOT/APR off) it would no longer be possible to observe the attitude instruments at the same time. One first officer stated, in the framework of comparison flights, that during these operations he preferred to look over at the commander's instruments in order to monitor the attitude.

At the same time it was possible to establish that during power setting the MFD was within the first officer's central field of vision. The MFD admittedly does not provide any attitude information. However, at least in rose mode it is possible to read off the flight direction and turn direction from the compass rose in the MFD display. This would explain the content of the first officer's statement ("left, we should left").

2.3.6.2 Control and control forces

The light control behavior of the Saab 340B is striking in comparison with that of Russian aircraft, in particular the AN-24. If one assumes that the commander's behavior was formed by aircraft with relatively heavy controls, it is conceivable that in dangerous situations the pilot would revert to this pattern and inadvertently perform more powerful control movements.

On this assumption it is also conceivable that the commander had not perceived the greater control forces which were caused by an unusual attitude, and in particular by a bank angle of more than 30°, as an alarm signal.

During the initial phase of the flight, the commander was conspicuously calm and precise in operating the controls – even in comparison with other pilots on comparison flights. Yet his control inputs in the final phase of the flight became increasingly hectic, less precise and more sweeping. Similar features in operating the controls have been described by Russian instructors as typical of pilots who are no longer able to interpret attitude clearly. In each case they tried, sometimes by instinctive trial and error, to find a solution to the problem. The control movements were used by instructors as an indicator of incipient disorientation when assessing pilots' performance.

This crew behavior was described in the FSU as well known and occurs particularly in the conversion of Russian pilots to aircraft with a western horizon (TU-154, IL-86, B-737, A-310, etc.). It can be assumed that Russian pilots who have undergone such retraining experienced at least slight forms of disorientation in the simulator. Since this problematic is known in the FSU, this experience may have led to raising awareness and hence to increasing vigilance with regard to this phenomenon. The Aeroflot airline has taken this process much further and also catalogued other problems of making the transition from an eastern to a western cockpit. Since the commander's conversion took place in a western environment (Crossair, Basle) and without knowledge of these problems, the commander did not have any opportunity of consciously dealing with the potential danger of disorientation.

2.3.6.3 Electronic instrument displays

The imitation of conventional electro-mechanical flight instruments using CRTs and combining the representation in conventional display instruments (e.g. altimeter) and on screens (e.g. HSI display on the EHSI) proved to be confusing in the accident flight's situation. We are dealing here with the course pointer on the EHSI turning from the 225° position to a 68° position, which clearly took place in a counter-clockwise direction. As mentioned above, this display may have reinforced the commander's impression that the aircraft was making a left turn to VOR ZUE.

2.3.6.4 Flight director

The flight director (FD) commands were not recorded by the DFDR. Consequently, the display was imitated in a simulation for the entire phase of the flight. If the EADI with activated FD on the Saab 340B is compared with the artificial horizon of an AN-24, a certain potential for confusion exists.

When controlling the aircraft, the commander followed the FD display until 16:55:55 UTC and a right bank angle of 8.4°. From that time the FD display began to slope to the left, since the angular speed around the longitudinal axis (roll rate) began to increase to more than 3°/s.

It is to be assumed that in the subsequent period, until approximately 16:56:03 UTC, the commander's confusion about the precise attitude and flight path began to set in. It suggests itself that an – at least temporary – misinterpretation of the FD display as an attitude display, by analogy with the aircraft symbol in the Russian horizon, occurred. The FD was then stably inclined at 15° left on the centre line of the ADI. With the subsequent drop of the nose of the aircraft, the FD display rose to a position 6° above the centre line. The FD was therefore visibly dominant in the centre of the EADI.

2.3.7 Cockpit procedures

2.3.7.1 General

It is worthy of note that during the take-off and climb phase of the Saab 340B a number of complex operations are necessary. These are, in particular, the CTOT/APR off procedure and setting the climb power.

The doctrine that only commanders were allowed to perform take-offs on the Saab 340B was possibly a consequence of this complexity and the rather low power reserves of the aircraft. This prescribed allocation of roles leads to the fact that the first officer's inhibition threshold for intervening during the take-off and climb phase is higher, since he is not used to carrying out this procedure himself.

In the present case, the inhibition threshold was probably raised even higher than usual as a result of the personalities of the two pilots involved in the accident.

Crossair had structured the procedures for the two-man cockpit consistently, for the most part, in particular as a way of implementing the philosophy that any commander must be able to constitute a functioning crew with any first officer.

2.3.7.2 Unusual attitudes

During Crossair pilot training, unusual attitudes training elements were practiced; these confronted the pilots with unusual attitudes. In this training, reactions were taught which led to active correction of these attitudes. In contradistinction to other unusual situations, the two-man cockpit procedures were not defined or only vaguely defined for this eventuality.

An aborted take-off, for example, is defined and practiced as a two-man operation; both pilots have clear rules of communication (wording) and action. The same applies to the go around maneuver. In the event of detection of an unusual attitude, however, no pattern of behavior and no defined and practiced communications procedure was laid down for the pilot non flying (PNF). There was indeed the convention that the PNF had to intervene, but this intervention was not described. In any case, only the pattern of action for crew member incapacitation would have been applicable. For this to happen in the case of the accident flight, however, the commander's behavior would have had to be interpreted by the first officer as a partial incapacitation.

The first officer had not been trained for a command or sequence of actions which was appropriate to the situation. It should be pointed out in this context that he was surprised by the unusual attitude and he had to overcome not only the inhibition due to the difference in authority in the cockpit but also a degree of incredulity.

The Russian flight procedures defined a clear procedure in the event of an unusual attitude (cf. Chapter 1.16.5.3). This procedure had been practiced several times by the commander in the course of his piloting career. It may therefore be assumed that not only did the first officer have difficulty in formulating his warning and intervening appropriately, but also the verbal intervention which was made by the first officer was only partially comprehensible to the commander. The commander was equipped for the present case with a different pattern of actions. In an extreme attitude situation he would have been entitled to expect the first officer to take over control. The latter, however, was occupied with other activities in addition to his monitoring function. In other words, the first officer's inactivity gave the commander a further reason for not perceiving the attitude as unusual.

2.3.8 Air traffic services

The workstations in the TWR/APP were occupied according to the duty roster at the time of the accident.

For the air traffic controllers in TWR/APP, handling flight CRX 498 was a routine, everyday process, with no irregularities.

After the changeover to DEP, a change in the departure clearance took place. Such reclearances are part of everyday aviation life and must be mastered by any crew of a commercial aircraft.

In the present case, the time at which the departure clearance was changed was a triggering factor in the accident. The air traffic controller intervened when he realized that CRX 498 turned to the right. It was, however, without result, since the pilot was otherwise occupied at this point in time; he also expressed this by saying "Moment please, stand by".

The DEP ATC showed himself to be flexible and offered the crew of CRX 498 a continuation of the right turn after he had established that the aircraft was not turning left as per instructions and that the continuation of the right turn was compatible with the traffic situation.

3 Conclusions

3.1 Findings

- There are no indications of a fire on board the aircraft before the crash.
- During the flights immediately preceding the accident flight (3 sectors) no technical complaints were entered in the technical log.
- The limits on crew duty time were complied with.
- The flight crew had been working together for four days prior to the day of the accident.
- The accident flight was the ninth flight which the two pilots had undertaken together.
- The aircraft was not de-iced before the accident flight.
- All attitude changes during climb and in the subsequent accident phase resulted exclusively from the control commands of the flight crew.
- No substantial turbulence occurred during the flight.
- There are no indications of icing.
- The flight management system (FMS) was retrofitted, correctly. It meets the requirements for B-RNAV operation.
- The correct navigation database (NDB) was installed on the accident flight.
- The GPS constellation at the time of the accident was adequate for determining the position. In addition, the VOR/DME navigation systems KLO and ZUE were available.
- The flight director was switched on and working up to impact in IAS and NAV (LRN) mode.
- A system for bank warning was not present and not prescribed on the aircraft involved in the accident.
- There are no indications that aircraft systems were negatively affected by electromagnetic interference (EMI).
- There are no indications of a fault in the communications equipment.
- The CVR and DFDR data could be analyzed.
- The displays on the mechanical instruments at the time of the crash were within the range of the data which the DFDR last recorded.
- The recorded DFDR data on the accident flight correlated in all phases with those of the comparison flights.
- Crossair owned a flight simulator for the Saab 340B and two FMS trainers.

- The flight simulator was last certificated to JAR STD 1A, Level CG. The last recertification took place on 31.08.1999.
- No FMS was installed in the flight simulator.
- During its use at Crossair, the flight simulator met the FAA/JAR requirements.
- The periodic checks (scheduled maintenance) prescribed by the aircraft manufacturer and the authorities were carried out within the specified intervals.
- The unscheduled maintenance was carried out in accordance with the regulations.
- The reliability program applied by Crossair for monitoring aircraft and systems corresponded to the industry standard.
- The deficiencies established with regard to maintenance records, procedures and quality had no effect on the accident.
- There is no indication that the airworthiness of aircraft HB-AKK was adversely affected at the time of the accident or that technical defects or malfunctions made any contribution to the accident.
- At 16:55:39 UTC, ATC changed the departure clearance (SID ZUE 1Y) by instructing a left turn direct to VOR ZUE.
- The commander dispensed with use of the autopilot under instrument flight conditions and during the work-intensive climb phase of the flight.
- According to the CVR recordings, the first officer made an entry in the FMS, without being instructed to do so by the commander, relating to the change to SID ZUE 1Y.
- From the analysis of the progress of the flight it is apparent that the first officer programmed the FMS without selecting a turn direction.
- According to the CVR recordings the flight crew set inappropriate priorities for their tasks after the change to SID ZUE 1Y.
- The commander had many years of experience on aircraft with instrumentation complying with the Russian standard.
- The CVR recordings indicate a one-sided distribution of labor with heavy strain on the first officer and a limitation of his monitoring function.
- In the commander's crew bag an opened pack of the Russian medication Phenazepam (psychopharmacon) was found.
- In the muscle tissue of the commander there was a concentration of 7 – 8 ng/g of Phenazepam.
- For several years the commander flew an aircraft (AN 24) which was operated according to the multi-crew concept of the former Soviet Union.
- The commander had been employed for about two years on the aircraft type Saab 340B in the operational environment of the FSU and had accumulated over1600 hours of flying experience on this type up to the commencement of his activity with Crossair.

- The personnel documents indicate that the commander tended to be calm, introverted, conflict-avoiding and not enquiring.
- The personnel documents indicate that the first officer tended to be zealous, obedient, loyal, conflict-avoiding, with little propensity to intervene.
- The flight crew had only one common language (English).
- The flight crew did not consistently apply the principles of crew resource management (CRM).
- The commander’s knowledge of English included a functional vocabulary of the lower intermediate stage, allowing him to take part in simple conversations.
- The first officer’s knowledge of English was assessed by Crossair employees as good.
- The commander was leased by Crossair as a direct entry commander.
- On recruiting direct entry commanders Crossair did not make use of assessment instruments.
- Documentation on inspections of Crossair by the FOCA sections responsible for these is not available.

3.2 Causes

The accident is attributable to a collision with the ground, after the flight crew had lost control of the aircraft for the following reasons:

- The flight crew reacted inappropriately to the change in departure clearance SID ZUE 1Y by ATC.
- The co-pilot made an entry in the FMS, without being instructed to do so by the commander, which related to the change to the SID ZUE 1 standard instrument departure. In doing so, he omitted to select a turn direction.
- The commander dispensed with use of the autopilot under instrument flight conditions and during the work-intensive climb phase of the flight.
- The commander took the aircraft into a spiral dive to the right because, with a probability bordering on certainty, he had lost spatial orientation.
- The first officer took only inadequate measures to prevent or recover from the spiral dive.

The following factors may have contributed to the accident:

- The commander remained unilaterally firm in perceptions which suggested a left turn direction to him.
- When interpreting the attitude display instruments under stress, the commander resorted to a reaction pattern (heuristics) which he had learned earlier.
- The commander’s capacity for analysis and critical assessment of the situation were possibly limited as a result of the effects of medication.
- After the change to standard instrument departure SID ZUE 1Y the crew set inappropriate priorities for their tasks and their concentration remained one-sided.
- The commander was not systematically acquainted by Crossair with the specific features of western systems and cockpit procedures.

4 Safety recommendations and safety actions taken

4.1 Safety recommendations relating to technical and operational aspects

4.1.1 Operation of the flight management systems (FMS)

4.1.1.1 Safety deficiency

When the direct to function (DTO) is used in auto mode without selecting a turn direction, the Universal UNS-1K FMS on the Saab 340B chooses the smaller angle for the turn. In most cases, e.g. during cruising, this automatic function causes no problems, since the next waypoint is reached via only a small change in heading. However, if the DTO function is used without explicitly entering a turn direction in a terminal control area (TMA), in which turns with large angles are typically performed, there is the possibility that this will not result in the turn direction instructed by ATC.

4.1.1.2 Findings

The flight crew deviated from the standard instrument departure (SID) after passing waypoint DME 2.1 KLO by flying a right turn instead of the instructed left turn to VOR ZUE. This would be consistent with a control command from the flight director, which would have been generated by the FMS after the entry “DTO ZUE” without the explicit choice of a turn direction.

4.1.1.3 Analysis

The procedures for the FMS on the Crossair Saab 340B do not prescribe the mandatory input of the turn direction instructed by ATC. A DTO entry by the crew without the explicit choice of a turn direction may lead to a conflict arising between the indication of the flight director and the turn direction expected by the crew. This circumstance may lead to a serious adverse effect on the crew’s situational awareness.

4.1.1.4 Safety recommendation

The procedures for programming the Universal UNS-1K FMS on the Crossair Saab 340B should be complemented as follows:

If ATC gives clearance for a course direct to a waypoint together with a prescribed turn direction, the “DTO” entry **must** be made together with the instructed turn direction (LEFT, RIGHT). This applies even when the change in course is obviously less than 180°. Maintenance of the qualification to use the FMS should be ensured by appropriate measures (e.g. simulator or other training equipment).

4.1.1.5 Opinion of the Federal Office for Civil Aviation (FOCA) (*Bundesamt für Zivilluftfahrt* – BAZL)

“Specified description, that a “direct to xxx” instruction associated with turn direction, e.g. “turn left direct to Zurich East” **must always be entered** in the FMS with p**referential direction** (regardless of whether the pilots anticipate that the Flight Guidance System will turn, in view of the shortest path, anyway to the correct side…).

This procedure description was taken up not only in the PIH (Pilot Information Handbook), but was also communicated in the fleet management’s Flight Ops News. (bold type in original)”

4.1.2 Procedure for programming the flight management system (FMS)

4.1.2.1 Safety deficiency

During programming of the FMS there is a danger that the pilot non-flying (PNF) will not be able to perform his monitoring function to the fullest extent. The pilot flying, in the other hand, may, whilst checking the entries made by the PNF, be diverted from scanning the flight instruments. The movement of the head necessary to do this may, furthermore, have an unfavourable effect on the PF's capacity for orientation.

4.1.2.2 Findings

After the ATC instruction "turn left to Zurich East" the commander issued no command to enter this instruction into the FMS. Independently of this, the co-pilot performed a reprogramming of the FMS and informed the commander. The commander then flew the aircraft into a right turn, which finally ended in a spiral dive.

4.1.2.3 Analysis

The position of the FMS CDU on the centre pedestal is less than optimal from an ergonomic viewpoint. In particular, the programming operation demands a distinct movement of the head away from the flight instruments towards the FMS CDU.

The design of the EFIS in the Saab 340B does not allow a reprogrammed flight path to be checked before it is activated. This check must therefore be carried out by the PF on the CDU.

4.1.2.4 Safety recommendation

On the Saab 340B, the autopilot should be switched on before any in-flight programming operation on the FMS .

4.1.2.5 Opinion of the Federal Office for Civil Aviation

The FOCA commented on this safety recommendation together with the following safety recommendation (cf. 4.1.3.5).

4.1.3 Use of the autopilot

4.1.3.1 Safety deficiency

During flight under IMC, above all at night and when changes to the departure clearance are to be expected, situations may occur in which the crew's ability to monitor the flight instruments is restricted. These phases of highly intensive work may lead to critical situations if the available aids such as the autopilot, for example, are not used.

4.1.3.2 Findings

Under instrument meteorological conditions (IMC) and during the labor-intensive climb phase of the flight, the commander refrained from using the autopilot.

Crossair's flight procedures did not prescribe the mandatory use of the autopilot during flight under IMC or in darkness.

4.1.3.3 Analysis

Use of the autopilot under IMC and at night would provide adequate protection from the loss of a controlled attitude.

4.1.3.4 Safety recommendation

Use of the autopilot should be recommended for all flight phases. In particular, use of the autopilot on departure under instrument meteorological conditions (IMC) and during phases with a high workload or in airspace with dense traffic should be prescribed.

4.1.3.5 Opinion of the Federal Office for Civil Aviation

"Generally classified definition concerning use of the autopilot in connection with FMS. This in the direction proposed by the BFU, that the autopilot is always switched on when the FMS is being used for navigation as the primary source, or when operating in flight phases with a high workload or dense traffic (SIDs and STARs).

This had led to changes in the OM-A (Operations Manual) and in the PIH. In addition, this problematic was also explained in detail to Saab 340 crews in Flight Ops News. In order to maintain a comprehensive fleet policy, no special treatment of the 340 has been introduced with regard to IMC/VMC; this concept of use applies to all fleets in IMC and VMC."

4.1.4 Harmonization of departure procedures with Saab 340B operating procedures

4.1.4.1 Safety deficiency

The standard instrument departure valid at the time of the accident, SID ZUE 1Y in Zurich, with a change to the departure clearance in the initial climb (turn left to ZUE), is not easy to harmonize with the operating procedures for the Saab 340B.

4.1.4.2 Findings

The flight crew of CRX 498 were instructed by DEP to turn left to VOR ZUE when the aircraft reached waypoint DME 2.1 KLO. In this phase of the climb, the workload was comparatively high.

The ATC instruction was implemented by reprogramming the FMS, which led to an additional workload.

4.1.4.3 Analysis

The current ATC practice of changing the departure clearance shortly after take-off generates an increased workload for flight crews.

Depending on the type of flight, reprogramming the FMS after an instructed deviation from a standard instrument departure (SID) constitutes a difficulty for the flight crew which must be taken into account. The objective of SID changes is to increase the capacity of an aerodrome, reduce delays and optimize procedures – this is also in the interests of the operators.

4.1.4.4 Safety recommendation

In order to ensure that the departure procedures in Zurich are compatible with the operating procedures for individual aircraft types such as the Saab 340B and at the same time in order to guarantee safe and efficient operation under all conditions, the current departure procedures should be examined.

4.1.4.5 Opinion of the Federal Office for Civil Aviation

"This recommendation is currently in progress. The first interim results indicate that no adaptations of departure procedures to the Saab 340 are necessary. The existing and long-standing involvement of operators in establishing these flight paths also ensures that requirements specific to aircraft types are covered."

4.2 Safety recommendations regarding human and organizational aspects

4.2.1 Transfer of foreign pilots' licences

4.2.1.1 Safety recommendation

In the case of validation of foreign licences which were not issued in accordance with JAR-FCL and which are to be granted for commercial flights, the authority is responsible for ensuring that the license holder meets the basic JAR-FCL requirements. A validation should in principle be time-limited and not subject to extension. This responsibility should not be delegated to the operator.

4.2.1.2 Opinion of the Federal Office for Civil Aviation

"The issue of CH validations took place prior to 1 May 2000 exclusively in accordance with RFP. Prerequisites were proof of a CH-IR check flight with TRE, photocopies of the foreign license with a type rating entry and the foreign medical, plus the last six pages of the logbook and a fully completed 30.12 application form jointly signed by the operator. In particular, in contrast with the validation practice according to JAR-FCL as described below, neither a skill test nor a JAR medical was required.

Since 1 May 2000, validations according to Appendix 1 to JAR-FCL 1.015 have been issued. The requirements are to be found in the FS FA (…) checklist. In comparison with validation according to RFP the requirements are substantially more stringent."

4.2.2 Validation of licences which were not issued under JAR-FCL

4.2.2.1 Safety recommendation

In the case of validation of licences which were not issued in accordance with JAR-FCL and in particular of licences from countries with unknown training procedures, the following criteria in particular are to be checked individually by the authority:

- Capabilities and knowledge according to JAR-FCL
- Flying experience taking into account the types of aircraft flown, their instrumentation, operators and the geographical-cultural regions in which flying took place. Special attention is to be paid to candidates whose instrument flight training took place on aircraft with attitude instruments which provide a display which differs from western instruments (this is known for the following types in particular: IL-18, IL-62, AN-24, TU-134, JAK-40)

- Linguistic skills of the candidate, adequate for the envisaged assignment area (especially the level of knowledge of English)
- Knowledge of the geographical and meteorological situation (especially high-mountain experience, experience with icing conditions)
- Experience with the imperial system of measurements

Gaps in knowledge must be filled by appropriate individual training.

The JAR-FCL proficiency check with an inspector from the supervisory authority is to be taken and passed in every case. It must specifically examine the above-mentioned key points. This check must in no circumstances be delegated to an operator, but it may be part of the operator proficiency check.

4.2.2.2 Opinion of the Federal Office for Civil Aviation

"With the exception of the skills and knowledge according to JAR-FCL mentioned under 1.2.2.1, which must be proven in accordance with the cited FS FA checklist, the recommendations are not relevant to licences. They are conclusively regulated in Subpart N of JAR-OPS, namely in paragraphs 1.943 (Initial Operator's Crew Resource Management Training), 1.945 (Conversion Training and Checking) and 1.975 (Route and Aerodrome Competence Qualification). More on this subject is also to be found under paragraph 4.2.4.2 (…).

The requirement that JAR-FCL Proficiency Checks be carried out exclusively by inspectors from the supervisory authority is currently taken into account to the extent that the examiners, in their activity, act as representatives of the FOCA. To this end a contract has been concluded or will be concluded in the next few weeks with each individual one. In their training, examiners will have their attention drawn to their independence. It may well be that the independence of examiners with no relation at all to the operator would be greater. However, the resources of the office do not permit it to have available a suitable, capable TRE for each aircraft type."

4.2.3 Validation of foreign medical certificates

4.2.3.1 Safety recommendation

As a rule, pilots without a JAR-FCL 3 medical certificate must undergo an initial examination according to JAR-FCL. In this context, the examination process may be shortened if specific examination results from the country of origin of the candidate are available in translated and certified form and the methodology of examination is known.

4.2.3.2 Opinion of the Federal Office for Civil Aviation

"With regard to the medical, the requirements have also been made more stringent: no recognition or first issue of a certificate will take place if no JAR medical, issued by a CH-AMC, is available."

4.2.4 Employment of foreign pilots with validated licences

4.2.4.1 Safety recommendation

An operator should in principle be able to assume that a pilot with a validated license can operate an aircraft in accordance with local standards. Nonetheless, particularly in the case of these candidates, the individual background (CRM knowledge, culture, language, experience with unusual instrumentation, flying in the metric system and so on) must be carefully clarified and taken into consideration on recruitment and employment.

4.2.4.2 Opinion of the Federal Office for Civil Aviation

"An operator cannot in principle assume that a pilot with a validated license can operate an aircraft in accordance with local standards! The following would be correct: the operator must ensure that a pilot can operate in accordance with the local standards! Despite increasing formal harmonization within the framework of FAR and JAR, differences between one pilot and another and one operator and another continue to exist. The BFU also cites the most important reasons; there is no gaping chasm between the "stick skills" of individual pilots. Rather it is the capabilities of teams which may give rise for concern. And these capabilities depend above all on team training, culture, CRM and company procedures. Here, despite validated licences, the operator continues to bear a great responsibility.

The harmonization/ standardization of JAR is an important step forward but constitutes no guarantee of continuous quality assurance with regard to "non stick skills"! It would therefore be appropriate for us to examine internal company training and checks with reference to the completeness of the syllabi. However, we would also need the **corresponding resources** to enable us to do this (bold type in original)."

4.2.5 Clarification of aptitude for crew members

4.2.5.1 Safety recommendation

The operators must apply appropriate criteria and instruments for the selection of crew members, which ensure that the cultural background and linguistic skills of candidates are highlighted in such a way that working in a multi-cultural environment does not hinder optimal crew resource management.

Appropriate linguistic capabilities (English) must be proven in a test based on a recognized scale.

4.2.5.2 Opinion of the Federal Office for Civil Aviation

"We can associate ourselves with this recommendation addressed to operators. In these areas, reinforced monitoring activity on our part would certainly be indicated; here too, however more resources are a prerequisite".

4.2.6 Training and crew pairing

4.2.6.1 Safety recommendation

Deficiencies in the linguistic and operational sphere must be eliminated by means of appropriate and individual training. The accumulation of any deficiencies which do still exist in a crew must be prevented by scrupulous crew pairing.

During proficiency training, candidates' individual difficulties must be addressed by appropriate methods (e.g. unusual attitude training, communication training). The result of this individual training must be checked during the proficiency check.

4.2.6.2 Opinion of the Federal Office for Civil Aviation

"We can also associate ourselves with this recommendation. It is certainly correct that the operator applies a strict standard to proficiency checks (and therefore to all conversion training and assignments in accordance with JAR-OPS 1.945: Changing Operator) with regard to cockpit organization and CRM. In this respect, a three-stage qualification standard would be necessary: 1) fully qualified, 2) conditionally qualified, 3) not qualified. Those pilots who are "stuck" at the third hurdle must continue training until they achieve stage 2 as a minimum. Such pilots must be monitored by means of corresponding crew pairing until the next check and then subjected to a fresh evaluation.

The aviation policy developments which have intervened in the interim and Crossair's new role as a national carrier using Swissair safety know-how also provide an excellent opportunity to implement recommendations like those cited above, and therefore to take a further step towards optimizing flight safety within this company."

4.2.7 Training and induction of direct entry commanders

4.2.7.1 Safety recommendation

In the case of direct entry commanders, especially those with a validated license, the operator must ensure a particularly scrupulous induction procedure. In addition to operational aspects, this should also make them acquainted with the special features of the cultural, linguistic and social environment. In the case of the obligatory line check, successful compliance with the following criteria must in turn be checked:

- CRM with particular reference to the two-man cockpit (where applicable)
- Management culture
- Appropriate capabilities of linguistic expression for the current operation

The supervisory authority must be entitled to inspect the contractual conditions of direct entry and leasing agreements.

4.2.7.2 Opinion of the Federal Office for Civil Aviation

"We can associate ourselves with this recommendation addressed to operators. In these areas, increased monitoring activity on our part would certainly be indicated; here too, however, more resources are a prerequisite".

4.3 Safety actions taken

On 25 February 2002, the Crossair operator indicated that it had taken the following measures on the basis of the safety recommendations of the BFU:

Quote:

- "The appendix (cf. Annex 8) shows extracts from the Operations Manual (OM), in which the paragraphs which have been amended as a direct reaction to the safety recommendations are marked. Essentially, these relate to programming the Navigation Management System, use of the autopilot and division of tasks/monitoring in the cockpit.
- As a further measure, the basic training of pilots from the FSU has been subjected to analysis. The selection criteria for direct entry commanders have been redefined and refined. Direct entry commanders must now complete three months flying service in the right-hand seat in order to become better acquainted with the operating environment.
- The bank angle warning of the GPWS has been activated on all fleets.
- The period after conversion training during which the pilot is considered to be "inexperienced" has been increased from 25 to 100 flying hours. This limit is integrated into the crew planning system."

End quote.

Glossary

AP	autopilot
APP	autopilot panel
ADC	aerodrome control
ADC	air data computer
ADF	automatic direction finding equipment
ADI	attitude direction indicator
ADS	air data system
AFS	automatic flight system
AGL	above ground level
AHC	attitude heading computer
AHRS	attitude heading reference system
AMOS	airline maintenance organization system
AMSL	above mean sea level
AND	attitude nose down
ANU	attitude nose up
APA	altitude preselector alerter
APR	automatic power reserve
APRON	apron
ASI	airspeed indicator
ATA	American Transport Association
ATIS	automatic terminal information service
AVOR	tooling/task planning
BFU	Aircraft Accident Investigation Bureau
B-RNAV	basic area navigation
CA	cabin attendant
CAM	cockpit area mike
CB	circuit breaker
CDU	control display unit
CHF	Swiss Francs
CHP	course heading panel
CRM	crew resource management
CRT	cathode ray tube
CTOT	constant torque on take off
CVR	cockpit voice recorder
CWP	central warning panel
DAT	digital audio tape
DCP	display control panel
DEP	departure control
DFDR	digital flight data recorder
DME	distance measuring equipment
DOC	designated operational coverage
DPU	display processor unit
DVOR	doppler VOR
EADI	electronic attitude director indicator
EFIS	electronic flight instrument system
EHSI	electronic horizontal situation indicator
EICAS	engine indicating and crew alerting system
ELEV	elevation
EMI	electromagnetic interference
FAA	Federal Aviation Authority
FCC	flight control computer
FD	flight director
FDAU	flight data acquisition unit

FDEP	flight data entry panel
FIB	focused ion beam
FIR	flight information region
FL	flight level
FMS	flight management system
ft	feet
GPU	ground power unit
GPWC	ground proximity warning computer
GPWS	ground proximity warning system
GSP	glare shield panel
HDG	heading
HIRF	high intensity radio frequency
HSI	horizontal situation indicator
IAS	indicated airspeed
IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
IMC	instrument meteorological conditions
IR	instrument rating
ITT	inter turbine temperature
JAA	Joint Aviation Authorities
KIAS	knots indicated airspeed
kt	knots
LAT	latitude
LONG	longitude
LRN	long range navigation system
METAR	aviation routine weather report
MFD	multifunctional display
MIH	maintenance information handbook
MME	maintenance management exposition
MOE	maintenance organization exposition
MPU	multifunction processor unit
MRT	multi radar tracking
NCU	navigation computer unit
NM	nautical mile
NVM	non-volatile memory
OAT	outside air temperature
PF	pilot flying
PNF	pilot non flying
QNH	altimeter setting that references the indicated altitude to sea level
RA	radio altimeter
RAIM	receiver autonomous integrity monitoring
RNAV	area navigation
ROC	rate of climb
ROD	rate of descent
S/N	serial number
SB	service bulletins
SID	standard instrument departure
SIGMET	information concerning en-route weather phenomena which may affect the safety of aircraft operations
SOP	standard operating procedures
STAR	standard instrument arrival
STC	supplemental type certificate
TAF	aerodrome forecast
TAS	true airspeed

TC	type certificate
TOM	take-off mass
TR	type rating
TRK	track
USD	US Dollar
UTC	universal time coordinated
VFR	visual flight rules
VMC	visual meteorological conditions
VOR	VHF omnidirectional radio range
VSI	vertical speed indicator
WO	work order

Time	Assumed Actions Commander			Flight Recorder Data						Assumed Actions Copilot		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:54:04	ground steering		power levers					0.0	*[radio:] cleared for take-off two eight…*			PTT
16:54:05	wheel		power levers					0.0	*..Crossair four niner eight*			PTT
16:54:06	ground steering		power levers					0.0				
16:54:07	wheel		power levers	*Are you ready?*				0.0	*take-off clearance*			
16:54:08	ground steering		power levers	*received*				0.0	*line-up checklist completed, ready*			
16:54:09	wheel		power levers					0.0				
16:54:10	ground steering		power levers	*time check*	[engine noise increasing]			0.0		power levers	engine instr.	condition levers
16:54:11	wheel	runway	power levers					0.0		power levers	flight instr.	condition levers
16:54:12	ground steering	runway	power levers					0.0		power levers	engine instr.	condition levers
16:54:13	wheel	instrument scan	power levers					0.0	*auto-coarsen high*	power levers	flight instr.	condition levers
16:54:14	ground steering	runway	power levers					0.0		power levers	engine instr.	condition levers
16:54:15	wheel	runway		*set take-off power*				0.0		power levers	flight instr.	condition levers
16:54:16	ground steering	instrument scan	yoke					0.0	*APR armed*	power levers	engine instr.	condition levers
16:54:17	wheel	runway	yoke					0.0		power levers	flight instr.	condition levers
16:54:18		runway	yoke					0.0	*sixty*	power levers	engine instr.	condition levers
16:54:19	yoke	instrument scan	yoke		landing gear rolling noise			0.0		power levers	flight instr.	condition levers
16:54:20	yoke	runway	yoke		landing gear rolling noise			0.0		power levers	engine instr.	condition levers
16:54:21	yoke	runway	yoke		landing gear rolling noise			0.0		power levers	flight instr.	condition levers
16:54:22	yoke	instrument scan	yoke		landing gear rolling noise			0.0	*take-off power is set*	power levers	engine instr.	condition levers
16:54:23	yoke	runway	yoke		landing gear rolling noise			0.0			flight instr.	yoke

Time	Assumed Actions Commander			Flight Recorder Data						Assumed Actions Copilot		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:54:24	yoke	runway	yoke		landing gear rolling noise			0.0			engine instr.	yoke
16:54:25	yoke	instrument scan	yoke		landing gear rolling noise			0.0			flight instr.	yoke
16:54:26	yoke	runway	yoke		landing gear rolling noise			0.0			engine instr.	yoke
16:54:27	yoke	runway	yoke		landing gear rolling noise			0.0			flight instr.	yoke
16:54:28	yoke		yoke		landing gear rolling noise			0.0	*Vee one, rotate*		engine instr.	yoke
16:54:29	yoke pulling	EADI	yoke pulling		rumble stops			0.0			flight instr.	
16:54:30	yoke	instrument scan	yoke				alt 1472	0.0			engine instr.	
16:54:31	yoke	instrument scan	yoke				alt 1456	0.0			flight instr.	
16:54:32	yoke	instrument scan	yoke					0.0				
16:54:33	yoke	instrument scan	yoke	*gear up*				0.7		gear handle	gear handle	
16:54:34	yoke	instrument scan	yoke		hydraulic pump noise			0.4	*positive rate, gear in transit*			
16:54:35	yoke	instrument scan	yoke		gear retraction rumble		alt 1456	1.4		gear handle	gear lights	
16:54:36	yoke	instrument scan	yoke					2.1				
16:54:37	yoke	instrument scan	yoke				gear unsafe	3.5				
16:54:38	yoke	instrument scan	yoke				gear unsafe	2.5				
16:54:39	yoke	instrument scan	yoke				gear unsafe	1.8				
16:54:40	yoke	instrument scan	yoke				alt 1568	1.8				
16:54:41	yoke	instrument scan	yoke			*[IB4476] TWR…*	gear unsafe	1.1				
16:54:42	yoke	instrument scan	yoke					0.4			gear lights	
16:54:43	yoke	instrument scan	yoke					0.0	*gear is up, final climb one two six*			

Time	**Assumed Actions Commander**			**Flight Recorder Data**						**Assumed Actions Copilot**		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:54:44	yoke	instrument scan	yoke					0.0			[EADI]	
16:54:45	yoke		yoke	*flight director on*			alt 1760	0.0				
16:54:46	yoke	EADI	yoke					-0.4		FD button	EFIS panels	
16:54:47	yoke		yoke					-0.7	*flight director on*		EADI	
16:54:48	yoke	EADI	yoke	*arm NAV*		*[TWR] LX 85…*		-0.7		NAV button	mode sel. pan.	
16:54:49	yoke		yoke			*cross runway...*		-0.4	*LRN one is captured*		EADI	
16:54:50	yoke	EADI	yoke			*contact approach ..*		0.0				
16:54:51	yoke		yoke				alt 2144	-0.4				
16:54:52	yoke	EADI	yoke	*LRN one… captured*		*[LX85] ..121.75*		-1.1				
16:54:53	yoke	EADI FD	yoke					-0.7				
16:54:54	yoke	instrument scan	yoke			*[TWR] IB 4476..*		-0.4				
16:54:55	yoke	instrument scan	yoke			*...evening*		-0.4				
16:54:56	yoke	instrument scan	yoke			*[IB4476] cont.*		-0.7				
16:54:57	yoke	instrument scan	yoke			*…..4476.*		-0.7				
16:54:58	yoke	instrument scan	yoke					-0.4				
16:54:59	yoke	instrument scan	yoke					0.4				
16:55:00	yoke	instrument scan	yoke				alt 2352	1.1				
16:55:01	yoke	instrument scan	yoke					0.4				
16:55:02	yoke	instrument scan	yoke					-0.4				

Time	**Assumed Actions Commander**			**Flight Recorder Data**						**Assumed Actions Copilot**		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:55:03	yoke	instrument scan	yoke			*Crossair 498, contact*		-1.1				
16:55:04	yoke	instrument scan	yoke			*departure, adé*		-0.7				
16:55:05	yoke	instrument scan	yoke				alt 2544	0.0	*[radio:] departure, Crossair..*			PTT
16:55:06	yoke	instrument scan	yoke					0.4	*..four niner eight.. bye*			PTT
16:55:07	yoke	instrument scan	yoke		signal tone			0.4		center pedestal	center pedestal	
16:55:08	yoke	instrument scan	yoke					0.4	*calling*			
16:55:09	yoke	instrument scan	yoke					0.0	*[radio:] Gruezi departure..*			PTT
16:55:10	yoke	instrument scan	yoke				alt 2752	0.4	*..Crossair four niner eight..*		altimeter	PTT
16:55:11	yoke	instrument scan	yoke				alt 2784	0.0	*..crossing 2800 now*			PTT
16:55:12	yoke	instrument scan	yoke					0.0				
16:55:13	yoke	instrument scan	yoke					-0.7				
16:55:14	yoke	instrument scan	yoke					-1.1				
16:55:15	yoke	instrument scan	yoke	*aaah, CTOT / APR off*		*Crossair four nine eight*	alt 2944	-1.1				
16:55:16	yoke	instrument scan	yoke			*climb to flight level 110*		-0.7				
16:55:17	yoke	instrument scan	yoke					-1.1				
16:55:18	yoke	instrument scan	yoke					-1.4	*[radio:] climbing level one one zero,..*			PTT
16:55:19	yoke	instrument scan	yoke					-2.1	*..Crossair four niner eight*			PTT
16:55:20	yoke	instrument scan	yoke		altitude pre-selector		alt 3120	-2.5		altitude selector	altitude selector	
16:55:21	yoke	instrument scan	yoke		setting clicks			-2.1	*one one zero confirm*	[pointing]	altitude selector	
16:55:22	yoke	altitude selector	yoke	*checked*				-1.1			altitude selector	

Time	Assumed Actions Commander			Flight Recorder Data						Assumed Actions Copilot		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:55:23	yoke	instrument scan	yoke					0.0				
16:55:24	yoke	instrument scan	yoke	*CTOT / APR off*				0.7				
16:55:25	yoke	instrument scan	yoke				alt 3280	1.4	*..is coming*	power levers	torque instr.	
16:55:26	yoke	instrument scan	yoke		clicking CTOT			2.5		power levers	CTOT switch	
16:55:27	yoke	instrument scan	yoke					3.2		power levers	torque instr.	
16:55:28	yoke	instrument scan	yoke					3.9		power levers	engine instr.	
16:55:29	yoke	instrument scan	yoke					4.2		power levers	engine instr.	
16:55:30	yoke	instrument scan	yoke				alt 3440	4.6		power levers	engine instr.	
16:55:31	yoke	instrument scan	yoke					4.9		power levers	engine instr.	
16:55:32	yoke	instrument scan	yoke					5.3		power levers	engine instr.	
16:55:33	yoke	instrument scan	yoke					4.9		power levers	engine instr.	
16:55:34	yoke	instrument scan	yoke					4.2		power levers	engine instr.	
16:55:35	yoke	instrument scan	yoke				alt 3616	3.9		power levers	engine instr.	
16:55:36	yoke	instrument scan	yoke					7.0		power levers	engine instr.	
16:55:37	yoke	instrument scan	yoke		APR off			4.6		APR switch	APR switch	
16:55:38	yoke	instrument scan	yoke		2 clicks switches			4.2		APR switch	engine instr.	
16:55:39	yoke	instrument scan	yoke			*four nine eight, turn left*		4.6		APR switch	engine instr.	
16:55:40	yoke	instrument scan	yoke			*to Zurich East*	alt 3808	1.4				
16:55:41	yoke	instrument scan	yoke					-4.2	*[radio:] turning left to Zurich East..*			PTT
16:55:42	yoke	instrument scan	yoke					-8.4	*..Crossair four niner eight*	FMS CDU	FMS CDU	PTT

Time	Assumed Actions Commander			Flight Recorder Data						Assumed Actions Copilot		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:55:43	yoke	instrument scan	yoke					-12.0		FMS CDU	FMS CDU	
16:55:44	yoke	instrument scan	yoke		[FMS CDU			-15.5		FMS CDU	FMS CDU	
16:55:45	yoke	instrument scan	yoke		key clicks unconfirmed]		alt 4000	-16.9		FMS CDU ENTER	FMS CDU	
16:55:46	steering acc.	instrument scan	steering acc.					-16.2	*from present, LRN is to..*			
16:55:47	FD comd.	EHSI EADI	FD comd.					-15.1	*..Zurich East, yeah*			
16:55:48		instr. Scan						-13.7			[EADI EHSI]	
16:55:49		[FMS CDU]		*checked*				-10.5				
16:55:50		[EHSI]					alt 4208	-7.0	*CTOT / APR off*			
16:55:51	yoke	instrument scan	yoke					-3.5				
16:55:52	yoke	instrument scan	yoke	*yaw damper on*				0.0	*yaw damper engaged*	YD switch	center pedestal	
16:55:53	yoke	instrument scan	yoke	*bleed air on*				2.5		BLEED SWITCH	BLEED PNL	
16:55:54	yoke	instrument scan	yoke		bleed air switch click			4.9		LEFT	CAB ALT	
16:55:55	yoke	instrument scan	yoke		air rush		alt 4416	8.4				
16:55:56	yoke	instrument scan	yoke		bleed air switch click			12.7		bleed air switch	overhead panel	
16:55:57	yoke	instrument scan	yoke		air rush			16.5	*bleeds are on*	bleed air switch	[cab. alt. Indicator]	
16:55:58	yoke	instrument scan	yoke					21.1				
16:55:59	yoke	instrument scan	yoke					26.0				

Time	**Assumed Actions Commander**			**Flight Recorder Data**						**Assumed Actions Copilot**		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:56:00	yoke	instrument scan	yoke	*set climb power*			alt 4608	31.0				
16:56:01	yoke	instrument scan	yoke					33.4	*coming [whispered]*	power levers	power levers	friction lock
16:56:02	yoke	instrument scan	yoke					35.2		power levers	engine instr.	power levers
16:56:03	yoke	instrument scan	yoke					41.2		power levers	engine instr.	power levers
16:56:04	yoke	instrument scan	yoke					41.5		power levers	engine instr.	power levers
16:56:05	**yoke**	**EADI**	**yoke**				alt 4720	39.4		power levers	engine instr.	power levers
16:56:06								38.3		power levers	engine instr.	power levers
16:56:07	**rugged aileron**		**rugged aileron**				alt 4720	38.7		power levers	engine instr.	power levers
16:56:08	**steering inputs**		**steering inputs**				propeller RPM	38.7		power levers	engine instr.	power levers
16:56:09							decr.	40.1		condition levers	condition levers	condition levers

Time	Assumed Actions Commander			Flight Recorder Data						Assumed Actions Copilot		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand
16:56:10							alt 4688	41.9		condition levers	MFD	condition levers
16:56:11	**increa-singly**		**increa-singly**					48.2	*turning left to Zurich East, ...*		MFD	condition levers
16:56:12	**rugged aileron**		**rugged aileron**					58.0	*we should left…*	[pointing]		condition levers
16:56:13	**steering inputs**		**steering inputs**				alt 4624	63.7		condition levers	[FMS CDU]	condition levers
16:56:14								65.4		condition levers	engine instr.	condition levers
16:56:15				**oh-na-nah..**			alt 4560	65.8	[audibly increased breathing rate]	condition levers	[left flight instr.]	condition levers
16:56:16							propeller RPM	70.3		condition levers	engine instr.	condition levers
16:56:17	**uncon-trolled**		**uncon-trolled**			*Crossair four nine eight,*	1320	73.5		condition levers	[flight instr.]	condition levers
16:56:18	**left-right**	v	**left-right**			*confirm you are turning left*	alt 4320	73.2			[flight instr.]	
16:56:19	**aileron**	v	**aileron**					79.8	*[radio:] moment please,..*		[flight instr.]	PTT
16:56:20	**steering inputs**	v	**steering inputs**			*OK, continue right*	alt 4048	103.8	*..standby! [even tone (stress?)]*		[flight instr.]	PTT
16:56:21	v	v	v			*to Zurich East*		125.9	[heavy breathing]		EADi	
16:56:22		v						137.5	No! [audible stress tremour ...		EADI	
16:56:23					overspeed warning			118.2	...and heavy breathing]	[yoke]	EADI	[yoke]
16:56:24					wind noise			97.8	turning left! left! left! left!….left! [urgent]	[yoke]	EADI	[yoke]
16:56:25							alt 2736	76.7		[yoke]	EADI	[yoke]
16:56:26										[yoke]		[yoke]
16:56:27									… oh---[cut-off]	[yoke]		[yoke]

Time	Assumed Actions Commander			Flight Recorder Data						Assumed Actions Copilot		
UTC	left hand	eye focus	right hand	CVR Commander	CVR cockpit area	CVR ATC	FDR	bank	CVR Copilot	left hand	eye focus	right hand

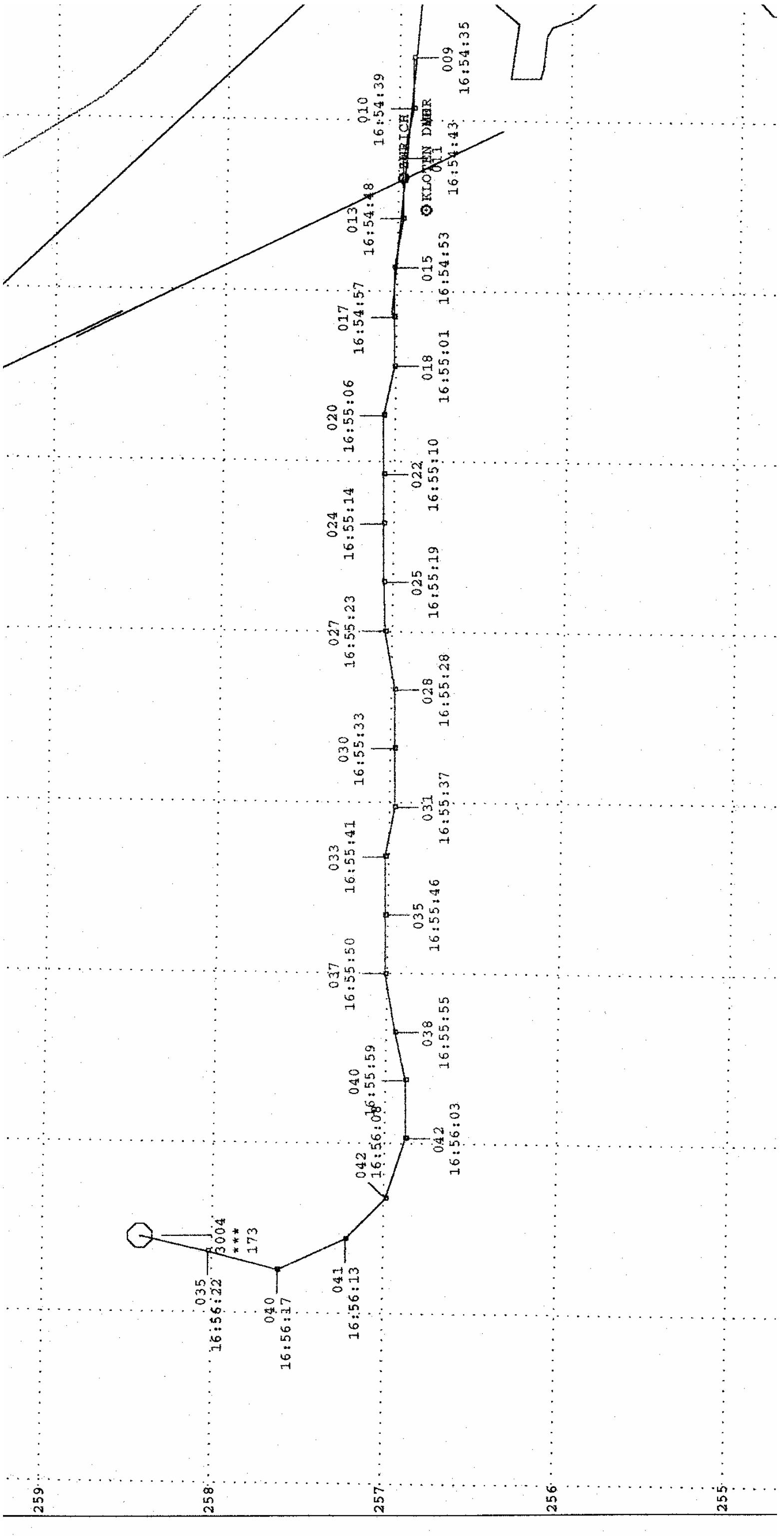
normal two-men-ops
deviation from SOP
aircraft deviates from flt path
aircraft cannot be recovered

two-men operation, closed loops
radio communication loops
take-off power setting
rotation
landing gear cycle
flight director on
NAV (LRN) on
CTOT/APR off, interrupted loop
FMS Programming
yaw damper on
bleed air on
climb power setting, incomplete

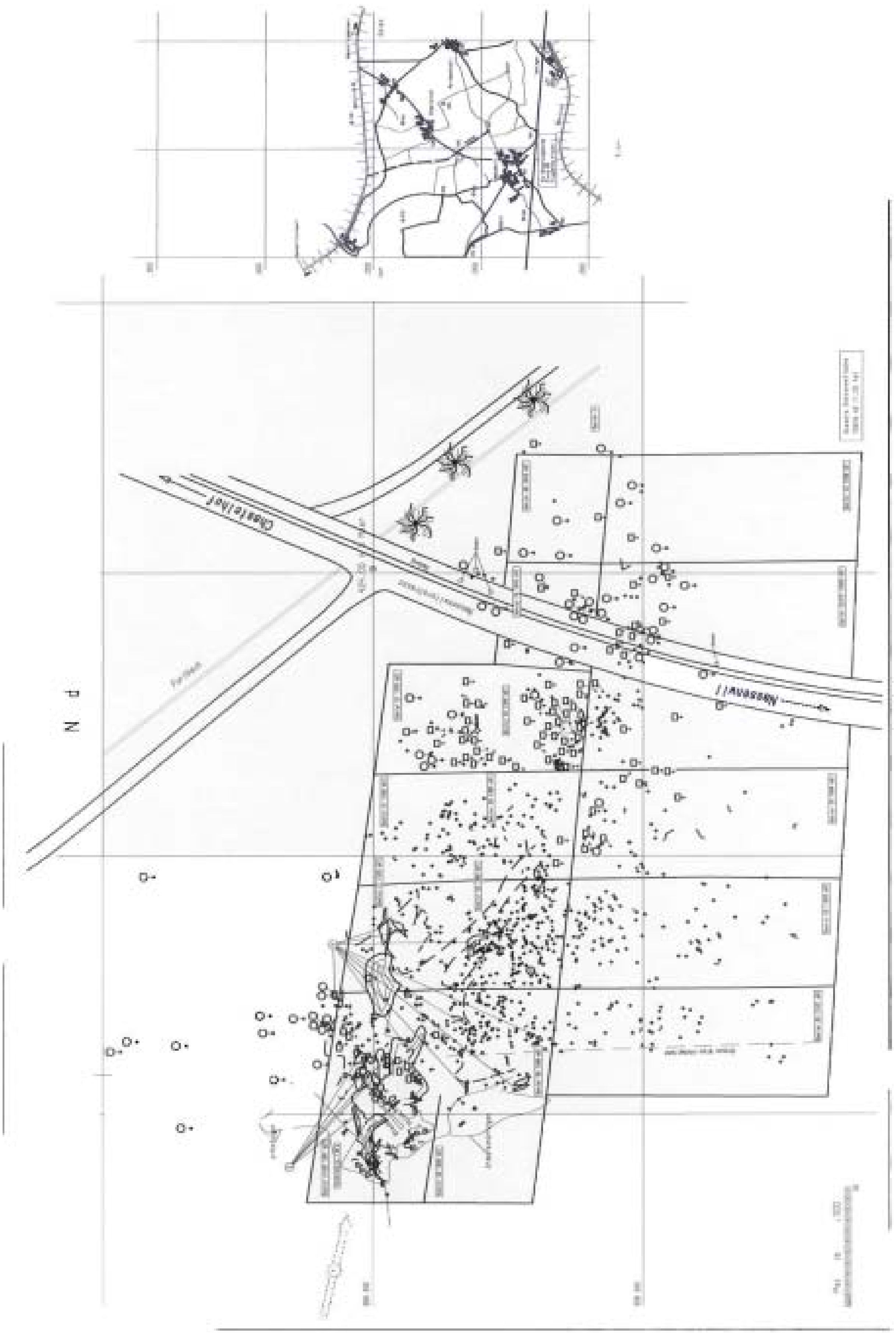
commander increasingly confused about aircraft attitude
copilot increasingly aware of aircraft attitude

Annex 2

Radarplot of flight CRX 498



Annex 3

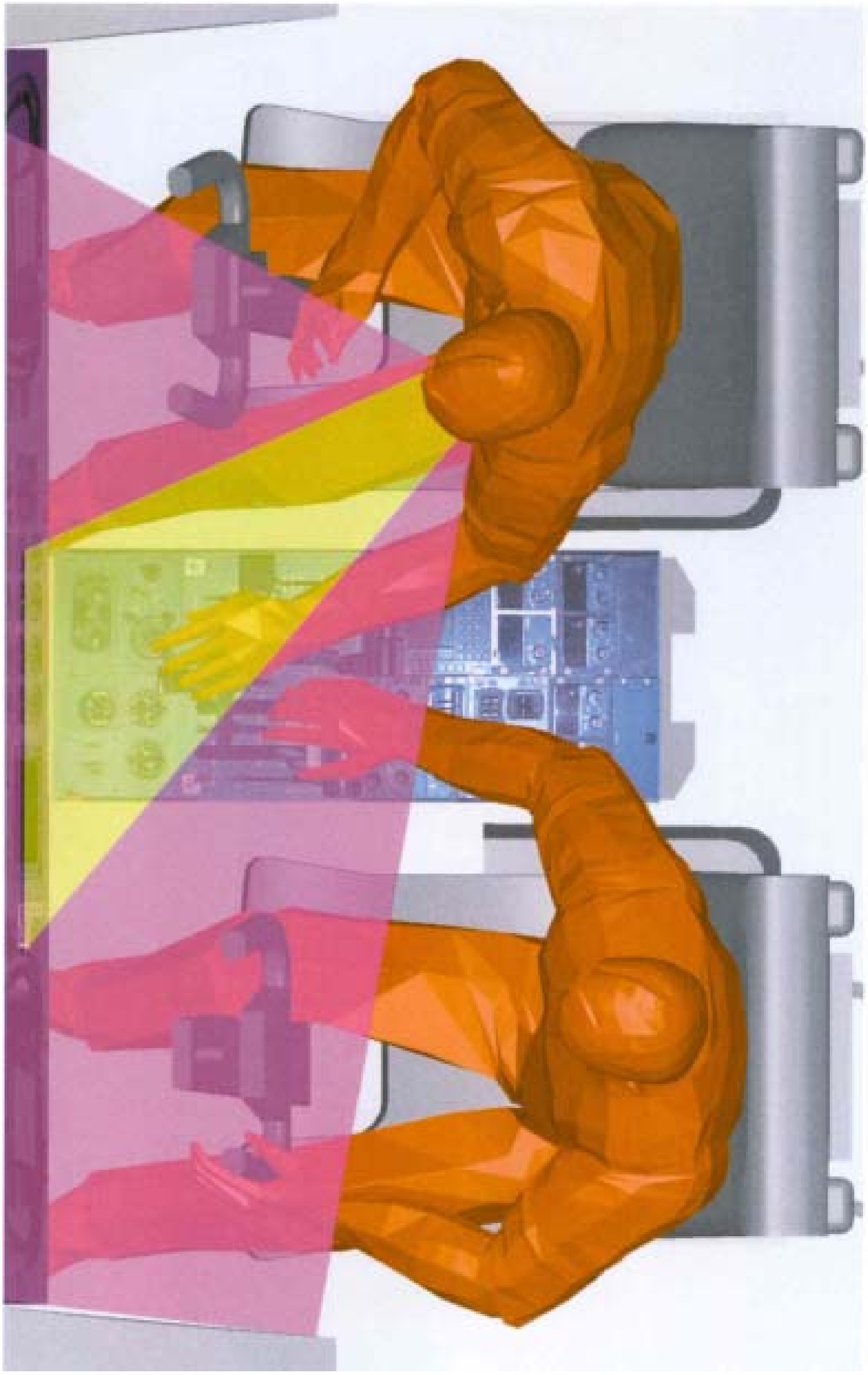


Annex 4

Pack of Phenazepam, found in the commander‘s crew bag

Annex 5

First officer's field of view – plan form



First officer's field of view – simulation

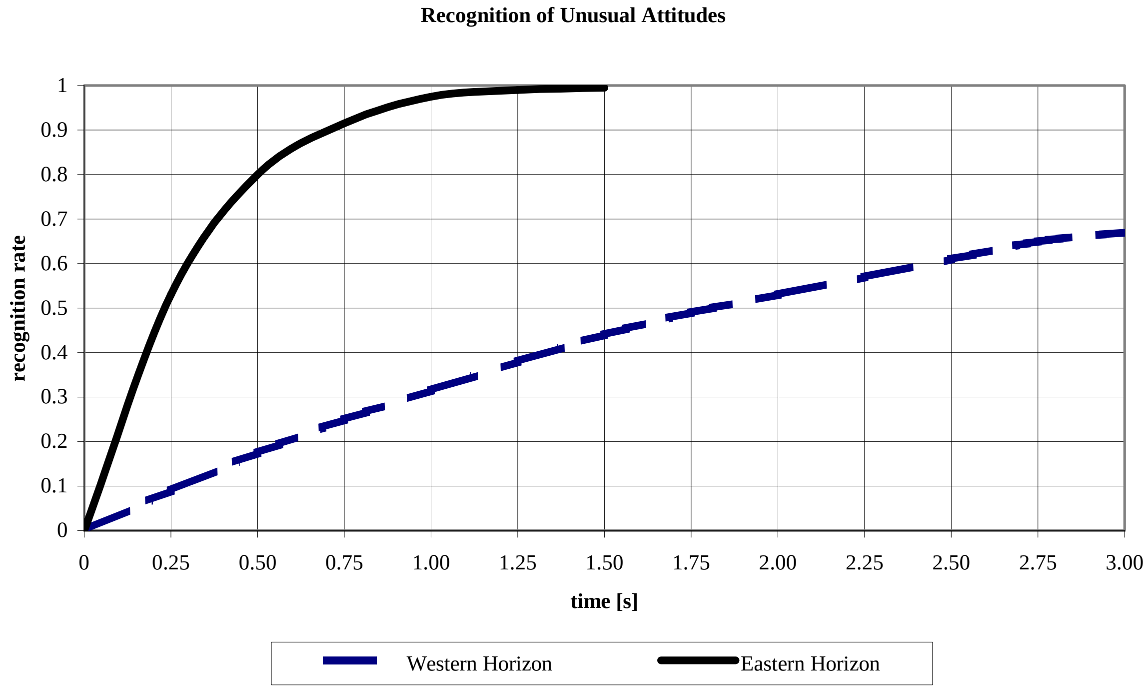
Annex 6

Gyro compass of russian design (above) in comparison with the EHSI of the SF-340 B (below). The pointer (red arrow) rotates with respect to the fixed scale, whereas on instruments of western type, the heading bug (blue arrow) is fixed with respect to the rotating compass card.

Annex 7

The diagram below shows the results of a study which registered the time needed by pilots trained on eastern horizons to detect an attitude with certainty. The rigid curve represents the situation in which eastern horizons were used, the dotted curve represents the one, when artificial horizons of western make were used.

For instance after one second, 98% of pilots were able to interprete the attitude, if it was represented by eastern horizons. But only 32% of the same pilots could reliably determine attitude after one second on western instruments.



Annex 8

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AUSZUG OM A Kapitel 8C, Version July 1st, 2000

- Aenderungen Gelb markiert
- Aenderungen als Folge Empfehlung LX498 Unfall rot markiert

8.4.7 .... **General Cockpit Procedures**

Policy for Crew Resource Management

All Crossair flight operations are based on the optimum use of Crew Resource Management. The principle of continuous mutual briefing and assistance shall be applied at all times. In normal cockpit work the commander shall endeavour to establish open communication between crew members in the cockpit and in the cabin as well as with ground personnel and Air Traffic Services.
All aircraft equipment shall be used with care and to the best of its capability.
Checklists and Standard Operating Procedures shall be used at all times in normal operations.
Normally the aircraft will be manoeuvered by one designated pilot. He will act as Pilot Flying (PF) for the time he has received this responsibility from the commander. The Pilot Not Flying (PNF) will assist to the maximum extent by performing checklist work, ATC communication, aircraft configuration changes and other duties at the discretion of the PF. During the critical flight phases the PNF shall support the PF by monitoring the primary flight instruments. All changes of control shall be performed in a clear manner. Standard phraseology shall be used with ATC and in cockpit communication in order to minimize the risk of misunderstandings. The rules of closed loop shall be respected at all times according to standard operating procedures.
A call out is a vocal notification by a pilot of either an order, the initiation of a sequence of events or an anomaly. It is also mandatory for any:

- Configuration change
- Mode or selection change
- System switching

Such a call out must always be confirmed vocally by the other pilot.

Policy for the Use of Equipment

All equipment shall be used to the best of its capability whenever it is technically available.

Use of Autopilot

Notwithstanding the above flight without autopilot is permitted in VMC and IMC provided that:

The PF keeps his attention constantly on the primary flight instruments and natural horizon if available. Whenever the PF has to divert his attention to other equipment the autopilot shall be engaged within its technical limitations.

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With the autopilot engaged the following applies:

The PF shall constantly monitor the autopilot mode and performance as well as the primary instruments. Whenever he has to divert his attention to other equipment a verbal handover to the other pilot shall be performed.

Use of Autothrottle

The autothrottle shall be engaged in the appropriate mode at all times if technically available. Deviations/exceptions are regulated in the OM B/PIH.

Use of HGS

The HGS shall be used according to the rules laid out in the OM B/PIH.

Flight without Autopilot/Autothrottle

Flight without Autopilot/Autothrottle is permitted according to MEL (refer to OM B). However specific flight/cabin crew procedures must be established and a briefing performed prior to flight.

8.3.2.8.1 FMS Policy

- Navigation management systems are restricted for "Basic Area Navigation" (B-RNAV). They may not be used for approach purposes, unless stipulated in the appropriate approach chart and the system capability is certified. (Refer to FMS usage according to the respective fleet-procedures).
- Navigation-setting procedures shall be applied as for basic navigation: The PNF selects the desired waypoint which he executes after cross-checking and confirmation from the PF.
- Any selected flight plan or single waypoint shall be verified regarding ist map position by means of the identifier and the co-ordinates.
- Where raw data are available they shall always be used to monitor the integrity of the navigation management system (VOR,DME, NDB displayed as second course or RMI information).
- Whenever navigation is based primarily on the FMS the use of the autopilot is recommended within the limitations of OM B/PiH.

Annex 9

Excerpts from the recordings of the *digital flight data recorder* (DFDR).